Department for Transport

The Safety Helmet Assessment and Rating Programme

LABORATORY TEST PROCEDURES

Version 1.0

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Test Protocol

1   Introduction

1.1   This document describes the test equipment and the processes that determine the performance data used for calculating the SHARP safety rating for motorcycle helmets. It is not intended to challenge either UNECE Regulation 22.05 or British Standard 6658:1985 which remain the legally required standards for motorcycle helmets sold in the United Kingdom.

1.2   These regulatory requirements include a range of performance criteria that are not replicated by the SHARP programme (e.g. high and low temperature assessments). It is for this reason that helmets must have been approved to one of these standards to be eligible for assessment by SHARP. However, the SHARP assessment subjects these helmets to additional tests that are calculated to explore the extent to which individual helmet models are designed to offer head protection that exceeds the minimum required by those standards.

1.3   These protocols may be used by manufacturers and laboratories to assist product development, but only SHARP can issue a helmet rating. This will be based on independent tests carried out by the official SHARP laboratory. All ratings issued by SHARP are published on the SHARP website (https://sharp.dft.gov.uk) where additional data concerning each helmet model are also available.

2   Reference Documents

2.1   British Standard: BS 6658:1985

2.2   ISO Standard: ISO DIS 6220:1983 and EN 960:1994

2.3   SAE Standard: SAE J211:2003 (CFC1000).

2.4   UNECE Regulation: Regulation 22.05

3   Test Equipment

3.1   Linear Impact Test Apparatus

3.1.1   Linear impacts are conducted using "twin wire" guided test apparatus that is similar in its essential characteristics as that described in British Standard (BS) 6658:1985. This document highlights certain relevant aspects of this standard and sets out where deviations are necessary:

    i)   The twin guide wires are stainless steel and of stranded construction, 4mm in diameter and positioned nominally 455mm apart.

    ii)   The tension in the twin guide wires is controlled by the application of a tensile force of not less than 1.5kN.

    iii)   The apparatus is provided with a means to secure the twin guide wires at their upper end such that their effective length is maintained to a minimum for each impact velocity used in the test programme.

iv) The test apparatus has the capacity to permit helmets to be tested at impact velocities of up to 10m/s.

3.1.2 Control carriage

3.1.2.1 A control carriage that can lift, hold and release the supporting arm assembly at/from the required height is required. The control carriage, with a supporting arm and linear impact head form, is capable of being positioned and held securely at any point along the length of the twin wire guides of the test apparatus. The carriage is capable of remote control with respect to the actions of raising and lowering the supporting arm on the twin wires and also the release of the supporting arm to conduct the impact test.

3.1.3 Supporting arm and mounting ball.

3.1.3.1 A supporting arm and a mounting ball designed for use with the linear impact head forms detailed in section 3.3 and compatible with the head form socket is required.

3.1.3.2 The supporting arm must be designed to permit a helmet to be impacted at each of the sites B, P, R and X, specified in UN ECE Regulation 22.05, without the need to modify the helmet in any way (i.e. cutting away the chin guard in part or in whole). The use of an alternative supporting arm for the crown impact test is permissible provided that it satisfies the essential criteria of section 3.1.3.3. to 3.1.4.

3.1.3.3 The supporting arm and mounting ball is to be of such a design as to accommodate the use of a tri-axial accelerometer during testing.

3.1.3.4 The mass of the supporting arm and mounting ball shall be distributed such that as far as is practicable, the supporting arm assembly maintains its horizontal (x and y plane) orientation, i.e. rotation and translation of the arm during guided fall shall be minimised.

3.1.3.5 The supporting arm shall be so designed and engineered that the centre of gravity of the assembly of the supporting arm, the mounting ball and required peripherals (e.g. clamps and retaining bolts), the accelerometer and each three quarter head form lie within a cone of 10 degrees included angle, having a vertical central axis and its vertex at the point of impact (BS6658:1985 Clause F2).

3.1.3.6 Under all circumstances the combined mass of the supporting arm assembly and each linear impact head form satisfies the head form mass requirement as specified in section 3.3.3 below.

