ESTC Shockpad Working Group

Performance Guide for Shockpads

2019 EDITION

1 Introduction

Shockpads are often used in the construction of synthetic turf sports systems. The shockpad is laid beneath the synthetic turf carpet and is designed to assist in the sports performance and player protection of the sports surface and to aid the retention of these properties through the long-term life of the playing surface.

Shockpads can be found in two generic groups; pre-fabricated shockpads and insitu laid or elastic (e) layers. Pre-fabricated shockpads are manufactured in a factory as tiles or rolls, transported to the field and installed onto the sub-base of the field. Insitu shockpads are produced from binders (normally polyurethane) and elastomeric granulate mixes. The two components are mixed on site, laid with a paving machine onto the field's sub-base and allowed
to cure.

Due to the wide range of different types of synthetic turf sports surfacing (non-filled, sand filled, long pile rubber filled, etc.) and the wide range of sporting uses they are put to, there is a wide range of shockpads with differing performance levels.

This performance guide to shockpads has been prepared by the European Synthetic Turf Organisation's Shockpad Working Group with three principal objectives:

1. To allow synthetic turf system developers to compare the performance of alternative shockpads in an objective way by ensuring that a common set of performance data is always available to allow a direct comparison to be made;
2. To specify minimum durability criteria to ensure that when a shockpad is incorporated into a synthetic turf system it will continue to perform adequately for the life of the synthetic turf sports system and normally for at least the life of two synthetic turf carpets.
3. To prepare a draft document for consideration by European Standards Committee (CEN) Technical Committee TC 217: Surfaces for Sports Areas as a European Standard for Shockpads to complement EN 15330.

2 Incorporated Test Methods

This is the second edition of the performance guide. It has been updated based the experiences gained since the first edition was published in 2013.

Test methods from other publications are incorporated into this Guide by dated or undated reference. Where dated references are used, subsequent amendments to or revisions of any of these publications will apply to this Guide only when incorporated into it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

EN 1177, Impact attenuating playground surfacing – Determination of critical fall height

EN 1969, Surfaces for sports areas – Determination of thickness of synthetic sports surfaces

EN 9863-1. Geosynthetics, Determination of thickness at specified pressures – Part 1: Single layers

EN 12616, Surfaces for sports areas – Determination of water infiltration rate

EN 13744, Surfaces for sports areas – Procedure for accelerated ageing by immersion in hot water

EN 13746, Surfaces for sports areas – Determination of dimensional changes due to the effect of varied water, frost and heat conditions

EN 13817, Surfaces for sports areas – Procedure for accelerated ageing by exposure to hot air

EN ISO 9863-1, Geosynthetics. Determination of thickness at specified pressure. Single layers

EN ISO 1183-1, Plastics. Methods for determining the density of non-cellular plastics Immersion method, liquid pyknometer method and titration method

EN ISO 527-3 Plastics – Determination of Tensile Properties Part 3: Test Conditions for Films and Sheets

EN TS 16717, Surfaces of sports areas – Method of test for the determination of shock absorption, vertical deformation and energy restitution using the Advanced Artificial Athlete

ISO 188, Rubber, vulcanized or thermoplastic – Accelerated ageing and heat resistance tests

ISO 3385, Flexible cellular polymeric materials. Determination of fatigue by constant load pounding

ISO 8543, Textile floor coverings: Methods for determination of mass

ISO 12958, Geotextiles and Geotextile related products. Determination of water flow capacity in their plane

DIN 38414, Methods for the examination of water, waste water and sludge and sediments: Determination of strippable and extractable organic bound halogens

3 Definitions

Shockpad – an elastic material placed beneath a synthetic turf, needle-punch or textile sports surface that is designed to aid the provision of the performance properties of the sports surfacing system.

Pre-fabricated shockpad – shockpad manufactured in a factory and normally comprising rolls or tiles that are laid on the base of the sports area.

In-situ shockpad or elastic (e) layer – shockpad formed as a wet pour mix and normally incorporating a binder (e.g. polyurethane) and elastomeric granulate that is mixed and machine-laid on site using a paving machine or similar.

Sports surfacing system – all components of the playing surface that influence its sports performance or bio-mechanical characteristics including the synthetic turf, needle punch or textile carpet, infill and shockpad or elastic layer, together with any supporting layers designed to contribute to the performance of the surface.

Product declaration – statement or datasheet provided by the shockpad manufacturer that describes the composition and expected performance of the shockpad.

4 Performance & Characterisation

Shockpads shall be tested using the test methods detailed below. For certain properties, minimum guideline requirements are specified; these are based on the Working Group's experience of what constitutes an acceptable shockpad product. For other properties, the range of performance required from a shockpad within a synthetic turf system will differ, depending on the system and intended sports use. In such cases, the system developer will need to determine if a particular shockpad is suitable for the intended application.

