# INTERNATIONAL STANDARD

# ISO 3471

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# Earth-moving machinery — Roll-over protective structures — Laboratory tests and performance requirements

*Engins de terrassement — Structures de protection au retournement — Essais de laboratoire et exigences de performance*



Reference number
ISO 3471:2008(E)

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3471 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety requirements and human factors*.



This fourth edition cancels and replaces the third edition (ISO 3471:1994), which has been technically revised. It also incorporates the Amendment ISO 3471:1994/Amd 1:1997 and the Technical Corrigendum ISO 3471:1994/Cor 1:2000.



## Introduction

A review of the initial work on the criteria for roll-over protective structures (ROPS) indicated that these criteria were based on requirements for machines now identified as mid-range size machines. Since the ROPS criteria were established, both smaller and larger machines have become common within the size range of earth-moving machines.

The criteria are a combination of linear and exponential, with respect to mass. For small machines, the exponential criterion has been changed to a linear function with respect to machine mass. For larger machines, the exponential criterion was excessive at very large machine masses, and thus was changed to become a linear function with respect to machine mass.

The longitudinal force criteria were added as new data became available. Situations could arise where ROPS designs would meet the lateral and vertical loading requirements, but yet be considered as lacking sufficient performance capability in the longitudinal load direction. For this reason, this International Standard incorporates a ROPS longitudinal force criterion. The longitudinal force criterion has been established at 80 % of the lateral force requirement.

The evaluation procedure will not necessarily duplicate structural deformations due to a given actual roll. However, specific requirements are derived from investigations on ROPS that have performed the intended function in a variety of actual roll-overs, as well as analytical considerations based upon the compatibility of ROPS and the machine frame to which it is attached.

# Earth-moving machinery — Roll-over protective structures — Laboratory tests and performance requirements

## 1 Scope

This International Standard specifies performance requirements for metallic roll-over protective structures (ROPS) for earth-moving machinery, as well as a consistent and reproducible means of evaluating the compliance with these requirements by laboratory testing using static loading on a representative specimen.

NOTE 1 The structure can also provide FOPS (falling-object protective structure) protection.

This International Standard is applicable to ROPS intended for the following mobile machines with seated operator as defined in ISO 6165 and with a mass greater than or equal to 700 kg:

— dozer;

— loader;

— backhoe loader;



— dumper;

— pipelayer;



— tractor section (prime mover) of a combination machine (e.g. tractor scraper, articulated frame dumper);

— grader;

— landfill compactor;

— roller;

— trencher.

This International Standard is not applicable to training seats or additional seats for operation of an attachment.

NOTE 2 It is expected that reasonable crush protection for a seat-belted operator will be provided under at least the conditions of an initial forward velocity of 0 km/h to 16 km/h on a hard clay surface of 30° maximum slope in the direction of roll, and 360° of roll about the longitudinal axis of the machine without loss of contact with the slope.

NOTE 3 This International Standard can be used to provide guidance to the manufacturers of roll-over protective structures should it be decided to provide such protection for these or other machines for a particular application.

## 2 Normative references

The following referenced documents are indispensable for the application 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 148-1:2006, *Metallic materials — Charpy pendulum impact test (V-notch) — Part 1: Test method*

ISO 898-1:1999, *Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs*

ISO 898-2:1992, *Mechanical properties of fasteners — Part 2: Nuts with specified proof load values — Coarse thread*

ISO 3164:1995, *Earth-moving machinery — Laboratory evaluations of protective structures — Specifications for deflection-limiting volume*

ISO 5353:1995, *Earth-moving machinery, and tractors and machinery for agriculture and forestry — Seat index point*

ISO 6165:2006, *Earth-moving machinery — Basic types — Identification and terms and definitions*

ISO 9248:1992, *Earth-moving machinery — Units for dimensions, performance and capacities, and their measurement accuracies*

## 3 Terms and definitions

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

**3.1**
**bedplate**
substantially rigid part of the test fixture to which the machine frame is attached to conduct the test

**3.2**
**boundary plane**
**BP**
plane defined as the vertical projected plane of the back, side, or knee area of the DLV

NOTE The boundary planes are used to determine the load application point.



**3.3**
**deflection-limiting volume**
**DLV**
orthogonal approximation of a large, seated, male operator wearing normal clothing and a protective helmet

NOTE Adapted from ISO 3164:1995.