3.1.4 The equipment shall be designed so that, when in guided free fall, the intended point of contact of any helmet being tested against an anvil placed below the apparatus is in vertical alignment with the centre of gravity of the equipment.
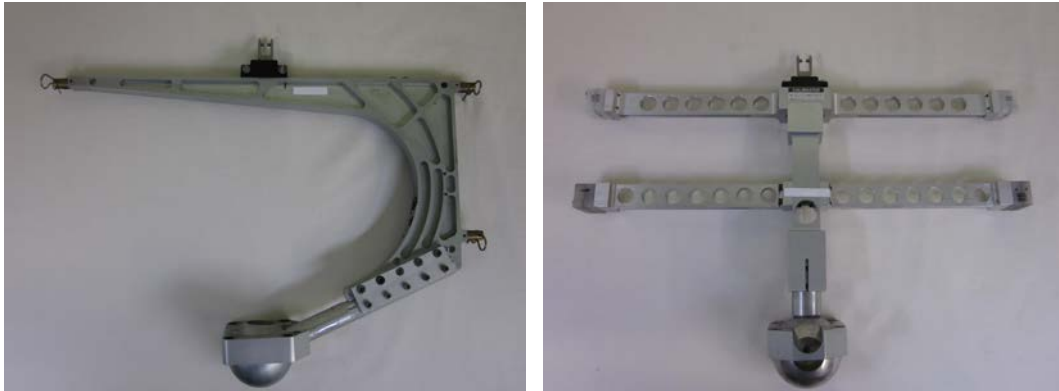
Figure 1. Supporting Arms

3.1.5   Anvils

3.1.5.1   Impacts are performed onto both flat and kerbstone anvils as defined in UN ECE Regulation 22.05.

3.1.5.2   The flat steel anvil has a circular impact face of diameter 130mm +/- 3 mm.

3.1.5.3   The kerbstone anvil has two sides forming an angle of 105 +/- 5°, each of them with a slope of 52.5 +/- 2.5° towards the vertical and meeting along a striking edge with a radius of 15 mm +/- 0.5 mm. The height must be at least 50 mm and the length not less than 125 mm.

Figure 2. Flat and Kerb Impact Anvils

3.2   Oblique Impact Test Apparatus

3.2.1   Oblique Impact testing requires the use of the "Method A" test apparatus and procedure as prescribed in UN ECE Regulation 22.05, the essential text of which is repeated below.

The test apparatus shall comprise:

(a) An anvil rigidly fixed to a base;
(b) A free fall guidance system;
(c) A mobile system supporting the helmeted headform;
(d) A headform conforming to that referred to in paragraph 7.4.1.2.6 [of Regulation 22.05]., and
(e) A system which may be adjusted such that the point of impact can be brought into correspondence with the upper part of the face of the anvil.
(f) A means of recording the continuously changing transmitted anvil force during the impact.
(g) A suitable energy-absorbing base and catch net to prevent damage to the helmet after the impact.

3.2.2   Anvil

3.2.2.1   *The anvil shall be mounted securely at an angle of 15° to the vertical with provision for fore-and-aft adjustment. The anvil shall have a minimum width of 200 mm and be adaptable to carry an abrasive surface.*

3.2.2.2   *The abrasive surface is established by the use of a sheet of grade 80 closed-coat aluminium oxide abrasive paper with a minimum supported length of 225 mm securely clamped to the base of the anvil to prevent slippage.*

3.2.2.3   *The anvil shall be used to assess the tangential forces caused by friction against the outer surface of the helmet.*

3.2.2.4   *The anvil shall be fitted with force transducer(s) connected to recording apparatus such that the transmitted longitudinal force component can be measured and continuously recorded with an accuracy of ±5 per cent during a glancing blow to any part of its exposed surface.*

3.3   Linear Impact Head Forms

3.3.1   Three quarter head forms of size code A, E, J, M and O and of appropriate geometry as specified in ISO DIS 6220:1983 and EN 960:1994 are required.

3.3.2   The head forms are made of a metal material which presents no resonance frequency below 3,000 Hz.

3.3.3   The falling mass of each size of test head form, supporting arm, accelerometer and required peripherals (e.g. clamps and retaining bolts) shall be as follows; size A - 3.1kg, E - 4.1kg, J - 4.7kg, M - 5.6kg and O - 6.1kg. Each assembly shall have a mass tolerance not exceeding +/-0.1 Kg and the mass of the supporting assembly shall not exceed 20% of the total mass of the drop assembly.

Figure 3. Three quarter head forms for linear impact testing.

3.4   Instrumentation

3.4.1   A tri-axial accelerometer is housed in the ball of each supporting arm assembly with the z axis aligned within 1 degree of the vertical plane and the x axis passing through the plane joining the guide wires. The three axes are mutually perpendicular. The accelerometer is able to measure acceleration of the head form in both the vertical and horizontal directions. As a minimum, the accelerometer shall be capable of operating in the range of 1 to 1000g and capable of withstanding a 2000g shock without damage.

