Performance Evaluation of Asphalt Mixtures

Guidance Note Series IM/900 NG1

Prepared for Infrastructure Malta

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ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
AAV	Aggregate Abrasion Value
CE	Conformité Européenne
EU	European Union
FI	Flakiness Index
IM	Infrastructure Malta
ITSR	Indirect Tensile Strength ratio
PSV	Polished Stone Value
RTFOT	Rotating Thin Film Oven Test
VFB	Voids Filled with Bitumen
VMA	Voids in Mineral Aggregate

1 INTRODUCTION

Infrastructure Malta (IM) have recently updated *Series 700 – Road Pavements - General* and *Series 900 – Road Pavements – Bituminous Bound Materials* of their Specification for Highway Works.

The revision included the updates to:

i. Grading envelopes and binder content of asphalt concrete mixtures to BS EN 13108-1
ii. Grading envelopes and binder content for superior asphalt concrete mixtures to BS EN 13108-1
iii. Grading envelopes and binder content for stone mastic asphalt mixtures to BS EN 13108-5
iv. Updates to binder types including the introduction of 40/60 Paving Grade Binder to BS EN 12591 and Polymer Modified Binder to BS EN 14023
v. Void content requirements for all asphalt mixtures
vi. The inclusion of performance measures in asphalt mix designs to tests in BS EN 12697
vii. The introduction of electronic measures for in-situ void content
viii. The update to surface regularity requirements and assessment of these in Clause 702

The purpose of this guidance note is to present the test methods for the assessment of asphalt mixtures and asphalt laying for technical approval by IM technical assessors.

2 ASSESSMENT OF MIX DESIGN AND/OR 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 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:

i. properties and test methods for bituminous mixtures;
ii. methods of sample preparation; and
iii. test procedures and conditions.

The tests and associated declarations are applicable with or without a CE marking and thereby manufacturers must declare these as stated below.

2.1 Aggregates to BS EN 13043 – Aggregates for Bituminous Mixtures and surface treatments for roads, airfields and other trafficked areas

The asphalt manufacturer must declare the following properties:

i. Resistance to fragmentation
BS EN 1097-2 Methods for the determination of resistance to fragmentation. This is an essential criterion as it indicates the strength of the aggregate represented by the Los Angeles Coefficient

ii. Water Absorption
BS EN 1097-6 Determination of particle density and water absorption. This is an essential criterion as it indicates the durability of the material and the proportion of absorbed bitumen in the mixture.

iii. Resistance to Freezing and thawing (magnesium sulfate soundness)
BS EN 1367 Tests for thermal and weathering properties of aggregates. This is a non-essential characteristic in Malta due to the low probability of low temperatures throughout the year

iv. Shape (Flakiness Index (FI))
BS EN 933-3 Tests for geometrical properties of aggregates. Determination of particle shape. Flakiness index. This is an essential criterion as it determines the ability of the aggregate to interlock and not be planar in the asphalt matrix.

v. Polished Stone Value (PSV) (For Surface Courses)
BS 812-114 Testing aggregates. Method for determination of the polished-stone value. This is an essential criterion for aggregates in the surface course to determine the resistance to polishing and thereby the resistance to the asphalt become slippery.

vi. Aggregate Abrasion Value (For Surface Courses)
BS 812-113 Testing aggregates. Method for determination of aggregate abrasion value (AAV). The AAV is a fundamental criterion of the aggregate and determines the ability of the aggregate to resist surface wear by abrasion in use.

vii. Bulk Density
BS 1097-3 Tests for mechanical and physical properties of aggregates. Determination of loose bulk density and voids. This is an essential criterion to determine the void content in the bulk and thereby determining the bitumen content of the asphalt mixture.

viii. "Sonnenbrand" of Basalt
BS EN 1367-3 Tests for thermal and weathering properties of aggregates. Boiling test for Sonnenbrand basalt. This is a test to determine the signs of sunburn in Basaltic aggregates. This must be declared to ensure source since Basalt is used in large quantities.

