Update on new and future CEN asphalt test methods

Cliff Nicholls[1, a], Kenneth Lind[2, b]

[1] Infrastructure Division, TRL Limited, Wokingham, United Kingdom
[2] Swedish Transport Administration, Borlänge, Sweden

[a] cliff_nicholls@hotmail.com
[b] kenneth.lind@trafikverket.se

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ABSTRACT

EN 12697 is an extensive series of European norms for test methods and preparation procedures. Since the introduction of the harmonised asphalt specifications were published in 2006 (which required theses test methods to be applied), several additional test methods have been published. These tests are crack propagation by semi-circular bending test, saturation ageing tensile stiffness (SATS) conditioning test, low temperature cracking and properties by uniaxial tension tests, determination of the ash content of natural asphalt and determination of friction after polishing. In addition, tests for interlayer bond strength, conditioning to address oxidative ageing, cohesion increase by spread ability-meter method (for cold mix asphalt), resistance to scuffing and surface shear strength test are being standardised. The paper will review these test methods in terms of why they are required, what options are covered by the draft, what the principal of the method and, for those still to be published, how far through the CEN system that the draft has reached.

Keywords: Asphalt, Comité Européen de Normalisation, Standardisation, Testing

1. INTRODUCTION

When the EN 13108 series of harmonised European specification and quality documents for asphalt were published in 2006, they were supported by the test methods in EN 12697. There were then 43 parts of EN 12697, which included procedures for sample preparation as well as actual test methods. The majority of the test methods are called up in one or more parts of EN 13108 whilst others covered properties on the road (e.g. EN 12697-40, in situ drainability [CEN, 2003a]) and pavement design purposes (e.g. EN 12697-36, thickness of a bituminous pavement [CEN, 2003b]).
Since then, some additional test parts have been added to the EN 12697 series whilst several of the existing parts have been updated. Furthermore, other properties have been identified and the associated test methods prepared. All the parts of EN 13108 are currently being revised to include the extension of CE marking for the additional test methods. Therefore, it is an opportune time to review the new test methods.
In addition, it has been agreed that the scope of EN 13108 is planned to explicitly include warm, half-warm and cold mix asphalts as well as hot mix asphalts. The revision will not go as far as bringing in this extension because all the necessary test methods and changes to existing EN 12697 part are not yet available. Nevertheless, some new parts are being prepared and the titles of future parts and revisions will exclude the term “for hot mix asphalt”.
Up to now, all the parts of EN 12697 have been published as full standards. Some of the new parts are being considered for publication as technical specifications instead. A technical specification is effectively a draft standard that needs to be reviewed after three years for conversion to a full standard, continuation for a further three years or withdrawal.
This paper summarises the tests and the reason for producing the five parts published since 2006 together with a further five parts being prepared. Any revisions to parts existing in 2006 are not included.

2. RECENTLY PUBLISHED TESTS

[redacted]Determination of the ash content of natural asphalt

An annex of EN 13108-4, hot rolled asphalt (CEN, 2006) is used to specify natural asphalt. However, the measurement of the ash content used a test method published by the Institute of Petroleum, which is not an international standard. Therefore that standard was converted into CEN standard EN 12697-47 (CEN, 2010a)
The method is for use in determining the ash content in natural asphalts (including lake asphalts), binders containing natural asphalts or bitumens. For the method to apply, any mineral matter in the binder has to be finely divided and cannot exceed 45 % by mass.
The method involves gently heating a weighed sample of the natural asphalt in a silica crucible until fuming ceases. The sample is then ignited at (650 ± 50) ºC until free from carbon. The mass of ash is then calculated as a proportion by mass of the original sample.

[redacted]Crack propagation by semi-circular bending test

Fatigue has traditionally been monitored by EN 12697-24 (CEN, 2012), resistance to fatigue. However, there are two phases that measure the fatigue properties of a material, the crack initiation and crack propagation. EN 12697-24 tends to be associated with the former, so the semi-circular bending (SCB) test was standardised for the second phase of crack propagation as EN 12697-44 (CEN, 2010b).
The SCB test method determines the tensile strength or fracture toughness of an asphalt mixture. A half cylinder test piece with a centre crack is loaded in three-point bending in such a way that the middle of the base of the test piece is subjected to a tensile stress. During the test, the deformation increases at a constant rate of 5 mm/min. The corresponding load increases to a maximum value, F_{max}, that is directly related to the fracture toughness of the test sample. In Figure 1, an example of the test frame and specimen is given.