Shockpads are designed to be laid beneath a synthetic turf playing surface. As some forms of synthetic turf surface (especially those with significant quantities of infill) will partly spread the impact forces being transmitted to the shockpad, those tests where this factor can be significant are made with and without standardised load spreading plate.

When independent third party testing of shockpads is required to assess compliance with this guide it is recommended the laboratory is certified to ISO/IEC 17025. Details of suitable test laboratories can be obtained from ESTC (www.estc.info).

4.1 Shock absorption

4.1.1 Performance requirements

The minimum Shock Absorption measured under any of the test conditions shall be as detailed in Table 1.

The maximum variation between the maximum and minimum values of Shock Absorption obtained under any of the test conditions detailed in Table 1 with the load spreading plate shall be 5% FR (absolute).

The maximum variation between the three test positions tested at 23 ± 2°C under dry conditions without the load spreading plate shall be 5% FR (absolute).

4.1.2 Testing requirements

The shock absorption properties of the shockpad shall be measured using an Advanced Artificial Athlete in accordance with EN TS 16717 under the following conditions:

Table 1 - Test conditions & requirements

Condition	Test temperature	With load spreading plate		Direct measurement onto shockpad	
Dry	23 ± 2°C	✓	≥ 30%	✓	≥ 20%
Wet	23 ± 2°C	✓	≥ 30%	-	-
Dry	40 ± 2°C	✓	≥ 30%	-	-
Dry	5 ± 1°C	✓	≥ 30%	-	-

The load spreading plate shall be as described in Annex B. It shall be loosely laid on the shockpad.

For tests at 23 ± 2°C tests shall be made in three test locations, each 200mm apart and at least 100mm from the sides of the test specimen. For tests at non-ambient laboratory conditions one series of measurements shall be made at least 100mm from the sides of the test specimen.

4.1.3 Production tolerance

A manufacturing tolerance of ± 5% FR (absolute) of the manufacturer's declared value is considered acceptable.

4.1.4 Performance when frozen

For shockpads intended for use in regions where the ambient temperature may be expected to fall below 0°C the shock absorption properties of the shockpad shall also be measured and reported under frozen conditions. Frozen conditions shall be produced using the procedure detailed in Annex A.6.

4.2 Deformation

4.2.1 Characterisation

The Vertical Deformation properties of the shockpad shall be measured and reported in accordance with clauses 4.2.2 and 4.2.3.

The maximum variation between the three test positions tested at 23 ± 2°C under dry conditions without the load spreading plate shall be 2 mm.

4.2.2 Testing requirements

The Vertical Deformation properties of the shockpad shall be measured in accordance with EN TS 16717 under the conditions detailed in Table 1. Test specimens shall be conditioned in accordance with clause 4.1.2.

4.2.3 Production tolerance

A manufacturing tolerance of ± 2mm of the manufacturer's declared value is considered acceptable.

4.3 Head Injury Criteria (HIC)

4.3.1 Characterisation

If a shockpad is intended to be used in a synthetic turf sports surface system that is required to achieve a minimum critical fall height (when tested in accordance with EN 1177) the HIC values of the shockpad recorded at the fall heights detailed in clause 4.3.2 shall be measured and reported.

4.3.2 Testing requirements

HIC shall be measured using test equipment in accordance with EN 1177. Tests shall be made with and without a load spreading plate as described in Annex B.

Note: As each impact may damage the plate a new area of the plate shall be impacted for each drop.

Tests shall be made at a range of drop heights starting at 300 mm and increasing in 300 mm increments until the HIC value exceeds 1500 or a height of 2000 mm is achieved, whichever occurs sooner.

Tests shall be made in a minimum of three locations per drop height with one drop per location.
The mean value for each height being calculated and reported.

Tests shall be made at 23 ± 2 °C under dry conditions.

4.4 Thickness

4.4.1 Requirement

The thickness of the shockpad shall be measured and reported.

4.4.2 Testing requirements

For insitu shockpads, elastic (e) layers and rubber granulate shockpads the thickness shall be measured in accordance with EN 1969.

For pre-fabricated foam and geofelt shockpads the thickness shall be measured in accordance with EN 9863-1.

4.4.3 Production tolerance

A manufacturing tolerance of ± 10% of the manufacturer's declared value is considered acceptable.

Note: When insitu shockpads and elastic layers are laid on site the installed thickness may be dependent on the regularity (evenness) of the base on which they are laid. As these are often outside the tolerances specified for the final playing surface, the thickness of the installed shockpad may vary in an attempt to improve the regularity of the field. For insitu shockpads and elastic layers the installed thickness on site should therefore be at least 90% of the manufacturer's declared value. Thicknesses greater than 100% are considered acceptable provided that the dynamic properties of the shockpad stay within the permitted tolerances for each dynamic property.

4.5 Mass per unit area

4.5.1 Requirement

The mass per unit area of the shockpad shall be measured in accordance with ISO 8543 and the result reported.

