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Performance Evaluation of Asphalt Mixtures

Guidance Note NG 1 Series IM/100

Prepared for Infrastructure Malta

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Acronyms and Abbreviations

Abbreviation	Definition
CE	Conformité Européenne
EU	European Union
ITSR	Indirect Tensile Strength ratio
SHRP	Strategic Highway Research Program
UK	United Kingdom

1 Introduction

The Marshall Mix design method is the accepted method for asphalt design in Malta. Contractors must submit a volumetric design for approval and if this meets the criteria set in Series 900 then the asphalt is acceptable for use on site. All compliance testing carried out is to ascertain the volumetric design submitted by the contractor.

This method gives little understanding of the expected behaviours of the asphalt in-situ. As an example, an asphalt may have excellent volumetric design but will behave differently when placed in a car park or when placed in a dock yard. As such, it is important to establish ways of assessing the performance of an asphalt in situ and this means additional testing and decelerations post volumetric design. EN12697 suite of standards, as established in the European Union (EU), aims to provide a number of tests to assess performance and for the contractors / manufacturers to declare this as part of their CE marking.

This report recommends the performance criteria that Malta should seek to utilise and how these are tested and measured. It also recommends changes to the current method of design and testing.

2 EN 13108 and CE Marking

The European Standard specifications for asphalt define the means of assessing a material against the essential requirements set out in the mandate for those documents. Generally, the assessment is defined in terms of the tests required to be undertaken (shown above) and the classes that materials can be allocated to (performance requirements) depending on the results of those tests. The set of classes that a material meets for each of the essential requirements defines its CE mark. Because the system is intended to apply across Europe without the need for retesting in each country, the tests have to be uniquely defined for each situation (as above).

However, the test conditions under which those tests are performed, when not given in the test method itself, are given in BS EN 13108-20, which has normative annexes for:

- properties and test methods for bituminous mixtures;
- methods of sample preparation; and
- test procedures and conditions.

It is a mandatory requirement for all procurement in the EU to align to the CE Marking requirements when a standard is available and as such all asphalt purchased must have a CE Marking with the declarations as expected by the purchaser and set in the specification.

3 Marshall Method

The Marshall design method is used to determine the optimum binder content of an asphalt mixture.

The test is limited to dense asphalt concrete and hot rolled asphalt mixtures. Stone mastic asphalts used in mainland Europe due to high resistance to fatigue and deformation cannot be designed using this method.

The system usually starts with a number of aggregate-binder blends (typically 5). As an example, one can have an asphalt concrete aggregate gradation blended with 4%, 4.5%, 5%, 5.5% and 6% binder content all undergoing the same testing. This would assume that the asphalt blends are both below and above the optimum binder content of the mixture.

Each sample is then heated to the anticipated compaction temperature and compacted with a Marshall hammer, a device that applies pressure to a sample through a tamper foot. The number of blows is typically 35, 50 or 75 on each side depending upon anticipated traffic loading. The 35 blows test is used for low traffic roads, 50 for medium traffic roads and 75 for high traffic roads. In Malta, 50 blows is the typical test specified. Marshall compactibility is also seen as not replicating the compaction achieved on site and therefore is not the chosen method for highway asphalts in the UK.

3.1 Marshall Stability and Flow Test

The Marshall stability and flow test provides an indicator of the performance of the Marshall asphalt in-situ. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50 mm/minute. Basically, the load is increased until it reaches a maximum and then when the load just begins to decrease, the loading is stopped, and the maximum load is recorded.

During the loading a dial gauge measures the specimen’s plastic flow as a result of the loads applied. The flow is measured in 0.25mm increments at the same time as the maximum load is recorded.

The higher the stability, the stronger an asphalt is at bearing load whereas the lower the flow the less susceptible the asphalt is to deformation. It is important to note that a minimum flow is essential so that the asphalt is not purely stiff and has a good binder content that allows to flex and be fatigue resistant.

The optimum binder content is then generally selected as 4 percent air voids as long as the mixture assessed passes stability and flow.

3.2 Limitations of the Marshall Method

Marshall method is still probably the most widely used mix design method in the world. It is simple, compact and inexpensive. Marshall test for stability and flow was designed to stress the entire sample rather than just a portion of it. It facilitates rapid testing with minimal effort. It is also compact, light, portable and produces densities reasonably closer to field densities.