2.2 Binder to BS EN 12591 – Bitumen and bituminous binders. Specifications for paving grade bitumens or BS EN 14023 – Bitumen and bituminous binders. Specification framework for polymer modified bitumens

The asphalt manufacturer must declare the following properties:

i. Penetration at 25°C
BS EN 1426 Bitumen and bituminous binders. Determination of needle penetration. Penetration is a required criterion as it determines the hardness of the bitumen.

ii. Ring & Ball Softening Point
BS EN 1427 Bitumen and bituminous binders. Determination of the softening point. Ring and Ball method. Softening point is essential and critical to the behaviour of the asphalt with regards to environmental temperatures and thereby must be declared at source.

iii. Flash point
BS EN ISO 2719 Determination of flash point. Pensky-Martens closed cup method. Flash point is the lowest temperature at which a liquid can form an ignitable mixture in air near the surface of the liquid, when given an ignition source. The lower the flash point, the easier it is to ignite the material. The flash point tells the critical temperature at and above which suitable precautions are required to be taken to eliminate the danger of fire during heating.

iv. Fraass breaking point (For Polymer Modified Binder)
BS EN 12593 Bitumen and bituminous binders. Determination of the Fraass breaking point. This apparatus is used to determine the breaking point of semisolid and solid bitumen. This determines the ability of bitumen to flex and stretch under stress without breaking. It is synonymous with life cycle fatigue properties of the bitumen.

v. Elastic recovery (For Polymer Modified Binder)
BS EN 13398 Bitumen and bituminous binders. Determination of the elastic recovery of modified bitumen. This value is especially applicable to bituminous binders modified with thermoplastic elastomers. This is essential to assess the ability of the bitumen to recover when stressed and not crack or deform.

vi. RTFOT Retained penetration (Optional), RTFOT Increase in Softening Point (Optional), RTFOT Change in mass (Optional)
BS EN 12607-1 Bitumen and bituminous binders. Determination of the resistance to hardening under influence of heat and air. RTFOT method. This test ensures that the bitumen does not change characteristics when passing through the asphalt manufacturing process and thereby that the end product in the asphalt mixture has properties that are similar to the original sourced bitumen.

2.3 Asphalt to BS EN 13108 – Bituminous mixtures. Material specifications.

The asphalt manufacturer must declare the following properties:

i. Grading
BS EN 12697-2 Bituminous mixtures. Test methods. Determination of particle size distribution. Test used to determine the distribution of aggregates in the asphalt mixture thereby assessing the coarse, fine and filler elements of the aggregate matrix.

ii. Binder Content
BS EN 1296-1 Bituminous mixtures. Test methods for hot mix asphalt. Soluble binder content. Test used to determine the soluble binder content in the asphalt mixture.

iii. Void Content
BS EN 12697-8 Bituminous Mixture. Test methods for hot mix asphalt. Determination of void characteristics of bituminous specimen. This test is an essential criterion and determines the void content of the mixture. This test is dependent on the test method for compaction used and this is as to whether the Marshall Hammer or the Gyratory Compactor are used.

iv. Voids filled with bitumen (VFB), Voids in mineral aggregate (VMA)
These are design parameters of the asphalt and are considered essential criteria in the asphalt mixture. High VMA (i.e. lack of filler) leaves high proportions of voids in the mixture which result in a weak asphalt structure and low strengths. Low VMA on the other hand result in the in-situ bleeding of the asphalt mixture. These methods thereby inform:
The void in the aggregate bulk where bitumen can be placed
The void left after bitumen fills a proportion of the void

v. Void content at 10 gyrations (Optional), Void content at 120 gyrations (Optional)
BS EN 12697-31 Bituminous mixtures. Test methods for hot mix asphalt. Specimen preparation, gyratory compactor. This method should be an essential criterion as it compacts the material in the laboratory in a way that on field replication is possible. The specimen then helps determine the expected in-situ void content.

vi. Maximum Theoretical density
BS EN 12697-5 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the maximum density. The theoretical maximum specific gravity (Gmm) of an asphalt mixture is the specific gravity excluding air voids. This is critical as it is used to calculate percentage air voids in the mixture when samples are taken or read in-situ.

vii. Bulk density
BS EN 12697-6 Bituminous mixtures. Test methods for hot mix asphalt. Determination of bulk density of bituminous specimen by hydro-static method. The bulk specific gravity test is used to determine the specific gravity of a compacted asphalt sample by determining the ratio of its weight to the weight of an equal volume of water. This in turn determines the actual void content when compared to the maximum theoretical density.

viii. Marshall Stability, Marshall Flow
BS EN 12697-34 Bituminous mixtures. Test methods for hot mix asphalt. Marshall 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. This is an essential characteristic.

ix. Resistance to permanent deformation (Optional)
BS EN 12697-22 Bituminous mixtures. Test methods for hot mix asphalt. Wheel tracking. 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.

x. Water Sensitivity (Optional)
BS EN 12697-12 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the water sensitivity of bituminous specimens. 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.