4.5.2 Production tolerance

A manufacturing tolerance of ± 15% of the manufacturer's declared value is considered acceptable.

4.6 Vertical Water infiltration rate

Shockpads designed to allow the vertical flow of water through them shall have a water infiltration rate of 500mm/h or greater when tested in accordance with EN 12616.

Three measurements shall be made, each at least 150mm apart from each other and the mean value of water infiltration rate calculated.

The mean value of water infiltration rate shall be reported.

4.7 Horizontal Water Flow Capacity

Shockpads designed to allow the horizontal flow of water shall have their horizontal water flow capacity measured in accordance with EN ISO 12958. The applied pressure shall be 2kPa, the contact surface shall be rigid/rigid and measurements shall be made using measurement slopes of 0.5%, 1% and 3%.

The results obtained at each slope shall be reported.

4.8 Tensile properties

4.8.1 Performance and testing

When tested in accordance with EN 12230 the tensile strength of solid samples of the shockpad material shall be ≥ 0.15 MPa.

Following air ageing in accordance with EN 13817 the maximum tensile strength of any shockpad shall be at least 75% of the unaged value and equal to or greater than 0.15 MPa.

Notes:

1. These requirements are based on samples prepared for laboratory testing to establish acceptable performance and durability. If sampling of insitu shockpads and e-layers from site is to be undertaken, the permitted minimum tensile strength should be agreed between the installation company and field owner.
2. Some forms of prefabricated shockpads have slots and channels incorporated into their structure to provide drainage or to aid dimensional stability. The design of such shockpads might mean it is not possible to obtain fully homogenous tests specimens. In such cases a test shall also be made on the shockpad in its finished state and the mean value of the maximum Force at Rupture shall also be reported. In such cases the mean value should be within 10% of the manufacturer's declared value.

4.8.2 Test specimens

Wherever possible tests shall be made on representative samples of the shockpad as supplied for use.

If the shockpad is greater than 25mm thick, 50mm wide strips shall be tested. Any failures at the point of clamping shall be disregarded.

4.9 Dimensional stability

The maximum value of bowing or curling resulting from the expansion of the shockpad shall be ≤ 5 mm when tested using the procedure described in Annex C.

Notes:

1. Experience has shown that European Standard EN 13746 does not allow shockpads to be tested accurately due to the limitations of the measuring procedure and the small changes in dimensions that can lead to a negative result. As such, this method of test should not be specified for shockpads.
2. At the time of publishing this Guide a satisfactory test for assessing the potential for shockpads (especially those that are flexible or have expansion slots or channels) to shrink has not been developed and consumers are advised to seek adequate warranty provision for this property.

4.10 Resistance to Dynamic Fatigue

When tested using the procedure described in Annex D, the maximum loss of Shock Absorption following the Dynamic Fatigue conditioning shall be 5%FR (absolute) and the Shock Absorption after the test shall be ≥ 20% FR (absolute). In addition, the change in thickness after the Dynamic Fatigue conditioning shall be ≤ 15%.

5 Toxicology tests

When tested using the procedures detailed in Table 2 shockpads shall satisfy the requirements specified in Table 2.

Table 2 - Toxicology tests			
Component		Test method	Requirement
Lead	Pb	EN ISO 11 885	≤ 0.025 mg/l
Cadmium	Cd	EN ISO 11 885	≤ 0.005 mg/l
Chromium (total)	Cr	EN ISO 11 885	≤ 0.050 mg/l
Mercury	Hg	EN 13506	≤ 0.001 mg/l
Zinc	Zn	EN ISO 11 885	≤ 0.500 mg/l
Tin	Sn	EN ISO 11 885	≤ 0.04 mg/l
Dissolved Organic Carbon		EN 1484	≤ 50 mg/l
EOX		DIN 38414-17	≤ 100 mg/kg

6 Test report / datasheet

A guideline test report / datasheet is shown in Annex E. If alternative forms of test reports are used they shall contain all the information detailed in Annex E.

Annex A – General test conditions

A.1 Sample conditioning

Unless otherwise specified, tests should be undertaken at a temperature of 23 ± 2°C and test specimens shall be conditioned for a minimum of 3 hours at the specified temperature prior to test.

Note: As shockpads are generally not sensitive to humidity it is not considered necessary to specify strict humidity conditions for the laboratory. Nevertheless, it is advisable for the humidity to be nominally 50%RH.

A.2 Test floor

Shock Absorption, Deformation and HIC tests shall be made on a rigid concrete floor concrete comprising a rigid, non-vibrating, smooth, level and even concrete floor on which a peak force (Fmax) of 6.60 ± 0.25 kN is achieved.

The shockpad shall be attached to the concrete floor using 50 ± 5 mm wide double-sided sticking tape. This shall be attached to the outer edges of the test specimen.