One big problem with the Marshall method is that although the Marshall Mix Design method has been used for many years, many believe that the impact compaction used with the Marshall method does not simulate mixture densification as it occurs in real pavement. Marshall stability also does not adequately estimate the shear strength of the asphalt mixture. This are the main reason why the UK stopped using Marshall mix design and switched to performance mix design, as these two parameters are inadequate at ensuring the mixture will not rut or deform in-situ. There is a growing feeling that although Marshall method is suitable it has been surpassed by much more modern methods of asphalt mixture design.

4 The Superpave Method and UK Adoption

The United States of America has developed the Superpave Method through its Strategic Highway Research Program (SHRP) completed in 1993. The Superpave method was designed to replace the Marshall method.

Essentially, the volumetric design in Marshall provides the basis for the Superpave method. The compaction device, the Marshall hammer, is replaced in the Superpave method with a gyratory compactor and the compaction effort is tied to the expected traffic.

The UK and Europe have adopted a lot of the research carried out in the US in the production and testing of asphalts.

Performance tests are carried out on the asphalt mixture to ascertain the behaviours of the asphalt in-situ. These tests are described below and are generally supplied on the CE Marking when asked upon by the client.

4.1 Gyratory Compactor Method - BS EN 12697-31

The Gyratory Compactor is used to simulate and reproduce the real compaction conditions under actual road paving operations, hence determining the compaction properties of the asphalt. BS EN 12697-31 specifies the method for compaction of cylindrical specimens of bituminous mixtures using a gyratory compactor. Such compaction is achieved by combining the rotary action and the vertical resultant force applied by a mechanical head. The method is used to:

- determine the air voids content of a mixture for a given number of gyrations;
- determine the relationship between density and number of gyrations; and
- prepare specimens for subsequent testing.

The standard applies to bituminous mixtures (both those made up in the laboratory and those resulting from work site sampling), with an upper aggregate size not larger than 31,5 mm.

4.1.1 Method

The mixture is prepared in accordance with the relevant standard and, if a core, heated sufficiently to be broken up in order to sample the required mass of material. The pre-heated mould is filled with the required mass of the bituminous mixture and kept at the test temperature for between 30 min and 120 min prior to compaction.

During the test, the cross-section and the mass of the specimen remain constant, but its height, which is continuously monitored, reduces until the test is ended, or a predetermined density is achieved.

The density of the material is derived from the height of the specimen.

4.1.2 UK experience

Gyratory compaction machines have become more common in UK laboratories. The method is used for the design as well as the assessment of asphalt mixture compactibility as stated in BS EN 12697-10.

4.2 Determination of the water sensitivity of bituminous specimens - BS EN 12697-12

This standard describes three test methods for determining the effect of saturation and accelerated water conditioning. These methods can be used to evaluate the effect of moisture with or without anti-stripping additives including liquids, such as amines, and fillers, such as hydrated lime or cement.

4.2.1 Method

Methods A and B, respectively, use indirect tensile strength and compressive strength of bituminous mixtures with bitumen of viscosity at 60 °C greater than 4000 mm^2/s, whilst Method C defines the bonding value of bituminous mixtures with bitumen of viscosity at 60 °C of 4000 mm^2/s or less 1 h after mixing.

However, if the slenderness of the specimens is less than 0,5 (ratio of the specimen), method B is not suitable.

4.2.2 UK experience

Water sensitivity tests by Method A are mandatory for certification of thin surface course systems.

4.3 Wheel tracking - BS EN 12697-22

This standard describes test methods for determining the susceptibility to permanent deformation under load of bituminous mixtures. This test method can be used for specimens that are either manufactured in a laboratory or cut from a pavement.

4.3.1 Method

The rut depth formed by repeated passes of a loaded wheel at a fixed temperature is measured. There are five methods:

- large size devices with samples conditioned in air
- extra-large size devices with samples conditioned in air
- small size devices, Procedure A, with samples conditioned in air
- small size devices, Procedure B, with samples conditioned in air
- small size devices, Procedure B, with samples conditioned in water

4.3.1.1 Large size device with samples conditioned in air

Two samples are conditioned by loading with a pneumatic tyre at 600 kPa for 1000 cycles at a temperature of (20 ±5) °C. The samples are then raised to the test temperature (which is not defined in the standard) for (14 ±2) h before the device is run. The deformation is measured at various times and the proportional deformation recorded as the ratio of the mean value.

