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Road vehicles — Design and performance specifications for advanced Pedestrian Legform Impactor (aPLI)

Véhicules routiers — Spécifications de conception et de performance pour l'impacteur en forme de jambe de piéton (aPLI)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 36, *Safety and impact testing*.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document has been prepared on the basis of the existing design, specifications and performance of advanced pedestrian legform impactor (aPLI) standard build level B (SBL-B). The purpose of this document is to document the design and specifications of this pedestrian legform impactor in a form suitable and intended for worldwide harmonized use.

In 2014, aPLI development started, with the aims of defining a globally accepted next-generation pedestrian legform impactor, with enhanced biofidelity and injury assessment capability by implementing an upper mass to represent the influence of the upper body of a pedestrian, and suitable for harmonized use. Participating in the development were research institutes, dummy and instrumentation manufacturers, governments and car manufacturers from around the world. Details are given in Annex A through Annex G and Annex P.

aPLI drawings in electronic format are available. Details are given in Annex I and Annex H.

Road vehicles — Design and performance specifications for advanced Pedestrian Legform Impactor (aPLI)

1 Scope

This document provides definitions, symbols, mechanical requirements, certification test procedure, electronic subsystem requirements and user's manual for advanced pedestrian legform impactor (aPLI), a standardized pedestrian legform impactor with an upper mass for pedestrian subsystem testing of road vehicles. It is applicable to impact tests involving:

— vehicles of category M1, except vehicles with the maximum mass above 2 500 kg and which are derived from N1 category vehicles and where the driver's position, R-point, is either forward of the front axle or longitudinally rearwards of the front axle transverse centreline by a maximum of 1 100 mm;

— vehicles of category N1, except where the driver's position, R-point, is either forward of the front axle or longitudinally rearwards of the front axle transverse centreline by a maximum of 1 100 mm;

— impacts to the bumper test area as defined by UN R127[1] and UN GTR No.9[2];

— pedestrian subsystem tests involving use of a legform for the purpose of evaluating compliance with vehicle safety standards.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6487, *Road vehicles — Measurement techniques in impact tests — Instrumentation*

ISO/TS 13499, *Road vehicles — Multimedia data exchange format for impact tests*

SAE J2570, *Performance Specifications for Anthropomorphic Test Device Transducers*

SAE J211-1, *Instrumentation for Impact Test Part 1 — Electronic Instrumentation*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
abduction
rotation of the *lower limb* (3.34) relative to the *upper mass* (3.49) as the lower limb is rotated toward the *struck side* (3.37)

3.2
adduction
rotation of the *lower limb* (3.34) relative to the *upper mass* (3.49) as the lower limb is rotated toward the *non-struck side* (3.35)

3.3
adult
person who is sixteen years old or older

3.4
aPLI
advanced pedestrian legform impactor
modified pedestrian legform impactor which incorporates a mass representing the inertial effect of the upper part of a pedestrian body to enhance *biofidelity* (3.8) and *injury assessment capability* (3.26) of conventional pedestrian legforms

3.5
aluminium honeycomb
manufactured material comprising multi-layered bonded sheets of aluminium bent or corrugated in a rib pattern, in which there is an internal pattern of hexagonal cylindrical spaces

Note 1 to entry: The aluminium honeycomb is used in this document as an energy-absorbing element in full assembly *certification* (3.13) tests.

3.6
AAUM
angular acceleration of upper mass
angular acceleration observed at the upper mass of the *advanced pedestrian legform impactor (aPLI)* (3.4) which is obtained by differentiating the angular velocity sensor (X), installed in the *upper mass* (3.49) as a required sensor

Note 1 to entry: See 7.1.3.4.

3.7
Belleville washer
type of spring which can be loaded along its axis, with its frusto-conical shape giving the spring characteristics

3.8
biofidelity
aspect of an *advanced pedestrian legform impactor (aPLI)* (3.4) capability to represent impact responses of human subjects

3.9
bone core
beam with a rectangular cross-section made of glass fibre reinforced plastic installed in the centre of the *femur* (3.14) and the *tibia* (3.40) that provides human-like bending stiffness

3.10
bumper angle
acute angle formed by the vertical plane tangential to the surface of a car bumper and the vertical transverse plane relative to the car

3.11
bumper system
component installed at the *hip joint* (3.24) inside the *upper mass* (3.49) composed of the bumper, the bumper mount and the compression surface, designed to apply a force on the upper part of the *femur* (3.14) in *adduction* (3.2) to enhance *injury assessment capability* (3.26) of the *advanced pedestrian legform impactor (aPLI)* (3.4)

3.12
capacity
maximum value of a physical quantity which can be measured by a sensor without causing sensor damage

3.13
certification
process by which the relevant *advanced pedestrian legform impactor (aPLI)* (3.4) component or full assembly is verified and documented to meet the specifications