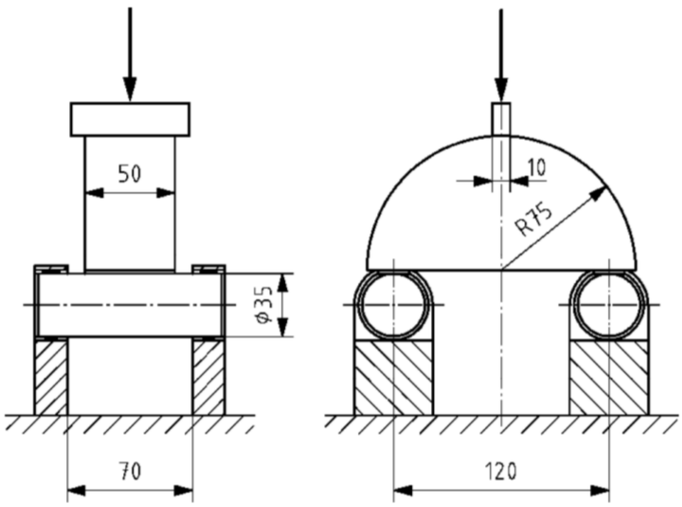

Figure 1. Example of the test frame and specimen for the SCB-test

The results of the test can be used to calculate:

- the maximum load that the material containing a notch (crack) can resist before failure, and
- when the presence of a notch is critical.

Saturation ageing tensile stiffness (SATS) conditioning test

The UK had a problem with water sensitivity of some base mixtures with consistent air voids contents and hard binder, in particular asphalt concrete mixtures with a binder content between 3,5 % and 5,5 %, air voids contents between 6 % and 10 % and 10/20 pen hard paving grade bitumen. The saturation ageing tensile stiffness (SATS) test was developed to assess the potential of mixtures for premature failure with these pore characteristics (Collop et al., 2007). The test was then converted into a European test method as EN 12697-45 (CEN, 2012b), although it is understood that the test has not been widely adopted outside the UK.

The SATS conditioning regime ages the specimens in the presence of water at a set pressure and temperature before a comparative test assesses the performance before and after conditioning. The comparative test is generally stiffness using indirect tension on cylindrical specimens to Annex C of EN 12697-26 (CEN, 2012), although other non-destructive test can also be used.

In the conditioning, nominally identical test specimens are subjected to moisture saturation by using a vacuum system. They are then transferred into a pressurised vessel partially filled with water, where they are subjected to a conditioning procedure by storage at 85 °C temperature and 2,1 MPa pressure for 65 h. Most of the specimens are conditioned above the water line, but some are conditioned below.

The ratios of the stiffness, ε, measured before and after the conditioning on the individual specimens situated above the water are averaged to determine the sensitivity of the material to ageing and moisture. The average ratio is the SATS Durability Index of the mixture components when the comparative test is the indirect tensile stiffness modulus.

The test is intended to be used as a screening test for the assessment of a combination of aggregate, filler and additives in respect of the retained adhesion properties after simulated ageing in a moist atmosphere for lean/stiff base and binder course mixtures.

Low temperature cracking and properties by uniaxial tension tests

The bituminous binders in asphalt are highly temperature susceptible and there are large parts of Europe that experience freezing conditions, with low temperature cracking being a common mode of failure. However, there were no tests for the low temperature properties of asphalt so a suitable set of tests were standardised as EN 12697-46 (CEN, 2012d).

The series of uniaxial tension tests for characterising the resistance of an asphalt mixture against low temperature cracking are:

- the tensile strength in dependence of the temperature by uniaxial tension stress test (UTST);
- the minimum temperature that the asphalt can resist before failure by thermal stress restrained specimen test (TSRST);
- the tensile strength reserve in dependence of the temperature (by a combination of TSRST and UTST);
- the relaxation time by the relaxation test (RT);
- the creep curve to back calculate rheological parameters by tensile creep tests (TCT); and
- the fatigue resistance at low temperatures due to the combination of cryogenic and mechanical loads by uniaxial cyclic tension stress tests (UCTST).

In the UTST, a specimen is pulled with a constant strain rate at constant temperature until failure. Results of the UTST are the maximum stress (tensile strength) $\beta_t(T)$ and the corresponding tensile failure strain $\varepsilon_{failure}(T)$ at the test temperature T (Figure 2).