xi. BS EN 12697-23 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the indirect tensile strength of bituminous specimens. This method is used in conjunction with the water sensitivity to determine the characteristic strength of the asphalt in environmental conditions and its typical loss of strength due to water and air.

xii. Stiffness (Optional)
BS EN 12697-26 Bituminous mixtures. Test methods for hot mix asphalt. Stiffness. 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:
a) rank bituminous mixtures based on stiffness, as a guide to relative performance in the pavement;
b) obtain data for estimating the structural behaviour in the road; and
c) judge test data according to specifications for bituminous mixtures.

xiii. Affinity to bituminous binders (Optional)
BS EN 12697-11 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the affinity between aggregate and bitumen. This test is essential for aggregates containing high silica content to determine the effects of affinity on early life fatigue such as stripping and fretting.

3 Assessment of Transportation, Laying and Compaction of Asphalt

At the point of installation asphalt mixtures require testing to determine compliance with declared values at production. The method of assessment has to comply with the test methods described in BS EN 12697 suite of standards, with the Specification for Road Works and with **BS 594987 Asphalt for roads and other paved areas. Specification for transport, laying, compaction and product type testing protocols.** The following tests are required to be completed by the appointed site technicians and quality assurers.

3.1 In-situ Tests and Procedures during laying

The following are tests that must be undertaken during the asphalt operation

i. Temperature
BS EN 12697-26 Bituminous mixtures. Test methods for hot mix asphalt. Temperature Measurement.
Temperature measurements are essential to ensure that the material is hot enough and adequate for laying. Laying records must show the temperature at arrival and the temperature at laying. The minimum temperatures for compaction are shown below:
a) **70/100 pen -** 90°C
b) **40/60 pen -** 105°C
Batches that do not meet this requirement must not be laid.
Temperature records must be provided for all truck loads.

ii. Bond Coat and Calibration of equipment

BS EN 12272-1 Surface dressing. Test methods. Rate of spread and accuracy of spread of binder and chippings. Calibration of spraying machines must be carried out in accordance with chapter 3 and chapter 5 of the standard. Operators must be able to declare performance.

iii. Thickness of Pavement

BS EN 12697-36 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the thickness of a bituminous pavement. The test method describes how the determination of the thickness of the pavement is determined. The tolerances in the Specification for Road Works is then applied to the findings.

iv. Sampling

BS EN 12697-27 Bituminous mixtures. Test methods for hot mix asphalt. Sampling. This is critical to the determination of compliance through further laboratory testing. Sampling must be taken from the back of the augers of the paver as specified in 4.3 of the standard or from laid but not rolled material using sample trays as specified in 4.5 of the standards. Material should not be sampled from the back of the transporter as this may have segregated. Sample records must be kept.

3.2 In-situ Tests and Procedures after laying

i. Coring

BS EN 12697-27 Bituminous mixtures. Test methods for hot mix asphalt. Sampling. Core samples may be taken as per the procedure stated in 4.7 of the standard. Cores and lose bulk can be used for the determination of void off-situ.

ii. Void Content by electronic or nuclear equipment

BS EN 12697-7 Bituminous mixtures. Test methods for hot mix asphalt. Determination of bulk density of bituminous specimens by gamma rays or BS 594987 Asphalt for roads and other paved areas. Specification for transport, laying, compaction and product type testing protocols. Clause 9.5.1. The in-situ tests give a clear indication as to whether further analysis and core extraction or laboratory specimens require further testing. Failure to achieve the required voids as per the Specification for Road Works will require remediation.

iii. Surface regularity

BS EN 13036-7 Road and airfield surface characteristics. Test methods. Irregularity measurement of pavement courses. The straightedge test. A 3m rolling straight edge as specified in the standard and in the Specification for Road Works is carried out on the finished works.

iv. Texture Depth

BS EN 13036-1 Road and airfield surface characteristics. Test methods. Measurement of pavement surface macrotexture depth using a volumetric patch technique. Texture depth requirements may be checked and assessed against the requirements set in the Specification for Road Works.

3.3 Ex-situ Tests and Procedures

i. Performance repeatability as per BS EN 13108-20 Bituminous mixtures. Material specifications. Type Testing.

Once the samples are taken to the laboratory any of the performance requirements of the aggregates, bitumen and asphalt can be replicated. Currently the most important tests are:

a) Grading

b) Bitumen Content through Binder recovery methods as specified in BS EN 12697-3 Bituminous mixtures. Test methods for hot mix asphalt. Bitumen recovery: Rotary Evaporator

c) Marshall Stability
d) Marshall Flow
e) Void Content through the methods specified in BS EN 12697-8 Bituminous mixtures. Test methods for hot mix asphalt. Determination of void characteristics of bituminous specimens

4 CONCLUSION

The testing protocols listed in this document provide the basis to quality assurance of the materials produced. They do not provide the basis to Quality Control as mentioned in **BS EN 13108-21 Bituminous mixtures. Material specifications. Factory Production Control** which need to be formulated separately.