3.14
femur
portion of the *lower limb* (3.34) between the *femur top* (3.15) and the upper *knee block* (3.29), excluding the *flesh* (3.22) and the *skin* (3.36)

3.15
femur top
aluminium part that forms the *hip joint* (3.24) and the junction between the *upper mass* (3.49) and the *femur* (3.14)

3.16
femur-1
measurement location of the *femur* (3.14) bending moment (137 mm vertically up from the flat surface of the knee meniscus) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

3.17
femur-2
measurement location of the *femur* (3.14) bending moment (217 mm vertically up from the flat surface of the knee meniscus) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

3.18
femur-3
measurement location of the *femur* (3.14) bending moment (297 mm vertically up from the flat surface of the knee meniscus) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

3.19
femur-LO
measurement location of the *femur* (3.14) bending moment which is equal to the measurement location of *femur-1* (3.16) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

Note 1 to entry: For the femur-LO, the femur's bending moment is specified in ISO/TS 13499.

3.20
femur-MID
measurement location of the *femur* (3.14) bending moment which is equal to the measurement location of *femur-2* (3.17) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

Note 1 to entry: For the femur-MID, the femur bending moment is specified in ISO/TS 13499.

3.21
femur-UP
measurement location of the *femur* (3.14) bending moment which is equal to the measurement location of *femur-3* (3.18) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

Note 1 to entry: For the femur-UP, the femur bending moment is specified in ISO/TS 13499.

3.22
flesh
moulded soft part constituting the outer layer of the *lower limb* (3.34) positioned inside the *skin* (3.36)

3.23
high-bumper car
car with a *lower bumper reference line height* (3.33) of 425 mm or more

3.24
hip joint
uniaxial joint that allows *abduction* (3.1) and *adduction* (3.2) and connects the *upper mass* (3.49) with the *lower limb* (3.34)

3.25
impact carriage
moving part of the full assembly *certification* (3.13) test fixture comprising the impact surface with an *aluminium honeycomb* (3.5) and a linearly guided rigid mass

3.26
injury assessment capability
aspect of an *advanced pedestrian legform impactor (aPLI)* (3.4) capability to produce peak injury values that correlate with those obtained from human body model impact simulations

3.27
ISO metric
objective rating metric used in this document to verify time histories of sensor output against experimentally or computationally produced target time histories

Note 1 to entry: For more information on the ISO metric, refer to ISO/TS 18571.

3.28
knee
middle part of the *lower limb* (3.34) that involves the knee joint, comprises the upper and lower *knee blocks* (3.29) and provides a junction between the *femur* (3.14) and the *tibia* (3.40)

3.29
knee block
aluminium block that forms either the upper part of the knee joint with condyles, or the lower part of the knee joint with the meniscus attached, accommodating knee ligaments, *Belleville washers* (3.7) that represent stiffness of the knee ligaments and sensors to measure elongation of the knee ligaments and linear acceleration and angular rate of the *knee* (3.28)

3.30
lateral
direction from the *struck side* (3.37) to the the *non-struck side* (3.35)

3.31
leg
portion of the *lower limb* (3.34) below the lower *knee block* (3.29), including the *flesh* (3.22) and the *skin* (3.36)

3.32
low-bumper car
car with a *lower bumper reference line height* (3.33) less than 425 mm

3.33
lower bumper reference line height
LBRL height
height of the geometric trace of the lowermost points of contact between a straight edge and the bumper, measured from the ground

3.34
lower limb
lower part of the *advanced pedestrian legform impactor (aPLI)* (3.4) attached to the *upper mass* (3.49) via a *hip joint* (3.24), representing the *thigh* (3.39), *knee* (3.28) and *leg* (3.31) of a human in a standing position

3.35
non-struck side
opposite side of the *struck side* (3.37)

3.36
skin
sheet of polychloroprene with fabric surface that covers the *flesh* (3.22), forming the outermost layer of the *lower limb* (3.34)

3.37
struck side
side facing a car in car tests, representing the outer side of the *lower limb* (3.34) of a pedestrian

3.38
subsystem test
test to evaluate safety performance of cars where subsystem impactors representing individual body regions of a pedestrian are propelled into a front-end collision with a stationary car, in impact conditions representing specific load cases in car-pedestrian accidents, as described in UN R127[1] and UN GTR No.9[2]

3.39
thigh
portion of the *lower limb* (3.34) between the *femur top* (3.15) and the upper *knee block* (3.29), including the *flesh* (3.22) and the *skin* (3.36)

3.40
tibia
portion of the *lower limb* (3.34) below the lower *knee block* (3.29), excluding the *flesh* (3.22) and the *skin* (3.36)