**3.4**
**deflection of ROPS**
movement of the ROPS, mounting system and frame section as measured at the load application point (LAP), excluding the effect of any movement of the test fixture(s)

**3.5**
**falling-object protective structure**
**FOPS**
system of structural members arranged in such a way as to provide operators with reasonable protection from falling objects (e.g. trees, rocks, small concrete blocks, tools)

**3.6**
**head portion of DLV**
upper 270 mm by 330 mm rectangular section of the DLV, whose dimensions are in accordance with ISO 3164

**3.7**
**lateral simulated ground plane**
**LSGP**
plane defined as where the machine comes to rest on its side, where the plane is 15° away from the DLV.

NOTE It is created by rotating a vertical plane parallel to the machine's longitudinal centreline about a horizontal line through the outermost point of the upper ROPS member, to which the lateral load is applied (see Figure 6). The LSGP is established on an unloaded ROPS and moves with the member to which the load is applied while maintaining its 15° angle with respect to the vertical.

**3.8**
**load distribution device**
**LDD**
device used to prevent localized penetration of the ROPS members at the load application point (LAP)

**3.9**
**load application point**
**LAP**
point (or a point within a defined range) on the ROPS structure at which the test load force ($F$) is applied

**3.10**
**machine frame**
metallic main chassis or main metallic load-bearing member(s) of the machine that extend(s) over a major section of the machine and upon which the ROPS is directly mounted

**3.11**
**mounting system**
all brackets, weldments, fasteners or other devices whose function is to attach the ROPS to the machine frame

**3.12**
**representative specimen**
ROPS, mounting system and machine frame (complete or partial) used for test purposes that is within the range of material and manufacturing variances designated by the manufacturer's production specifications

NOTE The intent is that all ROPS manufactured to these specifications be capable of meeting or exceeding the stated levels of performance.



**3.13**
**roll-over protective structure**
**ROPS**
system of structural members whose primary purpose is to reduce the possibility of a seat-belted operator being crushed in the event of a machine roll-over

NOTE 1 See Figures 1 to 5 and ISO 6683.

NOTE 2 It can include components such as sub-frame, bracket, mount, bolt, pin, suspension or flexible shock absorber.

NOTE 3 Non-load-carrying members (posts) are not considered.

**3.13.1**
**rollbar ROPS**
ROPS having one or two posts, formed or fabricated, and having no cantilevered structural member(s)

**3.13.2**
**one-post [two-post] ROPS**
ROPS having one or two posts, formed or fabricated, and having one or more cantilevered load-carrying structural members

**3.13.3**
**multiple-post ROPS**
ROPS having more than two posts, formed or fabricated, and joining load-carrying structural members

NOTE It can have cantilevered load-carrying structural members.

**3.14**
**ROPS structural member**
metallic member designed to withstand an applied force or absorb energy

**3.15**
**simulated ground plane**
**SGP**
plane simulating the flat ground surface on which a machine is assumed to come to rest after rolling over

**3.16**
**Socket**
**S**
test component that allows unrestricted point loading of the load distribution device (LDD)

**3.17**
**vertical projection of DLV**
cross-sectional area of the column formed by vertically projecting the outside corners of the deflection limiting volume (DLV), with dimensions according to ISO 3164, excluding the foot section

**3.18**
**vertical simulated ground plane**
**VSGP**
plane defined by contact with a top cross-member of the ROPS and that front or rear part of the machine capable of supporting an overturned machine

See Figure 16

NOTE The VSGP applies to the rollbar ROPS, as well as to the one-post and two-post ROPS. The VSGP can change with the deformation of the ROPS.



## 4 Symbols

For the purposes of this document, the following symbols apply.



$U$ energy absorbed by the structure, related to the manufacturer's maximum recommended mass, $m$, and expressed in joules

$F$ load force, expressed in newtons

$m$ manufacturer's maximum recommended mass, expressed in kilograms

- The manufacturer's maximum recommended mass includes attachments in operating condition, with all reservoirs full to capacity, tools and ROPS. It excludes towed equipment such as rollers and drawn scrapers.
- For the tractor scraper and articulated frame dumper, it is the maximum recommended mass of the tractor section (prime mover) only. In most cases, it is the tractor section, but shall be the ROPS-bearing section or ROPS-carrying section of the machine. Kingpins, hitches and articulated-steering components that attach to hitches or towed units are excluded from the mass of these machines.
- For rigid frame dumpers, $m$ excludes the mass of the dump body and the payload when the "excluding dump body" criteria are selected. When the "including dump body" criteria are selected, $m$ includes the mass of the dump body but excludes the mass of the payload.

  NOTE See Table 1 for examples.
- For rollers and landfill compactors, loosely contained ballast that would separate from the machine in the event of a roll-over is also excluded from $m$.