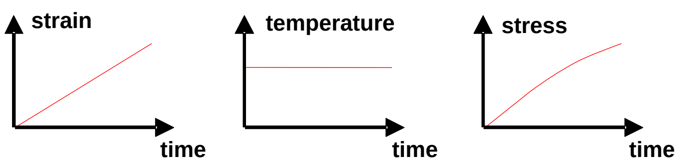

Figure 2. Test principle of UTST

In the TSRST, a specimen, which length is held constant, is subjected to a temperature decrease with constant temperature rate. Due to the prohibited thermal shrinkage, cryogenic stress is built up in the specimen. The results are the progression of the cryogenic stress over the temperature $\sigma_{cry}(T)$ and the failure stress $\sigma_{cry,\ failure}$ at the failure temperature $T_{failure}$ (Figure 3).

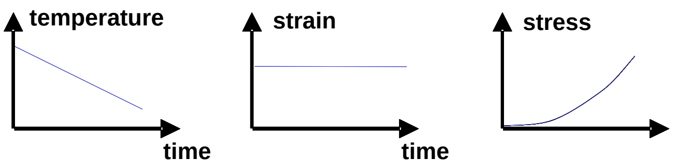

Figure 3. Test principle of TSRST

In the TCT, the specimen is subjected to a constant tension stress σ at a constant temperature *T*. The progression of the strain ε is measured. After a given time, the stress is withdrawn. Rheological parameters describing the elastic and viscous properties of the asphalt can be determined by interpreting the strain measurements (Figure 4).

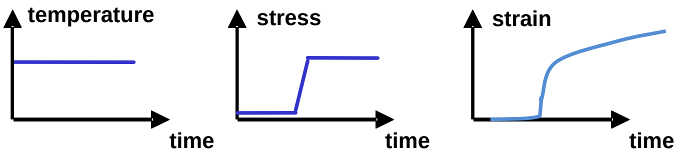

Figure 4. Test principle of TCT

In the RT, the specimen is subjected to a spontaneous strain ε, which is held on constant level. The decrease of tension stress by relaxation over the testing time is monitored. The results are the time of relaxation t_{rel} and the remaining tension stress σ_{rem} after the test ended (Figure 5).

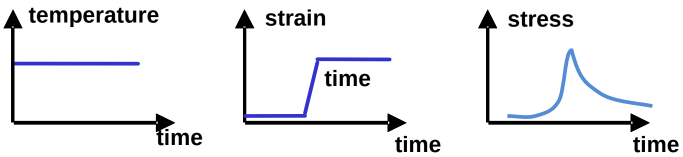

Figure 5. Test principle of RT

In the UCTST, a specimen is subjected to a cyclic tensile stress which is characterised by a sinusoidal stress to simulate the dynamic loading condition by traffic in combination with a constant stress, which symbolises the cryogenic stress. During the test, the strain response is monitored and the course of the stiffness is recorded until fatigue failure. Results of the tests are the number of applied load cycles until failure $N_{failure}$ and the number of load cycles until the conventional fatigue criterion is reached $N_{f/50}$ (Figure 6).

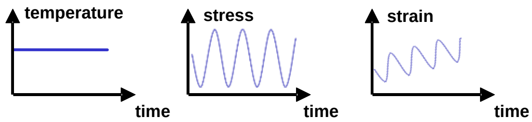

Figure 6. Test principle of UCTST

[redacted]Determination of friction after polishing

The potential skid resistance of asphalt mixtures tend to be assessed by the micro-texture of the coarse aggregate, as measured by its polished stone value to EN 1097-8 (CEN, 2009), and the macro-texture of the surfacing, as measured by the patch test to EN 13036-1 (CEN, 2010c). However, the Wehner Schulze method was developed to determine the skid resistance of aggregates or asphalt mixtures directly, and this was standardised as the friction after polishing test in EN 12697-49 (CEN, 2014).

The test method determines the friction at 60 km/h after polishing during a fixed number of passes on surfaces of bituminous mixtures samples. These samples can be either produced in a laboratory or cores taken from the site.

The main piece of equipment is a device comprising a polishing station and a unit for measuring the friction (Figure 7). The polishing station, which is continuously supplied with a mixture of water and quartz powder, contains three polishing rollers that can be lowered and that move across the test surface at a predefined loading force.