3.4.2   A load cell is installed in the anvil mounting of the linear impact equipment. The load cell shall have a measuring range of 0 to 200kN. The charge meter has a full scale measuring range of ±2 to 2200000 pC and a frequency range of ≈ 0 to 200kHz.

3.4.3   A three axis load cell is mounted in the anvil of the oblique impact equipment. The load cell has a measuring range of -20 to +20kN in F_X & F_Y and -10 to +40kN in F_Z. The charge amplifier has a full scale measuring range of ±200 to 200,000 pC and a frequency range of ≈ 0 to >45kHz.

3.4.4   A velocity meter is installed to measure the velocity of the drop assembly at a point not exceeding 60mm above the anvil contact point.

3.5   Data Acquisition

3.5.1   Test data are acquired and managed in accordance with SAE J211;2003 (Channel Filter Class 1000).

3.5.2   Time history is recorded at a minimum of 16kHz for both linear and oblique impacts.

3.5.3   For linear impacts the test data includes complete acceleration / time history in each of the three axes of the head form accelerometer. These data are supplemented by force / time data from the impact anvil load cell.

3.5.4   Test data for the oblique impact tests include the complete longitudinal, lateral and normal anvil forces / time history.

3.6 **Equipment Checks/Calibration**

3.6.1 Pre-test checks are conducted in accordance with the requirements of section 4.2. Periodic calibration is as defined below.

3.6.2 The measuring instruments shall be calibrated in accordance with the procedures detailed by their manufacturer and at the frequencies set out below or as specified by the manufacturer if the period is shorter.

Tri-axial accelerometer and power supply unit/coupler	12 months
Load cell and charge meter	12 months
Three axis load cell and charge amplifier	24 months
Velocity meter	12 months

4 **Methodology**

4.1 **Pre-test Helmet Preparation**

4.1.1 Storage & Conditioning

4.1.1.1 Each helmet is exposed to a temperature of 25 °C ± 5 °C for at least 4 hours prior to test.

4.1.1.2 Helmet Mark-up.

The helmets are marked on their external surface using apparatus capable of providing accurate and repeatable results (e.g. a jig with laser sighting). The marking up of the helmets is completed prior to the conditioning of the helmet.

4.1.1.3 Helmet Positioning

4.1.1.3.1 For mark-up each helmet is placed on a mark-up headform having the same geometry as that prescribed for the particular impact velocity of the test. A load of 50 N is applied on the crown of the helmet in order to position the helmet on the head form. It is ascertained that the vertical median plane of the helmet coincides with the median vertical plane of the head form.

4.1.1.3.2 The lower edge of the upper boundary of the helmet aperture is positioned such that the minimum angle for the upward field of vision, required by UNECE Regulation 22.05, is achieved. Once such a position is determined, a horizontal line is drawn on the shell at the level of the AA' plane. This horizontal line represents the plane from which impact points B, X and R are determined.

4.1.2 Impact Location Marking

Identification of the impact positions is achieved by the procedures defined in UN ECE Regulation 22.05.

4.1.2.1 Five impact positions are used in the assessment, these are defined as:

Position B, in the frontal area, situated in the vertical longitudinal plane of symmetry of the helmet and at an angle of 20° measured from Z above the AA' plane.

Position R, in the rear area, situated in the vertical longitudinal plane of symmetry of the helmet and at an angle of 20° measured from Z above the AA' plane.

Position X, on both the left and right lateral area, situated in the central transverse vertical plane and 12.7 mm below the AA' plane.

Position P, in the crown area and centred at the intersection of the central vertical axis and the outer surface of the helmet shell.
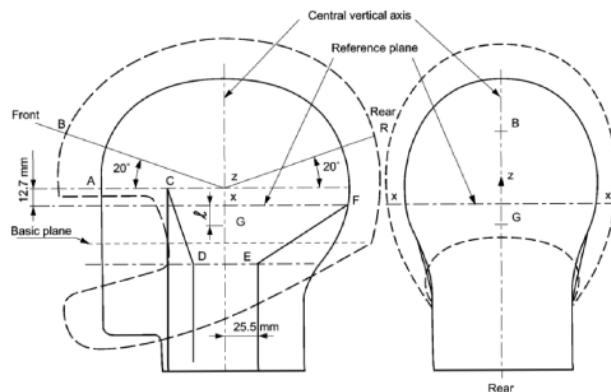

Figure 4. Helmet Marking Geometry (Ref: UN ECE Regulation 22.05, Annex 4).