3.41
tibia-1
measurement location of the *tibia* (3.40) bending moment (134 mm vertically down from the flat surface of tibia plateau) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

3.42
tibia-2
measurement location of the *tibia* (3.40) bending moment (214 mm vertically down from the flat surface of tibia plateau) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

3.43
tibia-3
measurement location of the *tibia* (3.40) bending moment (294 mm vertically down from the flat surface of tibia plateau) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

3.44
tibia-4
measurement location of the *tibia* (3.40) bending moment (374 mm vertically down from the flat surface of tibia plateau) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

3.45
tibia-LO
measurement location of the *tibia* (3.40) bending moment which is equal to the measurement location of *tibia-4* (3.44) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

Note 1 to entry: For the tibia-LO, the tibia bending moment is specified in ISO/TS 13499.

3.46
tibia-MID-LO
measurement location of the *tibia* (3.40) bending moment which is equal to the measurement location of *tibia-3* (3.44) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

Note 1 to entry: For the tibia-MID-LO, the tibia bending moment is specified in ISO/TS 13499.

3.47
tibia-MID-UP
measurement location of the *tibia* (3.40) bending moment which is equal to the measurement location of *tibia-2* (3.44) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

Note 1 to entry: For the tibia-MID-UP, the tibia bending moment is specified in ISO/TS 13499.

3.48
tibia-UP
measurement location of the *tibia* (3.40) bending moment which is equal to the measurement location of *tibia-1* (3.44) used in the development and evaluation phase of the *advanced pedestrian legform impactor (aPLI)* (3.4)

Note 1 to entry: For the tibia-UP, the tibia bending moment is specified in ISO/TS 13499.

3.49
upper mass
block of mass attached on top of the *lower limb* (3.34) via a *hip joint* (3.24) to represent inertial contribution of the upper part of a pedestrian body when hit by a car

3.50
validation of biofidelity
evaluation of an anthropomorphic test device in terms of its representativeness of impact responses of a human body

3.51
validation of injury assessment capability
evaluation of an anthropomorphic test device in terms of the correlation of the peak values of its injury metrics with those of a human body, specifically represented by multiple HBMs

4 Abbreviated terms

See Table 1.

Table 1 — Abbreviated terms

Abbreviation	Meaning
AAUM	Angular Acceleration of Upper Mass
ACL	Anterior Cruciate Ligament
aPLI	advanced Pedestrian Legform Impactor
BLE	Bonnet Leading Edge

Table 1 *(continued)*

Abbreviation	Meaning
BM	Bending Moment
BP	Bumper
DAS	Data Acquisition System
FE	Finite Element
HBM	Human Body Model
LBRL	Lower Bumper Reference Line
MCL	Medial Collateral Ligament
PCL	Posterior Cruciate Ligament
PMHS	Post Mortem Human Subjects
RCM	Real Car Model
SCM	Simplified Car Model
SP	Spoiler
TG	Task Group

5 Mechanical requirements for an aPLI

5.1 Upper mass

5.1.1 General description

The upper mass assembly shall consist of the components and assemblies listed in the upper mass assembly drawing aPLI-11000 (see Annex I).

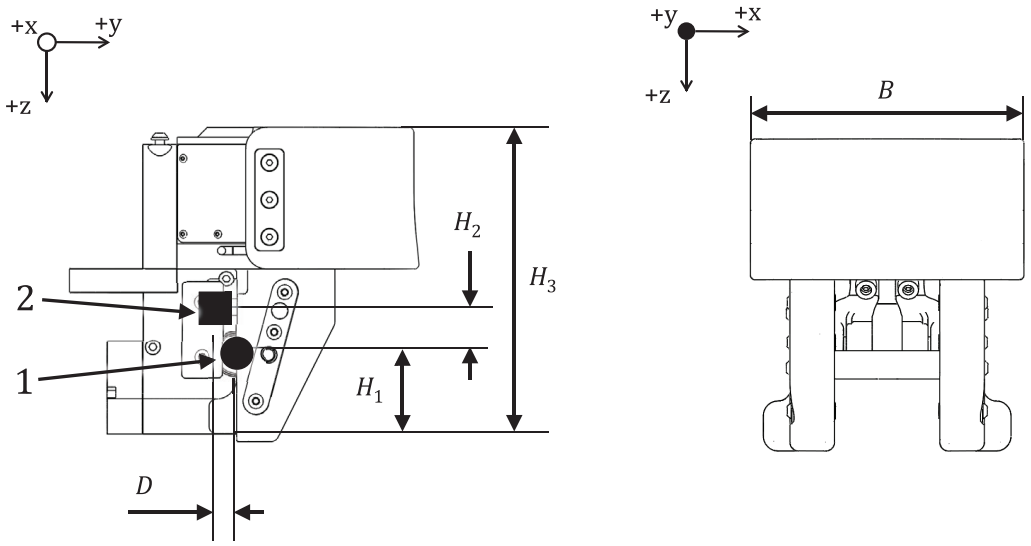
5.1.2 Drawings and specifications

— The upper mass assembly and components shall conform to the assembly drawing aPLI-11000 (see Annex I) and the subassembly and component drawings listed therein.