Figure 7. FAP device

In the friction measuring unit, a rotating measuring head is lowered onto the test surface while water is being added. The measuring head is fitted with three sliding blocks and can be declutched electronically. The moment generated by the contact between the rubber sliders and the surface is continuously measured and recorded until the measuring head comes to a standstill.
The friction force is calculated from the torque measurements and the friction coefficient. A graph of the friction coefficient μ is fitted on the measured points by a 6th order polynomial fitting. The mean value of the friction coefficient of the fitted graphs at 60 km/h is taken as the result. The test result FAP is the average calculated from at least two individual measurements.

3. NEW TESTS BEING DRAFTED

Interlayer bond strength

The bond between different layers is an important property for pavements but is not a property of just the layer being laid, so cannot be included in the asphalt specifications. However, it was agreed that a harmonised European test for this site property would be of benefit to the industry.
There cannot be a single test method for bond because there is more than one property. At the interaction of two rough horizontal surfaces, the resistance to a horizontal force will be considerable but there would be no resistance to lifting off the top layer; at the interaction of two smooth surfaces (say glass) with water present, the resistance to a horizontal force will be negligible but there would be considerable resistance to lifting off the top layer.
The draft, to be Part 48, gives three separate normative test methods, these being the torque bond test (TBT), shear bond test (SBT) and the tensile adhesion test (TAT), In addition, two further test methods are described in informative annexes, these being the compressed shear bond test (CSBT) and the cyclic compressed shear bond test (CCSBT). The five methods give different results because they measure different failure modes.
The TBT is suitable for testing the bond strength between pavement layers either on site or in a laboratory, and can be used to assess the capability of bond coats or tack coats. It assesses the resistance to the stresses generated primarily by traffic accelerating or braking, but also by thermal movements when the layers are of different materials (e.g. asphalt, microsurfacing or cement concrete). The test can be carried out immediately after laying.
A core is carefully cut to below the layer interface but, if the test is undertaken on site, the core is not broken off. In a laboratory, the lower layer of the core has to be effectively secured. A steel plate is glued to the top road surface either in situ or the in the laboratory. A rotational horizontal force is then applied to the steel plate and the torque moment is measured. The temperature will influence the test result so temperature conditioned specimens are tested in the laboratory whilst a correction factor is needed for in-situ tests.
The SBT is a laboratory test that assesses the resistance shear similarly to the TBT, but for horizontal shear stresses rather than torsional shear stresses. Again, the SBT can be used to assess the capability of bond coats or tack coats.
The thickness of the layer above the interface has to be greater than 20 mm and the layer(s) below the interface greater than 70 mm. Cylindrical test specimens are subjected to direct shear loading at controlled temperature with constant shear rate. The development of shear deformation and force is recorded and the maximum recorded shear stress is determined as shear strength at the interface between layers.
The TAT assesses the tensile bond strength between two road construction layers by determining the adhesion between a surface layer and the bottom layer, perpendicular to the plane of the specimen. The test is appropriate to thin surface layers where the mass of the surfacing may not be sufficient to hold it in place.
A test-plunger is glued on the incised and ground surface of the top layer and is pulled off with a suitable tension testing device at constant test temperature and strain rate. The maximum force related to the tension area is the adhesive tension strength.
The CSBT assesses shear behaviour of interlayers subjected to both horizontal and vertical traffic loads. A cylindrical specimen is subjected to direct shear loading whereas an axial load, normal to the interface, is applied to the specimen. The maximum shear stress at the interface between layers is determined.
The CCSBT assesses the interlayer bond stiffness at various temperatures, loading frequencies and normal stress levels. A cylindrical specimen is subjected to cyclic direct shear loading whereas an axial load, normal to the interface, is applied to the specimen. During the test, the temperature, frequency and normal stress are varied in several stages. As such, the complex shear stiffness as function of the test temperature, frequency and shear deformation amplitude at the interface between layers can be determined.