4.1.2.2   Where, as a result of the mark-up procedure, it is clear that a direct anvil strike, normal to the tangential plane of the impact point cannot be achieved, perhaps because of helmet contours, aerodynamic features etc., an alternative impact site may be selected, or the obstruction managed in an alternative way. The validity of this test at an alternative location will be subject to the consideration required by paragraph 4.3.1.1.8.

4.2   Pre-test Equipment Checks

4.2.1   Test equipment is checked at the beginning of each day's testing and repeated if the number of individual impacts exceeds 75 in a single day or, if the supporting arm is changed.

4.2.2   Checks are carried out to confirm the correct orientation of the tri-axial accelerometer, the operation of the data recording system and correct functioning of mechanical components using a striker having a spherical profile below the horizontal plane when installed on the supporting arm. This hemispherical striker is machined so that it can be attached to the supporting arm using the standard ball and socket arrangement when installed and ready for use with the prescribed test head forms. The tri-axial accelerometer is aligned in accordance with section 3.4.1.

4.2.3   The striker has a circumference of 549mm and nominal mass of 4.68kg when installed on the supporting arm. It must be possible to fit and remove the striker without disturbing the fitting of the ball to the supporting arm. It must also be

possible to access the fittings securing the ball to the supporting arm so that adjustments can be made while the striker is *in situ*.

4.2.4 The calibration head form and the supporting arm assembly is impacted onto a Modular Elastomer Programmer (MEP) test piece. The MEP is 152mm in diameter and 25mm thick, having 63 Shore A hardness. The MEP is mounted on a 6.35mm thick aluminium plate and is centred on the vertical axis of the accelerometer.

4.2.5 For the purposes of checking, the effective length of the twin wires is controlled in accordance with section 4.3.1.2.2. Two drop heights are established from which notional acceleration values at impact of 175g and 300g are achieved.

4.2.6 The checks are performed by dropping the head form and supporting arm assembly five times from each reference height to check that the acceleration values are recorded within the prescribed range. The data from the last three of these drops are reviewed; at least 95% of the resultant acceleration determined from the X, Y and Z values measured by the tri-axial accelerometer must be in the z-axis for the test to be valid. The decelerations recorded in the z-axis by the tri-axial accelerometer must be within ± 5% at each of the target values. The velocity immediately prior to impact and the measured deceleration values are recorded.

4.3 Test Procedures

4.3.1 Linear Impacts:

Impact energy absorption is determined by recording against time the acceleration imparted to a head form fitted with the helmet, when dropped in guided free fall at a specific impact velocity upon a fixed steel anvil.

4.3.1.1 Requirements.

4.3.1.1.1 The linear impact assessment comprises 30 individual impacts, 5 applied to each of 6 helmet samples.

4.3.1.1.2 The impacts to each helmet follow the standard sequence of Front (Position B), Side Left (Position X_L), Side Right (Position X_R), Rear (Position R) and Crown (Position P). For data management purposes it is recommended that the tests are ordered and numbered in accordance with the following table:

Nominal Impact Speed (m/s)	6	7.5	8.5
Nominal Headform Size	J	O	M
Impact Location & Anvil		Test Number	
Flat Front	1	11	21
Flat Side L	2	12	22
Flat Side R	3	13	23
Flat Crown	4	14	24
Flat Rear	5	15	25
Kerb Front	6	16	26
Kerb Side L	7	17	27
Kerb Side R	8	18	28
Kerb Crown	9	19	29
Kerb Rear	10	20	30

4.3.1.1.3 All of the impacts on an individual helmet are against the same anvil type (either the flat or the kerb anvil). Each size of helmet tested is subject to tests on both the flat and the kerb anvil.

4.3.1.1.4 The impact tests are conducted at:

6.0 m/s using a head form size J,

7.5 m/s using a head form size O, and

8.5 m/s using a head form size M.

The tolerance for the impact velocity is -0/+0.15m/s. At least 95% of the resultant acceleration calculated from the output of the tri-axial accelerometer must be in the z-axis for the test to be valid. In the case that either parameter fails to satisfy the respective tolerance the whole test for that helmet sample is invalid.

4.3.1.1.5 By exception, where it is not possible to select a helmet from the model range that fits the required head form correctly, a smaller or larger head form may be used. In this case the impact velocity is adjusted to maintain equivalent impact energy with that of the standard configuration.