  NOTE Soil, mud, rocks, branches, debris, etc. that commonly adhere to, or lie on, machines in use are not considered part of the mass of any machine. Material dug, carried, or handled in any manner is not considered part of the machine mass in determining test requirements.

$L$ length of the ROPS, in millimetres

— $L$ is not applicable to rollbar ROPS.

— For one- or two-post ROPS with cantilevered load-carrying structural members, $L$ is the longitudinal distance from the outer surface of the ROPS post(s) to the outer surface of the furthest cantilevered load-carrying members at the top of the ROPS (see Figures 1, 4 and 5). It is not necessary for the ROPS structural members to cover the complete vertical projection of the DLV.

— For multiple-post ROPS, $L$ is the greatest longitudinal distance from the outer surface of the front to the outer surface of the rear posts. See Figure 2.

— For ROPS with shaped structural members, $L$, is the vertical projection of $H$ with the outer surface of the structural members. See Figure 3.

— For ROPS with curved structural members, $L$ is defined by the intersection of plane A with the outer surface of the vertical member. Plane A is defined as the bisector of the angle formed by the intersection of planes B and C. B is the tangent line at the outer surface parallel to plane D. Plane D is the plane intersecting the intersections of the curved ROPS members with the adjacent members. Plane C is the projection of the top surface of the upper ROPS structural member. See Figure 3.

$W$ width of the ROPS, in millimetres

— For a rollbar ROPS, $W$ is the width to the outermost points of the structural member(s).



— For a one- or two-post ROPS with cantilevered load-carrying structural members, the width, $W$ is that portion of the cantilevered load-carrying members (See Figures 1, 4 and 5) that covers at least the vertical projection of the width of the DLV as measured at the top of the ROPS, from the outside faces of the cantilevered load-carrying members.



— For all other ROPS, the width, $W$, is the greatest total width between the outsides of the left and right ROPS posts as measured at the top of the ROPS, from the outside faces of the load-carrying members. See Figure 3.

— For ROPS with shaped structural members, $W$ is the vertical projection of $H$ with the outer surface of the structural members. See Figure 3.

— For ROPS with curved structural members, $W$ is defined by the intersection of plane A with the outer surface of the vertical member. Plane A is defined as the bisector of the angle formed by the intersection of planes B and C. B is the tangent line at the outer surface parallel to plane D. Plane D is the plane intersecting the intersections of the curved ROPS members with the adjacent members. Plane C is the projection of the top surface of the upper ROPS structural member. See Figure 3.

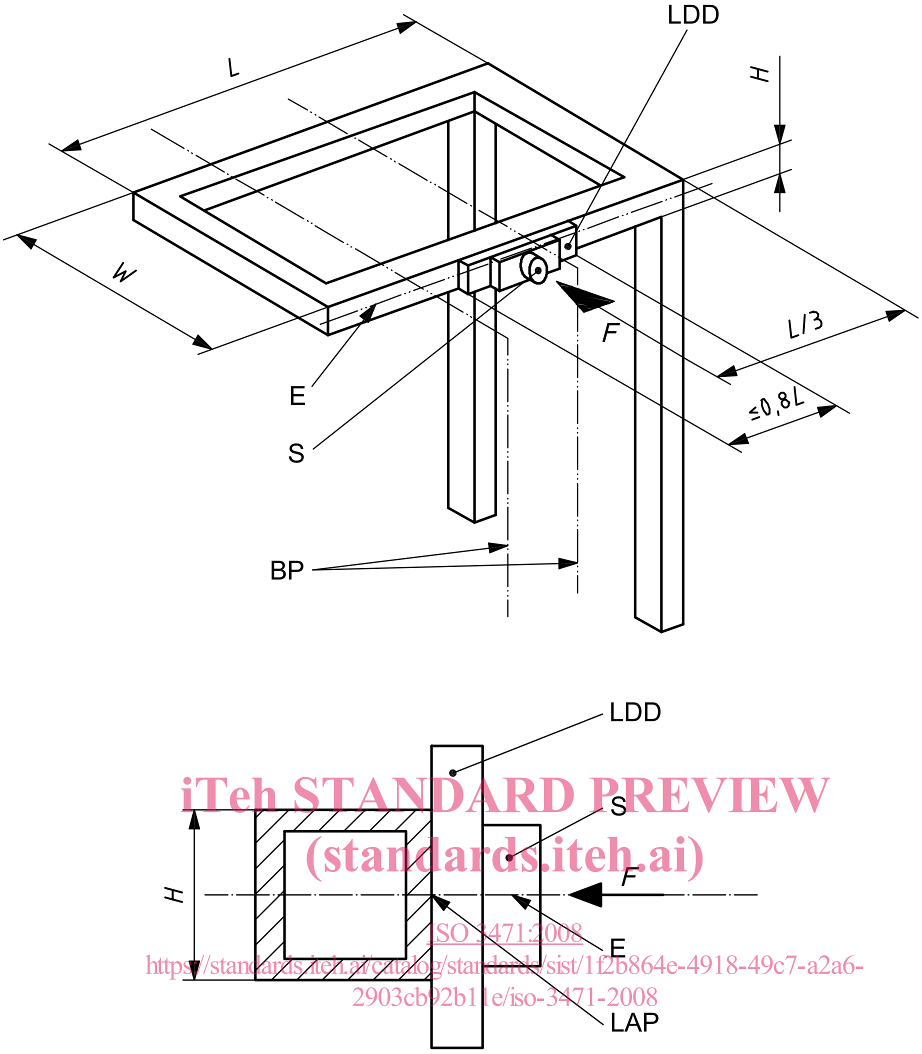
$\Delta$ deflection of the ROPS, expressed in millimetres