Resistance to scuffing

A mode of failure for asphalt that does not have a standardised test method is the resilience of surfacings to scuffing and other actions of traffic. In order to quantitatively assess this resilience requires a simulative test to scuff a sample. Four devices that have been developed for scuffing, so it has been decided to produce a draft for a Technical Specification, as Part 50, until the definitive method can be selected. However, a rational selection will require sufficient comparative studies with the four dedicated devices, which may be unlikely. It would be useful if another procedure could be developed using existing equipment.
Each of the devices are used for determining the resistance to scuffing of asphalt mixtures which are used in surface layers and are loaded with high shear stresses in road or airfield pavement. These shear stresses occur in the contact area between tyre and pavement surface and can be caused by cornering of the vehicle. Due to these shear stresses,

material loss will occur at the surface of these layers. The tests will normally be performed on asphalt layers with a high air voids content (e.g. porous asphalt), but can also be applied on other asphaltic mixtures. Test specimens used are either produced in a laboratory or cut from the pavement.
The four different devices are:

- The Aachener ravelling tester (ARTe)
- The Darmstadt scuffing device (DSD)
- The rotating surface abrasion test (RSAT)
- The Triboroute.

For the ARTe device (Figure 8), the slab is conditioned at (20 ± 2) ºC before mounting in the slab fixation box which, in turn, is mounted in the lateral moving table. During the test, the lateral moving table travels 600 times forwards and backwards over the slab. The slab is then removed from the slab fixation box and any loose material removed from the surface using a vacuum cleaner. The surface is inspected visually for any differences between the initial and end surface and the three dimensional texture of the slab surface measured.

Figure 8. Example of ARTe device

For the DSD device (Figure 9), the asphalt specimens are photographed, weighed and then conditioned at (40 ± 1) °C before being fixed in the device. The test tyre is lowered onto the specimen to applying (1,000 ± 10) N of pressure through the pneumatic pressure cylinder. When the targeted pressure is reached, the test starts. The tyre then moves over the table whilst any lose grains are vacuumed up or wiped off as required. After the test, another photograph is taken for visual comparison with the first photograph and the specimen is re-weighed.

Figure 9. Example of DSD device

For the RSAT device (Figure 10), the specimens are slabs of octagonal shape which are cured for at least 14 days before testing. A test specimen is mounted into the slab holder and then stored for a period of 14 to 18 hours at the test temperature, usually (20 ± 1) °C but can be between (-10 ± 1) °C and (25 ± 1) °C. A new wheel is used for each test with the specimen being preloaded using a minimum load of 20 kg for a period of at least 1 h and then the specimen is completely cleaned. The test lasts 24 h with 86 600 rotations in a relatively complex movement under a total wheel load of (35,0 ± 0,1) kg. The test is stopped early if too much damage occurs on the specimen. During the test, any loose material is removed from the surface of the specimen using a vacuum cleaner and then separated between mineral aggregate and rubber in order to determine the aggregate loss during the test.

Figure 10. Example of RSAT device

For the Triboroute device (Figure 11), the specimen is positioned on a rigid horizontal frame and the flatness and macro-texture of the upper surface is evaluated. The surface has to be free of any grease or other product capable of interfering with mechanical contact between the rubber pad and the target surface. For textures greater than 0,5 mm, the Triboroute is used in controlled force whilst, for lower textures, it is used in controlled displacement rate. The specimen and fixation box are conditioned at the test temperature of (20 ± 2) ºC for at least 2 h. The test with controlled force comprises three phases of the pre-loading phase, the cyclic loading phase and the logarithmic shaped block (LSB) rising phase. The test with controlled displacement rate comprises two phases of the monotonic loading phase and the LSB rising phase.

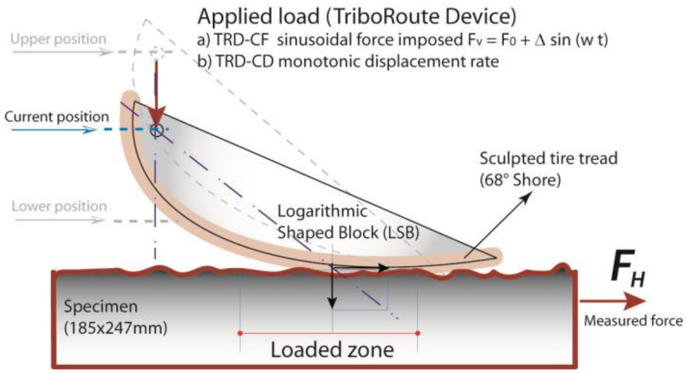

Figure 11. Schematic of Triboroute device

Surface shear strength test

A variant of the TBT (Section 3.1) has been used (on airfield runways and taxiways) for slurry surfaces and other thin surfacings to assess their potential integrity. Therefore, the CEN Airfields group requested that the test method be standardised, which was agreed as Part 51. However, because of the limited experience with the test, it is proposed to issue it as a technical specification rather than a standard. The test measures the surface shear strength for airfield surface courses, which is regarded as a measure of the robustness of asphalt surface courses against shearing.