4.3.1.1.6 Impacts are within a 10 mm radius of the defined points: B, X_L, X_R, R and P.

4.3.1.1.7 When conducting the kerb impact tests the orientation of the kerb edge is parallel to the XX' plane at points B, P, and R, and parallel to the AA' plane at point X.

4.3.1.1.8 On completion of the tests, an example from the sample is dismantled and the helmet shell and energy management components examined to ensure that the material located at, and around, the stated impact positions are representative of that found elsewhere within the extent of protection (figure 4). If differences are identified additional impact tests are undertaken on a further helmet sample.

Impact points for these tests are chosen to test the performance of any alternative construction within the area of the extent of protection.

4.3.1.2 Procedure.

4.3.1.2.1 The tension in the twin guide wires is controlled by the application of a tensile force of not less than 1.5kN.

4.3.1.2.2 Each of the twin guide wires of the test apparatus is rigidly secured at a position as close as possible but in no case more than 750 mm above the height of the carriage assembly when in its holding position prior to release.

4.3.1.2.3 The test head form is so positioned that the impact point on the helmet, when correctly positioned on the headform, is vertically above the centre of the anvil. The use of auxiliary retention devices (e.g. Velcro straps) between the chin strap, and the supporting arm may be necessary to maintain the helmet in its correct position on the headform during free fall.

4.3.1.2.4 The helmet is tested with the visor in the closed position however, the visor may be removed completely if it becomes insecure during the test sequence.

4.3.1.2.5 For system (flip-front) helmets, the locking mechanism used to secure the faceguard in the closed position is locked in accordance with the manufacturer's advice for the particular helmet design. Where impact damage prevents the faceguard from being fully locked, the faceguard is secured as far as possible in the fully closed position.

4.3.2   **Oblique Impacts**

Oblique impact testing is used to establish the frictional value for the surface of the helmet.

4.3.2.1 Helmet Selection and Positioning

4.3.2.1.1 The procedure is that defined in UN ECE Regulation 22.05. paragraph 7.4.1.1.2.

4.3.2.2 Requirements

4.3.2.2.1 The procedure is that defined as Method A (abrasive anvil), in UN ECE Regulation 22.05. paragraph 7.4.1.

4.3.2.2.2 An oblique impact head form of size J, as specified in Section 7.3.3. of UN ECE regulation 22.05, with a new and appropriate size helmet is used for the two oblique impact tests.

4.3.2.2.3 For data management purposes it is recommended that the tests are ordered and numbered in accordance with the following table:

Oblique	Medium J-Headform 8.5 m/s
Side L	31
Side R	32

4.3.2.2.4 The impact velocity (in the vertical plane) is 8.5m/s (-0/+0.15m/s).

4.3.2.2.5 Contrary to paragraph 4.1.3.2 above, the helmet shall be tested in the condition in which it is purchased, i.e. no adjustments are made for helmet contours, aerodynamic features etc. The helmet shall be tested with the visor in the closed position. In cases where the security of the visor is affected by impact testing, the visor shall be reattached for subsequent tests or, if this is not possible, removed.

5 Data Collection

5.1 Linear data:

Data can be collected using a suitable data acquisition system, capable of recording multiple channels at a minimum of 16 kHz and following the practice of SAE J211:2003 (CFC 1000).

Following a linear impact test sufficient data are recorded digitally to provide the measured impact velocity, the anvil force / time loadings and a complete head form acceleration / time history in each of the three axes of the head form accelerometer.

These data are processed to provide:
- values for linear acceleration in the X, Y and Z directions;
- calculation of the vertical resultant (R) of the drop assembly;
- the period where head form acceleration is greater than 150g (ms);
- the time duration to peak acceleration (ms);
- the Head Injury Criterion.

Data are exported into individual MS Excel files for each impact and stored.

5.1.1 Face Guard Locking Mechanism (system (flip-front) helmets).

After each linear impact test the helmet is inspected to determine whether the locking mechanism has remained fully effective. Instances of any failure of the mechanism to keep the face guard fully locked are recorded.

5.2 Oblique impact data:

Data are collected using a suitable data acquisition system, capable of recording multiple channels at a minimum of 16kHz and following the practice of SAE J211:2003 (CFC 1000).

Following an oblique impact test sufficient data are recorded digitally to provide the measured impact velocity and complete longitudinal, lateral and normal force / time histories.

These data are processed to provide the:
- peak longitudinal force;
- peak lateral force;
- peak normal force;
- anvil resultant force.

Data are exported into MS Excel files for each of the two oblique impact tests and stored.

A summary sheet, containing data from the 32 impact configurations is published for use in determining the helmet rating.