This document is for use in all asphalt work in Malta carried out by IM and the values set in the Specification for Road Works determine the basis for compliance.

APPENDIX A – NOMINATED TESTS AND LIMIT VALUES

Test	Test Method	Sub-Method	Value
AGGREGATES			
Resistance to fragmentation	BS EN 1097-2 Methods for the determination of resistance to fragmentation	N/A	Surface Course: LA 20 Binder / Base Course: LA 35 Base-Wearing Course: LA28
Water Absorption	BS EN 1097-6 Determination of particle density and water absorption	N/A	WA < 3%
Shape (Flakiness Index (FI))	BS EN 933-3 Tests for geometrical properties of aggregates. Determination of particle shape. Flakiness index.	N/A	Surface Course: FI 25 Other: FI 35
Polished Stone Value (PSV) (For Surface Courses)	BS 812-114 Testing aggregates. Method for determination of the polished-stone value	N/A	Construction Class V to VI ≥ 38 Construction Class HD and I to IV ≥ 57
Bulk Density	BS 1097-3 Tests for mechanical and physical properties of aggregates. Determination of loose bulk density and voids	N/A	Declared
"Sonnenbrand" of Basalt	BS EN 1367-3 Tests for thermal and weathering properties of aggregates.	N/A	Declared

	Boiling test for Sonnenbrand basalt.		
BITUMEN			
Penetration at 25°C	BS EN 1426 Bitumen and bituminous binders. Determination of needle penetration.	N/A	40/60 50/70 Class 4 – Class 7 for PMB
Ring & Ball Softening Point	BS EN 1427 Bitumen and bituminous binders. Determination of the softening point. Ring and Ball method	N/A	≥ 39°C and ≤ 70°C Class 5 maximum for PMB
Flash Point	BS EN ISO 2719 Determination of flash point. Pensky-Martens closed cup method.	N/A	Declared
Fraass breaking point (For Polymer Modified Binder)	BS EN 12593 Bitumen and bituminous binders. Determination of the Fraass breaking point.	N/A	Class 5 minimum PMB
Elastic recovery (For Polymer Modified Binder)	BS EN 13398 Bitumen and bituminous binders. Determination of the elastic recovery of modified bitumen.	N/A	Class 5 maximum PMB
RTFOT Retained penetration (Optional), RTFOT Increase in Softening Point (Optional), RTFOT Change	BS EN 12607-1 Bitumen and bituminous binders. Determination of the resistance to hardening under influence of heat and air. RTFOT method.	N/A	Declared

in mass (Optional)			
ASPHALT			
Grading	BS EN 12697-2 Bituminous mixtures. Test methods. Determination of particle size distribution.	Relevant Clause in Series 900	Declared
Binder Content	BS EN 1296-1 Bituminous mixtures. Test methods for hot mix asphalt. Soluble binder content.	Relevant Clause in Series 900	Declared
Void Content	BS EN 12697-8 Bituminous Mixture. Test methods for hot mix asphalt. Determination of void characteristics of bituminous specimen.	Relevant Clause in Series 900	Declared
Voids filled with bitumen (VFB), Voids in mineral aggregate (VMA)	BS EN 12697-34 Bituminous mixtures. Test methods for hot mix asphalt. Marshall test.	Table 900-6	Declared
Void content at 10 gyrations (Optional), Void content at 120 gyrations (Optional)	BS EN 12697-31 Bituminous mixtures. Test methods for hot mix asphalt. Specimen preparation, gyratory compactor.	Relevant Clause in Series 900	Declared
Maximum Theoretical density	BS EN 12697-5 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the maximum density.	N/A	Declared