A.3 Wet test conditions

Wet test conditions shall be produced by immersing the shockpad in water to a depth of at least 10 mm above the top of the shockpad. After a minimum of 30 minutes, remove the test specimen from the water and place it on a free draining base to allow it to drain by gravity for 5 ± 2 minutes. Test the specimen for the appropriate property within a further 15 ± 2 minutes.

A.4 Procedure for tests at 40°C

Place the shockpad test specimen in an air-circulating oven conforming to ISO 188, at a temperature of 47.5 ± 2.5 °C. After 120 ± 5 min, remove the test specimen from the oven.

Place the test specimen on the test floor and allow it to cool. Monitor its temperature using a digital temperature probe inserted into the test specimen. When the temperature probe reads 42 ± 0.5 °C, measure the Shock Absorption. Move the apparatus and repeat to obtain three results ensuring the temperature of the test specimen does not fall
below 38°C.

A.5 Procedure for tests at 5°C

Place the shockpad test specimen in a conditioning cabinet at a temperature of -10°C to 0°C. After 120 ± 5 min, remove the test specimen from the conditioning cabinet. Place the test specimen on the test floor and allow it to warm. Monitor its temperature using a temperature probe inserted into the test specimen. When the temperature gauge reads 5°C, measure the Shock Absorption. Move the apparatus and repeat to obtain three results ensuring the temperature of the test specimen does not rise above 7°C.

A.6 Procedure for tests at -5°C

Immerse the shockpad in water to a depth of at least 10 mm above the top of the shockpad. After a minimum of one hour, remove the test specimen from the water and place it on a free draining base to allow it to drain by gravity for 30 ± 2 minutes before placing the test specimen in a conditioning cabinet at a temperature of -8°C to -12°C. After 240 ± 5 min, remove the test specimen from the conditioning cabinet. Place the test specimen on the test floor and allow it to warm. Monitor its temperature using a temperature probe inserted into the test specimen. When the temperature gauge reads -5°C ± 0.5 °C, measure the Shock Absorption. Move the apparatus and repeat to obtain three results ensuring the temperature of the test specimen does not rise above -3°C.

Annex B – Load Spreading Plate

Table 1 – properties of load spreading plate			
Property	Unit	Test method	Nominal Values
Material	-	-	Polypropylene composite *
Dimensions	mm	-	500 ± 10 x 500 ± 10
Thickness	mm	-	1.0 ± 0.2mm
Density	g/cm^3	EN ISO 1183	0.91 ± 0.05
Tensile properties:		EN ISO 527	
Strength at break MD/CD	MPa		150 ± 10
Tensile strain MD/CD	%		16 ± 3
E- modulus	GPa		3

* The plate must be replaced whenever tests cannot be made on an area without damage, or where the plate cannot lie flat on the test specimen due to buckling or bowing.

A suitable product is Curv C100A by Propex Fabrics, Germany (see www.curvonline.com) Article number is 7811004400100 for sheet dimensions 500*500*1 mm. Technically this product is comparable to 7811004400010 which only differs in dimensions.

Annex C - Test Method for the Assessment of dimensional stability of the shockpad

C.1 Apparatus

Test rig as shown in Figure C.1 and C.2 and comprising a flat rigid base plate and adjustable side frame with internal dimensions of 302 x 302 mm. The side frame shall be rigid and 50 ± 5mm in height. The test rig shall allow the measurement of the distance between the test specimen and a fixed guide bar in three positions in two directions at 90° to each other to an accuracy of ± 1 mm. The minimum distance between the top of the test specimen and reference bar shall be 100mm. The measurement positions shall be:

1. over the centre of the test specimen
2. 10 ± 2 mm from the edge of the test specimen in each direction