$H$ Height of the load application zone, expressed in millimetres

— For a straight member, $H$ is the distance from the top to the bottom of the member, as shown in Figure 1.

— For a curved member, $H$ is the vertical distance from the top of the member to the vertical plane at the end of $L$ where it intersects the inner surface of the curved member at Y, as shown in Figure 3.

— For a shaped member, $H$ is three times the vertical width of the top member, as shown in Figure 3.






**Key**

BP boundary planes of DLV

E horizontal mid-point of upper ROPS structural member

*F* load force

*H* height of upper ROPS structural member

*L* length of ROPS

LAP load application point

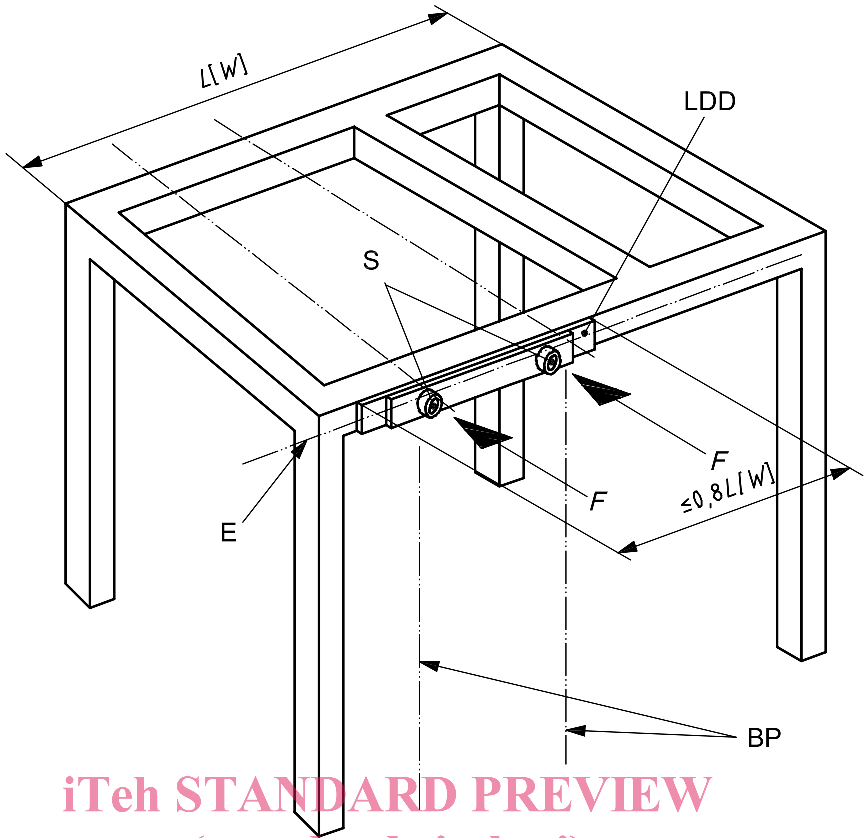
LDD load distribution device

S socket

*W* width of ROPS

NOTE The LDD can extend beyond the dimension *H*.

**Figure 1 — Example of lateral load application point (LAP) of two-post ROPS**






**Key**

BP boundary planes of DLV

E horizontal mid-point of upper ROPS structural member

*F* load force

*L* [*W*] length [width] of ROPS

LDD load distribution device

S socket

NOTE See Figure 1 for an example of LAP and LDD details. Two sockets are shown in this example to illustrate that more than one may be used simultaneously to apply the required force.

**Figure 2 — Example of load application point (LAP) of four-post ROPS**