— The total assembly (including sensors and DAS) shall have a mass of 11,8 kg ± 0,3 kg.

— The overall dimensions and the centre of gravity shall be located as indicated in Figure 1.

— The flesh material and/or external surface characteristics shall enable attachment of adhesive targets.



Key

1 hip joint

2 centre of gravity of upper mass

D horizontal distance between the centre of gravity of upper mass and hip joint: 8 mm + 10 mm / - 0 mm

H_1 height of hip joint: 58 mm ± 2 mm

H_2 height of centre of gravity: 31 mm + 10 mm / -0 mm

H_3 height of upper mass: 220 mm + 16 mm / - 2 mm

B breadth of upper mass: 200 mm ± 5 mm

NOTE 1 An empty circle at the origin of the coordinate vector means a vector going into the page away from the viewer.

NOTE 2 A black circle at the origin of the coordinate vector means a vector coming out of the page toward the viewer.

Figure 1 — Overall dimensions of the upper mass and location of the centre of gravity

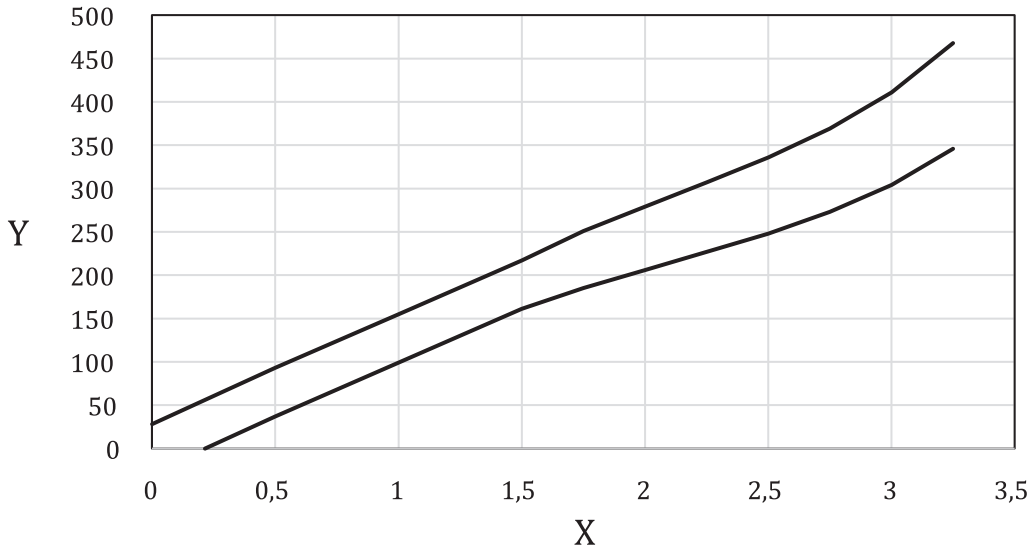
5.1.3 Compliant material specifications

The stiffness of the compliant materials included in the upper mass assembly are specified by the corridors described in this subclause.

— The performance of the hip abduction stop (part aPLI-11062) is specified by the corridor presented in Figure 2. Tabulated data of the corridor is described in Table 2. Performance shall be confirmed using component samples. Load is applied to the sample using a flat indenter at a rate not exceeding 15 mm / min.

— The performance of the solid flesh material on the impact face of the upper mass (reference part aPLI-11010) is described in 5.3.3.

— The performance of the hip adduction bumper (part aPLI-11059) is specified by the certification procedure described in 6.1.1.



Key

X	compression [mm]
Y	force [N]
———	corridor

Figure 2 — Mechanical properties for the hip abduction stop (specified by corridor)

Table 2 — Mechanical properties for the hip abduction stop (specified by tabulated data)

Compression [mm]	**Force** [N]	
	Upper corridor	**Lower corridor**
0,00	28	-28
0,50	93	37
1,00	155	99
1,50	217	161
1,75	251	185
2,00	279	206
2,25	307	227
2,50	336	248
2,75	369	273
3,00	411	304
3,25	468	346

5.1.4 Certification

When the upper mass is assembled according to 8.1.1, the upper mass shall be tested using the procedure specified in 6.1, and the test results shall meet the specifications given in 6.1.

5.2 Lower limb

5.2.1 General description

The lower limb assembly shall consist of the components and sub-assemblies listed in the lower limb assembly drawing aPLI-00010 (Annex I).