4.3.1.2 Extra-large size device with samples conditioned in air

Two samples are conditioned at the test temperature for (16 ±2) h. A pneumatic-tyred wheel with a load of 10 kN tracks the samples at a frequency of 24 cycles/min. The deformation is measured along three transverse lines initially, and after various intervals up to 30000 cycles. The test ends when the required number of cycles has been completed or the rut depth has reached 20 mm. The mean rut depth and the proportional rut depth are calculated.

4.3.1.3 Small size device, Procedure A, with samples conditioned in air

Six specimens are conditioned at the test temperature for between 4 h (6 h for thicknesses >60 mm) and 24 h before being tracked for 1000 cycles under a solid rubber tyre 50 mm wide with a 700 N load. The first five cycles are used for conditioning. The wheel-tracking rate is calculated from the average rate of deformation in µm/cycle over the last third of the test and the proportional deformation is calculated from the average total deformation as a proportion of sample thickness.

4.3.1.4 Small size device, Procedure B, with samples conditioned in air

Two specimens are conditioned at the test temperature for not less than 1 h before being tracked for 10000 cycles under a solid rubber tyre 50 mm wide with a 700 N load. The deformation is measured at least every 500 load cycles. The wheel-tracking rate is calculated as the mean value in mm/10_3 cycles and the proportional rut depth as for the large size device.

4.3.1.5 Small size device, Procedure B, with samples conditioned in water

This is the small size device, Procedure B, with samples conditioned in air except that the samples are held in water during conditioning and testing.

4.3.2 UK experience

Deformation testing with small size device to Procedure B conditioned in air for asphalt designed for maximum loads <13 t and with large size devices for asphalt designed for axle loads ≥13 t is referenced in BS EN 13108-1 for asphalt concrete and BS EN 13108-5 for stone mastic asphalt. However, specifications adopted for highways and airfield projects in the UK have mostly used the small device. Results from said test are effective at classifying performance in-situ.

The test temperature should be set to 60°C as a minimum to replicate hot conditions when the bitumen is beyond its softening point and therefore mobile. It may be appropriate for the temperature to be even higher in Malta and for rut rates to be set accordingly.

4.4 Stiffness - BS EN 12697-26

This is used for the characterisation of stiffness of asphalt by alternative tests, including bending tests and direct and indirect tensile tests. The tests are performed on compacted bituminous material under a sinusoidal loading or other controlled loading, using different types of specimens and supports to:

- rank bituminous mixtures based on stiffness, as a guide to relative performance in the pavement;
- obtain data for estimating the structural behaviour in the road; and

- judge test data according to specifications for bituminous mixtures.
- As this standard does not impose a particular type of testing device the precise choice of the test conditions depends on the possibilities and the working range of the device used.

4.4.1 Method

Suitable shaped samples are deformed in their linear range, under repeated loads or controlled strain rate loads. The accepted test procedures, with methods given for them in annexes, are:

- two-point bending on trapezoidal and prismatic specimens (Annex A);
- three-point and four-point bending on prismatic specimens (Annex B);
- indirect tensile resilient modulus on cylindrical specimens (Annex C);
- direct tension-compression on cylindrical specimens (Annex D);
- direct tension-compression on cylindrical and prismatic specimens (Annex E); and
- cyclic indirect tension on cylindrical specimens (Annex F).

The test methods for determining the stiffness of asphalt mixtures are not identical since the test results are affected by loading patterns, test temperature, test frequency and stress distribution within the specimens.

4.4.2 UK experience

Any specification calling for stiffness test should state the specific test method and conditions. Stiffness testing in the UK, is almost entirely with the indirect tensile stiffness (IT-CY) procedure (Annex C) at a test temperature of 20°C and a loading time of 124 ms. Stiffness categories used for different asphalt materials can be found in PD 6691 and Highways England's specifications in Series 900.

5 Recommendation

It is recommended that Malta adopts a performance specification as set in the UK, Germany, France and other countries in the EU / Europe. Testing parameters should be set in line with expected conditions in Malta i.e. high heat, slow / fast moving traffic dependant on location and very high axial loads.

When a specification is set, it is up to asphalt producers to align to the requirements at Factory Production Control (FPC) which will then allow Infrastructure Malta to de-risk failure from poorly designed asphalts, specifically rutting / deformation, fretting and fatting.