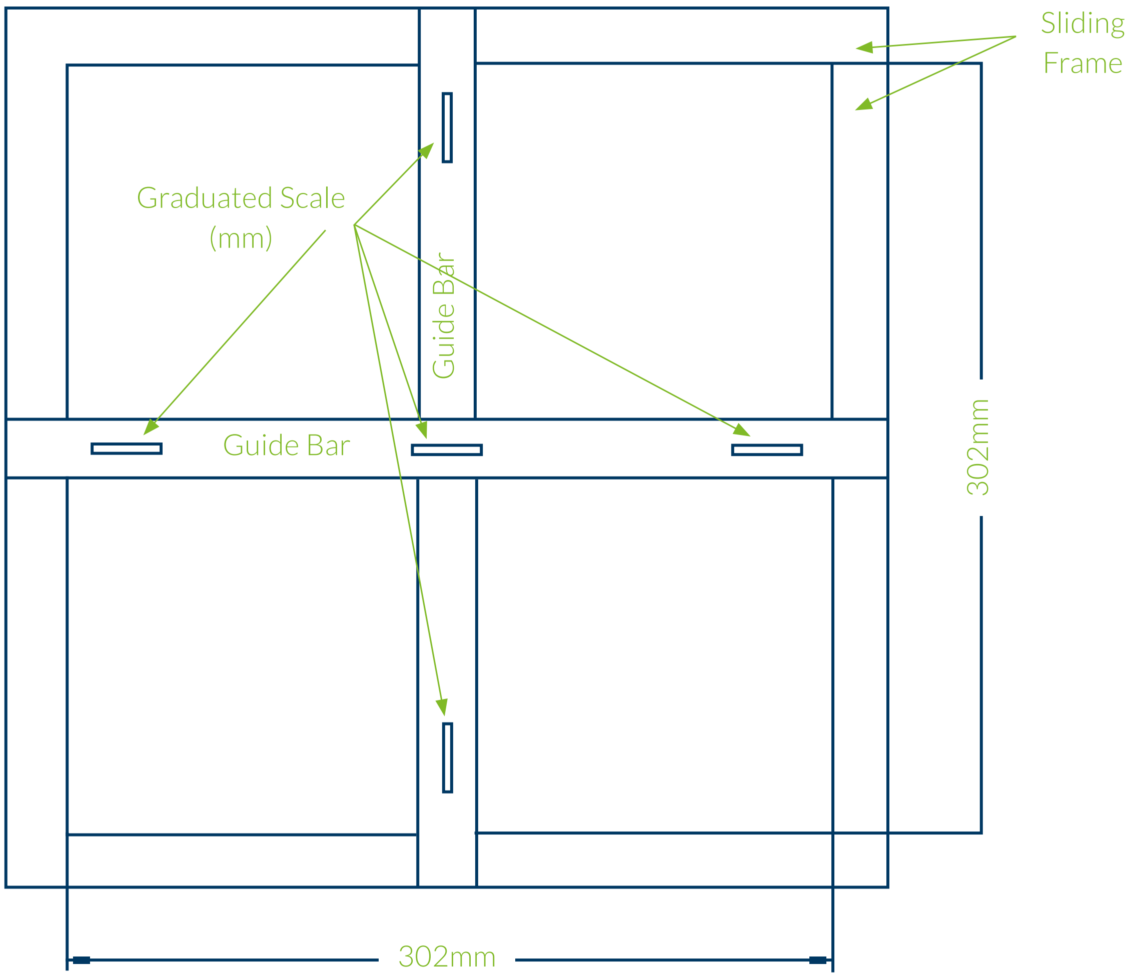

Figure C.1 – test rig (plan view)