Bulk density	BS EN 12697-6 Bituminous mixtures. Test methods for hot mix asphalt. Determination of bulk density of bituminous specimen by hydro-static method.	N/A	Declared
Marshall Stability, Marshall Flow	BS EN 12697-34 Bituminous mixtures. Test methods for hot mix asphalt. Marshall test.	Relevant Clause in Series 900	Declared
Resistance to permanent deformation (Optional)	BS EN 12697-22 Bituminous mixtures. Test methods for hot mix asphalt. Wheel tracking.	Relevant Clause in Series 900	Declared
Water Sensitivity (Optional)	BS EN 12697-12 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the water sensitivity of bituminous specimens. BS EN 12697-23 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the indirect tensile strength of bituminous specimens.	Relevant Clause in Series 900	ITSRmin 70
Stiffness (Optional)	BS EN 12697-26 Bituminous mixtures. Test methods for hot mix asphalt. Stiffness.	Relevant Clause in Series 900	Declared
Affinity to bituminous binders (Optional)	BS EN 12697-11 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the affinity	N/A	Declared

	between aggregate and bitumen.		
TRANSPORTATION AND LAYING			
Temperature	BS EN 12697-26 Bituminous mixtures. Test methods for hot mix asphalt. Temperature Measurement.	N/A	Measured in-situ
Bond Coat and Calibration of equipment	BS EN 12272-1 Surface dressing. Test methods. Rate of spread and accuracy of spread of binder and chippings.	N/A	Declared
Thickness of Pavement	BS EN 12697-36 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the thickness of a bituminous pavement.	N/A	Measured in-situ
Sampling	BS EN 12697-27 Bituminous mixtures. Test methods for hot mix asphalt. Sampling.	BS EN 12697-27 Clause 4.3 and Clause 4.5	Carried out in-situ
POST LAYING IN-SITU			
Coring	BS EN 12697-27 Bituminous mixtures. Test methods for hot mix asphalt. Sampling	BS EN 12697-27 Clause 4.7	Carried out in-situ
Void Content by electronic or nuclear equipment	BS EN 12697-7 Bituminous mixtures. Test methods for hot mix asphalt. Determination of bulk density of bituminous specimens by gamma rays or BS 594987 Asphalt for roads and other	BS594987 Clause 9.5.1	Measured in-situ

	paved areas. Specification for transport, laying, compaction and product type testing protocols.		
Surface regularity	BS EN 13036-7 Road and airfield surface characteristics. Test methods. Irregularity measurement of pavement courses. The straightedge test.	Clause 702	Measured in-situ
Texture Depth	BS EN 13036-1 Road and airfield surface characteristics. Test methods. Measurement of pavement surface macrotexture depth using a volumetric patch technique.	N/A	Measured in-situ
POST LAYING EX-SITU			
Grading	BS EN 12697-2 Bituminous mixtures. Test methods. Determination of particle size distribution.	BS EN 13108-20	Measured ex-situ
Binder Content	BS EN 1296-1 Bituminous mixtures. Test methods for hot mix asphalt. Soluble binder content.	BS EN 13108-20 Method B 1.5 of BS EN 12697-1	Measured ex-situ
Void Content	BS EN 12697-8 Bituminous Mixture. Test methods for hot mix asphalt. Determination of void characteristics of bituminous specimen.	Method C.5 of BS EN 13108-20	Measured ex-situ
Voids filled with bitumen (VFB), Voids in mineral	BS EN 12697-34 Bituminous mixtures. Test methods for hot mix asphalt. Marshall test.	Table 900-6	Measured ex-situ

aggregate (VMA)			
Maximum Theoretical density	BS EN 12697-5 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the maximum density.	Method D.2 of BS EN 13108-20	Measured ex-situ
Bulk density	BS EN 12697-6 Bituminous mixtures. Test methods for hot mix asphalt. Determination of bulk density of bituminous specimen by hydro-static method.	Method D.2 of BS EN 13108-20	Measured ex-situ
Marshall Stability, Marshall Flow	BS EN 12697-34 Bituminous mixtures. Test methods for hot mix asphalt. Marshall test.	Method D.10 of BS EN 13108-20	Measured ex-situ
Resistance to permanent deformation (Optional)	BS EN 12697-22 Bituminous mixtures. Test methods for hot mix asphalt. Wheel tracking.	Method D.6 of BS EN 13108-20	Measured ex-situ
Water Sensitivity (Optional)	BS EN 12697-12 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the water sensitivity of bituminous specimens. BS EN 12697-23 Bituminous mixtures. Test methods for hot mix asphalt. Determination of the indirect tensile strength of bituminous specimens.	Method D.3 of BS EN 13108-20 ITSRmin 70	Measured ex-situ

Stiffness (Optional)	BS EN 12697-26 Bituminous mixtures. Test methods for hot mix asphalt. Stiffness.	Method D.8 of BS EN 13108-20	Measured ex-situ
Compaction Degree	BS EN 13108-20 Bituminous mixtures. Material specifications. Type Testing.	Method C.4 of BS EN 13108-20	Measured ex-situ