A plate is bonded to the surface course and rotated using a torque meter to determine the torsional strength of the top layer and, in the case of ultra-thin surface courses, the rotational shear strength between layers. The test can be carried out either in situ or in the laboratory cores which may be subjected to curing conditions. The in situ test is done without the necessity to core into the substrate. A curing procedure can be used to assess the effect of moisture in the development of surface shear strength with time.

The surface shear strength depends on the depth of the surface course together with the properties of the surface course material. The binder course material and any bonding agent applied between the two layers may have an influence on the test result for, in particular, ultra-thin surface course.

Conditioning to address oxidative ageing

The mandate for the asphalt specifications asks for requirements on durability but, because the properties of bitumen, and hence asphalt, will change with time, there is no assessment of that change. Part of the reason for the omission is that there is no accepted ageing procedure that is applicable to all asphalts subject to all climatic conditions. Therefore, a draft is being prepared as Part 52, but again it is proposed to issue it as a technical specification rather than a standard. The draft describes procedures for use on:

- loose asphalt for short-term ageing;
- loose asphalt for long-term ageing;
- compacted specimens with simple conditioning;
- compacted specimens with more complex conditioning.

The procedures are applicable to asphalt manufactured in the laboratory or in a mixing plant. The procedures on compacted specimens are applicable to specimens from laboratory production or cores taken from the field.

For the procedures on loose asphalt, the loose mixture is placed into a pan and conditioned within a heating cabinet with forced air ventilation for a specific duration at elevated temperature to accelerate ageing due to oxidation. Additionally pressure can be applied for further acceleration of conditioning. The procedure for long-term ageing has extended condition relative to the short-term ageing procedure.

For the simpler procedure on compacted specimens or cores from the field, the specimens are placed into a pan and conditioned within a heating cabinet with forced air ventilation for a specific duration at a specific temperature. For the more complex procedure on compacted specimens, the specimens are placed within a triaxial cell (comparable to triaxial cells used for permeability tests on soils) and a forced flow of gaseous oxidant agent (ozone enriched compressed air) through the specimen is used to condition the specimen for a specific duration at a specific temperature.

Material conditioned can then be used for further testing to assess the effect of oxidative ageing on the characteristics of the asphalt mixture and, hence, on their durability and recyclability. Alternatively, binder can be extracted from the conditioned mixture to assess the effect of oxidative ageing on binder characteristics taking into account potential effects of mineral aggregates on ageing.

[redacted]Cohesion increase by spread ability-meter method

The move to explicitly include cold mix asphalt in the product standards requires tests to monitor some additional properties that are required. One of these is the workability of the mixture and how it changes with curing. A draft is proposed, to be Part 53, in which the property measured is the cohesion increase of a mixture under fixed temperature and hygrometry conditions, using a spreadability–meter (at least until a better name is found for the equipment).

The method was designed for cold mix asphalt mixtures, particularly emulsion mixtures, but can be used on other asphalt types apart from mastic asphalt. The mixtures, which have to have an upper aggregate size not larger than 31,5 mm, can be either made up in a laboratory or be sampled from site.

For emulsion-based asphalts and other cold mix asphalt (those mixed and laid at temperatures below 60 °C), the test method characterises the "pot-life" of the mixture, the time between mixing and compacting. This time depends on a number of parameters including the type and binder content of the emulsion, the type of aggregate and the type of grading curve. For other asphalt mixtures, the test method is intended to be of assistance to the designer for mixture design rather than as a type test.

The mixture is used to fill a mould and struck off with a straightedge before going into a climatic chamber or oven. The moulds are conditioned for a fixed time before being set in the workability-meter in which a piston applies a monitored shear force to the sample. The measurement of the resistance against the shear is measured on specimen after different conditioning times.

4. CONCLUSIONS

The tests that have been, and are being, added to the EN 12697 series will have different uses but will be of use to the industry. However, the new test methods that have not yet been published will not be available for being incorporated into the asphalt product standards until the five-year review after the one currently underway. The publication for the revised versions is currently scheduled for July 2016 with the final withdrawal of the existing standards for July 2017, but it is hoped to bring these dates forward.

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The figures are taken from the relevant part of EN 12697.

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