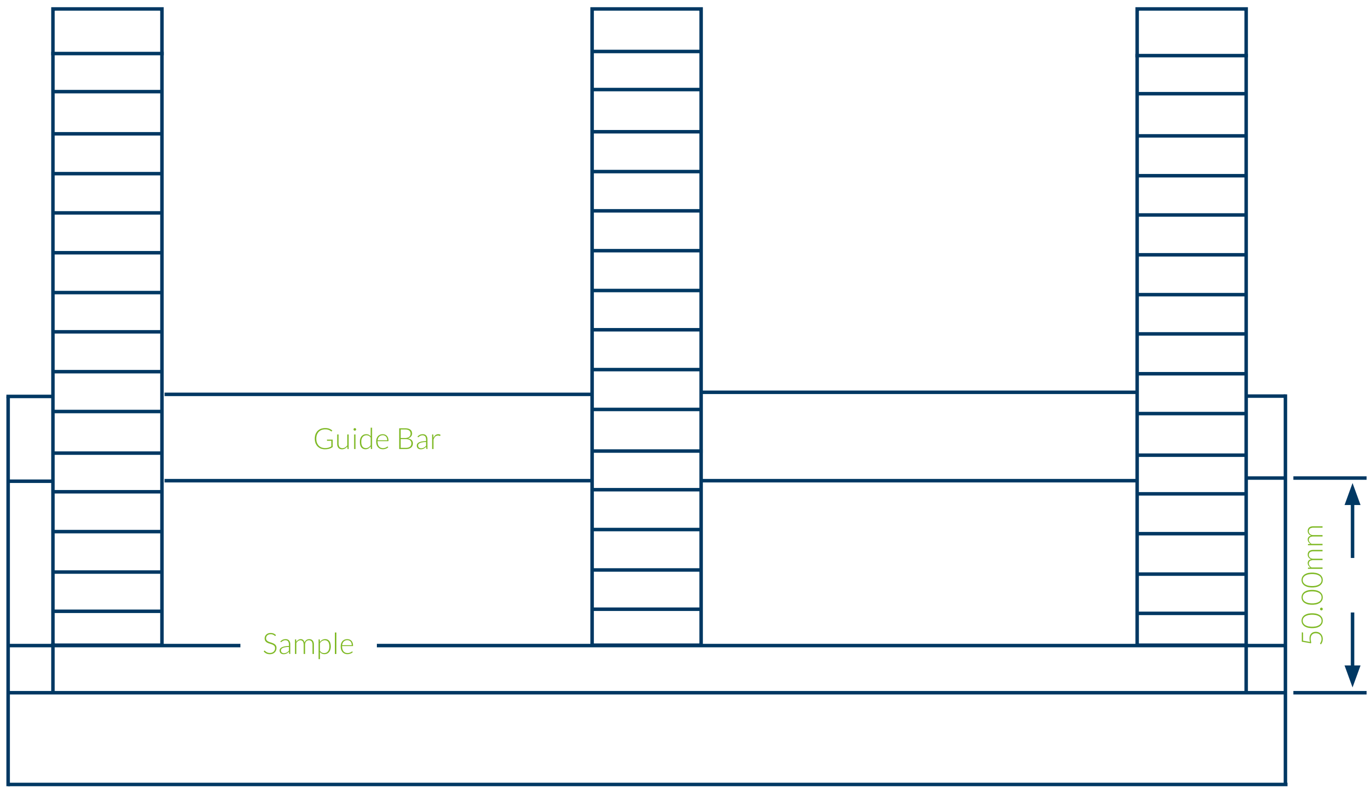

Figure C.2 – test rig (side elevation)

Air circulating oven complying with ISO 188 and capable of maintaining a test temperature of 70 ± 2ºC.

C.2 Test specimens

Three samples of the shockpad each measuring 300 ± 1mm x 300 ± 1mm.

C.3 Procedure

C.3.1 Place a test specimen in the test frame and adjust the side frames so on all four sides of the test specimen there is a gap of 1 ± 0.25 mm between the test specimen and the test frame.

C.3.2 Measure the height between the test specimen and the guide bar in each test position (five total).

C.3.3 Place the test rig containing the test specimen into the air-circulating oven at a temperature of 70 ± 2ºC. After conditioning the test specimen for 240 ± 10 minutes remove the test rig and within 5 ± 1 minutes measure the distance between the test specimen and the reference bar in each test position.

C.3.4 Allow the test rig and specimen to condition at 23 ± 2ºC for 24 ± 1 hours before repeating steps C.3.2 and C.3.3 two further times.

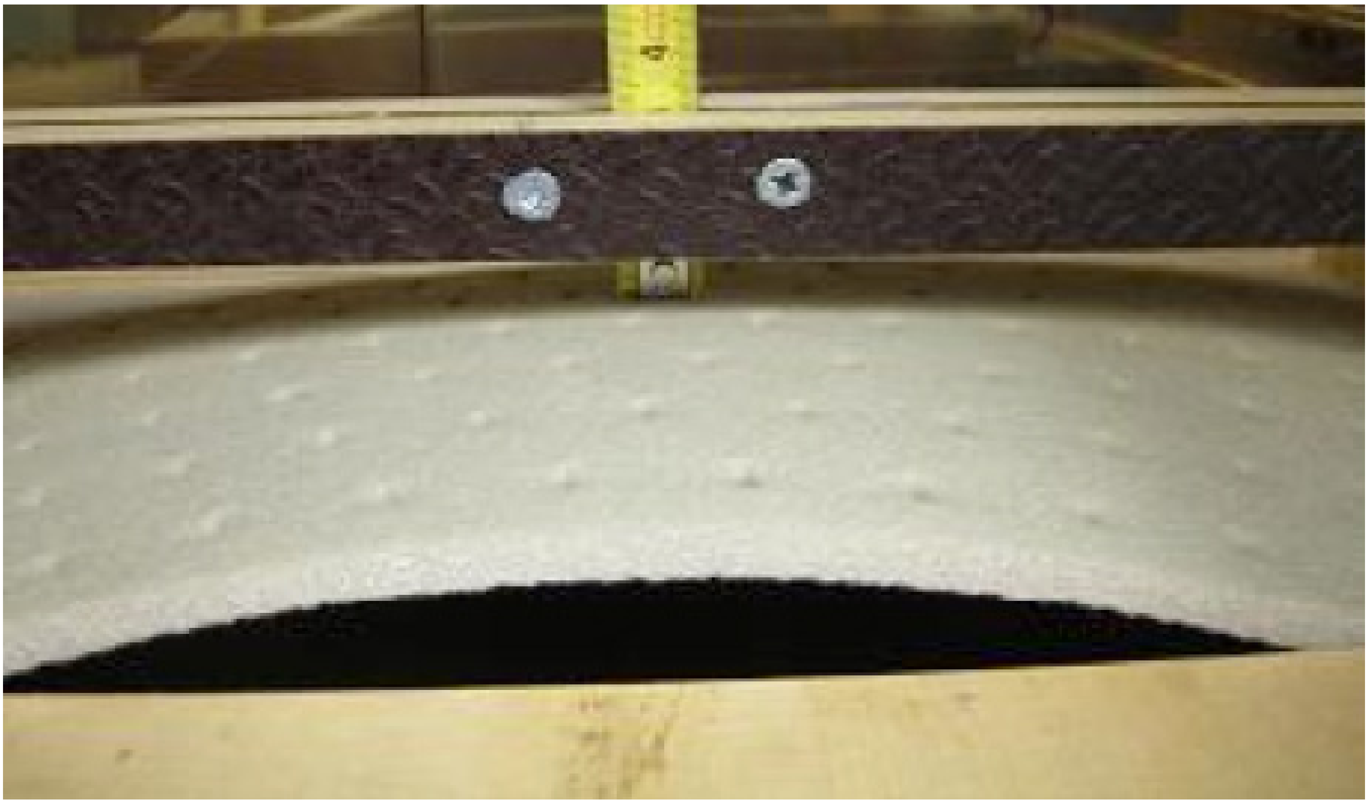

Figure C.3 – example of shockpad bowing (concave)

C.4 Calculation and expression of results

C.4.1 Calculate the difference in the distance between the initial values recorded at the start of the test and at each stage of the test.

C.4.2 Report the maximum difference recorded at any stage of the test, noting if the bowing is concave (bowing in the centre of the test specimen) or convex (lifting of the edges of the test specimen).

Annex D – test method for the assessment of Resistance to Dynamic Fatigue

D.1 Apparatus

Dynamic fatigue repeated impacter as described in ISO 3385 but modified as follows:

- Indenter diameter: 100 ± 5 mm
- Indenter radius: 8 ± 2 mm
- Maximum impact load: 750 ± 50N
- Impact frequency: 10 ± 1 cycles / min.
- Duration of test: 10,000 ± 100 cycles

The principals of the test are illustrated in Figure D1.

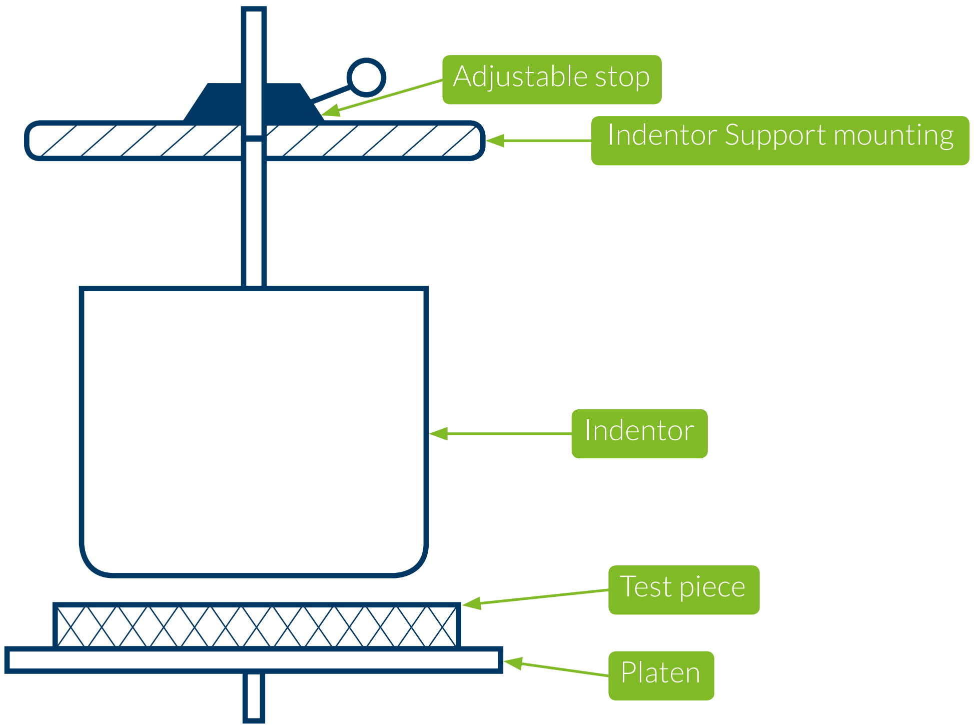

Figure D1 – schematic view of test apparatus

D.2 Test specimens

A sample of shockpad measuring 375 ± 50 mm x 375 ± 50 mm.

D.3 Procedure

Determine the shock absorption of the test specimen in accordance with EN TS 16717 (without a load spreading plate).

Determine the thickness of the shockpad. For insitu shockpads the thickness shall be measured in accordance with EN 1969. For pre-fabricated shockpads, etc. the thickness shall be measured in accordance with EN 9863-1.

Place the test specimen on the Dynamic Fatigue test rig so the indenter is located in the centre of the test specimen. Adjust the indenter position to ensure the specified impact load is applied to the test specimen.

Start the Dynamic Fatigue Test Rig and allow the test specimen to be impacted 10,000 ± 100 cycles.

Note: as some forms of shockpad will compress because of the repeated impacts it may be necessary to readjust the indenter position to ensure the specified impact load is retained throughout the test.

At the completion of the test remove the test specimen and ensure it remains in a flat condition during the relaxation period, which shall be equal to two minutes per compression cycle (2*10000 minutes for 10000 cycles at 10 cycles per minute).

After this conditioning period, reassess the Shock Absorption and Thickness of the test specimen ensuring both measurements are made in the impacted area during the Dynamic Fatigue loading.

Assess the test specimen for any signs of cracking, delamination or break-up.

Repeat the procedure on two further test specimens (three in total).

D.4 Calculation of results

Calculate the mean values of Shock Absorption for the three test specimens before and after Dynamic Fatigue conditioning. Calculate the loss in Shock Absorption as a result of the Dynamic Fatigue conditioning.

Calculate the mean values of Thickness for the three test specimens before and after Dynamic Fatigue conditioning. Calculate the percentage change in Thickness as a result of the Dynamic Fatigue conditioning.

D.5 Reporting

Report the mean values of Shock Absorption before and after Dynamic Fatigue conditioning and any loss in Shock Absorption (to one whole unit).

Report the mean values of Thickness before and after Dynamic Fatigue conditioning and any change in Thickness (to the nearest 0.5mm).

Report by photographic means any signs of cracking, delamination or break-up observed.

Annex E – guideline report / data sheet

<table>
<tr><td>Product name</td><td colspan="2"></td></tr>
<tr><td>Manufacturer</td><td colspan="2">For insitu shockpads and elastic layers this shall include the rubber granules supplier and binder manufacturer</td></tr>
<tr><td>Date of test</td><td colspan="2"></td></tr>
<tr><td>Test laboratory</td><td colspan="2"></td></tr>
<tr><td>Description of shockpad construction</td><td colspan="2">A full description of the shockpad shall be given. For insitu shockpads and elastic layers this shall include details of the grade of rubber granules (product name, mesh size and quantity kg/) and the binder (manufacturer, type and quality l/m^2).</td></tr>
<tr><td rowspan="2">Photograph identification</td><td>Top view</td><td>Side view</td></tr>
<tr><td></td><td></td></tr>
</table>

Property	Test condition		Result				Guideline requirement
Thickness							≥ 90%
	Manufacturing tolerances compared to product declaration						≤ ± 10%
Mass per unit area							
	Manufacturing tolerances compared to product declaration						≤ ± 15%
Shock Absorption	Dry, 23 ± 2°C direct measurement onto shockpad	Individual test position results	1	2	3	mean	≥ 20% FR
		Maximum variation between three test locations					≤ ± 5% FR
		Manufacturing tolerances compared to declaration					≤ ± 5% FR
	Dry, 23 ± 2°C + load spreading plate	Individual results					≥ 30% FR
	Wet, 23 ± 2°C + load spreading plate						
	Dry, 40 ± 2°C + load spreading plate						
	Dry 5 ± 1°C + load spreading plate						
	Maximum variation between all test conditions						≤ ± 5% FR
When frozen wet -5 ± 1°C (if applicable)							
Vertical Deformation	Dry, 23 ± 2°C direct measurement onto shockpad	Individual test position results	1	2	3	mean	
		Maximum variation between three test locations					≤ 2mm
	Dry, 23 ± 2°C + load spreading plate						
	Wet, 23 ± 2°C + load spreading plate						
	Dry, 40 ± 2°C + load spreading plate						
	Dry, 5 ± 1°C + load spreading plate						

Property	Test condition		Result				Guideline requirement
HIC (when applicable)	Dry, 23 ± 2°C without load spreading plate		Drop height & HIC				
			300mm	600mm	900mm	1200mm	
			1500mm	1800mm	2100mm	2400mm	
	Dry, 23 ± 2°C + load spreading plate		300 mm	600mm	900 mm	1200mm	
			1500mm	1800mm	2100mm	2400mm	
Water infiltration rate							≥ 500 mm/h
Horizontal water flow rate (l/s m) (if applicable)			Slope				
			1%	3%	5%		
Tensile properties – solid sheet	Unaged	Tensile strength (MPa)					
	After air ageing	Tensile strength (MPa)					≥ 0.15 MPa
		% of unaged value					≥ 75%
Tensile properties – samples with slots and groves, etc	Unaged	Tensile strength (MPa)					
		Force at rupture					± 10% manufacturer's declaration
Dimensional stability	Maximum degree of bowing and type						≤ 5 mm
Resistance to Dynamic fatigue	Change in Shock Absorption (%FR) and absolute value following test		Initial	Final	Change		
							≤ 5%FR Absolute value to be ≥ 20%FR
	Percentage change in thickness						≤ 15%

Property	Test condition		Result	Guideline requirement
Toxicology	Lead	Pb		≤ 0.025 mg/l
	Cadmium	Cd		≤ 0.005 mg/l
	Chromium (total)	Cr		≤ 0.050 mg/l
	Mercury	Hg		≤ 0.001 mg/l
	Zinc	Zn		≤ 0.50 mg/l
	Tin	Sn		≤ 0.04 mg/l
	Dissolved Organic Carbon			≤ 50 mg/l
	EOX			≤ 100 mg/kg

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