International Standard 3471

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

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

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

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 3471 was developed by Technical Committee ISO/TC 127, *Earth moving machinery*, and was circulated to the member bodies in June 1979.

It has been approved by the member bodies of the following countries :

Australia	Germany, F.R.	Spain
Austria	Italy	Sweden
Belgium	Japan	United Kingdom
Chile	Philippines	USA
Czechoslovakia	Poland	USSR
Egypt, Arab Rep. of	Romania	
France	South Africa, Rep. of	

No member body expressed disapproval of the document.

This second edition cancels and replaces the first edition (i.e. ISO 3471-1975).

Printed in Switzerland

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

1 Scope

1.1 This International Standard sets out

a) the static laboratory tests for measurement of structural characteristics, and

b) the requirements for performance in a representative test

of a roll-over protective structure (ROPS) design, and is closely related to the deflection-limiting volume (DLV) (see ISO 3164).

1.2 The static laboratory tests are means of measuring the characteristics of the structures used to protect the operator at velocities of 0 to 16 km/h (0 to 10 mile/h) over hard clay where roll-over would be limited to a maximum roll angle of 360° down a slope of 30° maximum without penetration of the specified DLV by structural members of the ROPS.

1.3 This International Standard is intended to establish a consistent, reproducible means of evaluating force-deflection characteristics of ROPS under static loading and to prescribe performance requirements for these structures under such loading in a representative test.

1.4 For the purposes of this International Standard "representative test" means a test of a specimen whose material, dimensional, and processing requirements are typical of those ROPS being produced.

2 Field of application

2.1 This International Standard applies to the following types of operator-controlled machines, regardless of the type of steering system utilized, as defined in ISO 6165 :

— crawler loaders and wheel loaders;

— crawler tractors and wheel tractors;

— graders;

— tractor-scrapers.

2.2 Excluded from this International Standard are :

— compactors;

— machines having a power rating less than 15 kW (20 hp);

— excavators;

— drag lines.

3 References

ISO 3164, *Earth-moving machinery — Laboratory evaluation of roll-over and falling-object protective structures — Specification for the deflection-limiting volume.*

ISO 3449, *Earth-moving machinery — Falling-object protective structures — Laboratory tests and performance requirements.*

ISO 6165, *Earth-moving machinery — Basic types — Vocabulary.*

4 Definitions

For the purposes of this International Standard, the following definitions apply :

4.1 roll-over protective structure (ROPS) : System of structural members arranged on a machine in such a way as to accomplish its primary purpose to reduce the possibility of an operator, when wearing a seat belt, being crushed should his machine roll over. Structural members include any subframe, bracket, mounting, socket, bolt, pin, suspension or flexible shock absorber used to secure the system to the machine frame but excludes mounting provisions which are integral with the machine frame.

4.2 machine frame : The main chassis or main load bearing member(s) of the machine which extend(s) over a major part of the machine and upon which the ROPS is directly mounted.

4.3 ROPS-machine frame assembly : The ROPS system attached to the machine frame.

4.4 bedplate : A substantially rigid part of the testing structure to which the machine frame is attached for the purpose of the test.

4.5 deflection-limiting volume (DLV) : That volume, related to the operator, which serves to set limits and deflections permissible when performing laboratory evaluations of ROPS and falling object protective structures (FOPS). The volume, an approximation, is based on the seated dimensions of the larger operator. (See ISO 3164.)

4.6 simulated ground plane (SGP) : Surface, on which an earth-moving machine after rolling over is assumed to come to a standstill with the machine lying on its side (see 8.1.2).

5 Symbols

The following symbols are used in this International Standard :

5.1 ROPS : Roll-over protective structure.

5.2 U : Energy absorbed by the structure related to the machine mass, expressed in joules or pounds-force inches.

5.3 F : Force expressed in newtons or pounds-force.

5.4 M : Machine mass, expressed in kilograms (pounds), being the manufacturer's maximum recommended mass including attachments in operating condition with all reservoirs full to capacity, tools and ROPS; exclusive of towed equipment such as rollers, compactors, and drawn scrapers. For the tractor scraper, it is manufacturer's maximum recommended mass of the tractor portion only.

Kingpins, hitches, and articulated steering components that attach to hitches or towed units are excluded from the mass of these machines. Soil, mud, rocks, branches, debris, etc. that commonly adhere to or lie on machines in use are not to be considered as part of the mass of any machine. Material dug, carried, or handled in any manner is not to be considered part of the machine mass in determining test requirements.

5.5 DLV : Deflection-limiting volume.

5.6 Δ : Deflection of ROPS expressed in millimetres (inches).

6 General

The following points are stated to aid in understanding the underlying principles, intention, and application of this International Standard.

6.1 The ROPS can be integrated into the operator's cab or into the FOPS.

6.2 This evaluation procedure will not necessarily duplicate structural deformation caused by a given actual roll.

6.3 This evaluation procedure is generally destructive of the ROPS-machine frame assembly, as permanent deformation is apt to be induced in either or both.

6.4 Although ROPS meeting these criteria may not give crush protection under all conceivable circumstances in which a machine could overturn, it is expected that crush protection will be ensured under at least the following conditions : an initial forward velocity of 0 to 16 km/h (0 to 10 mile/h) on a hard clay surface of 30° maximum slope; 360° of roll about the machine's longitudinal axis without losing contact with the slope and without penetration of the DLV by structural members of the ROPS.

6.5 The horizontal force requirement and limitation on deflection (DLV) are intended to ensure that the ROPS will penetrate unfrozen soil thereby giving a braking action to a roll.

6.6 The energy requirement and limitation on deflection (DLV) are intended to ensure that the ROPS will deflect when it strikes or impacts a surface that will not significantly deform (frozen ground, concrete, rock) while retaining significant capability to withstand subsequent impacts.

6.7 The vertical loading requirement is intended to ensure that a deformed ROPS will be able to support the machine when it is in an upside-down position.

6.8 The criteria established for the deflection limitation, for the energy absorbed and for the lateral loading, do not mean that the minimum side force and the minimum energy required correspond to the permissible limits of the DLV nor that they are attained simultaneously.

6.9 The temperature-material requirements of 8.3 are intended to be a base-line of measurement for testing to ensure that the ROPS will have meaningful resistance to brittle fracture and does not necessarily relate to operating conditions.

6.10 Because, in an actual roll, loading will be dynamic (possibly impact) the use of conventional "safety factors" based on static force loading should be used with caution. The "safety factor" of an ROPS is related more to energy absorption capability and details of weld design and welding procedure than it is to static force resistance.

7 Static laboratory tests

7.1 Facilities

Facilities for securing the ROPS-machine frame assembly to the bedplate, as described below, and for applying the horizontal and vertical loads shall be provided.

The DLV and its location should be in accordance with ISO 3164. The DLV should be fixed firmly to the same part of the machine to which the operator's seat is secured, and should remain there during the entire formal test period.

7.2 Instruments

The test apparatus shall be equipped with instruments for measuring the force applied to the protective structure and the deflection (deformation) of the structure.

Measurement	Accuracy
Deflection of ROPS	± 5 % of maximum deflection measured
Force applied to ROPS	± 5 % of maximum force measured

The above percentages are nominal ratings of the accuracy of the instrumentation and shall not be taken to indicate that compensating tests are required.

7.3 Arrangements for load application

Typical, but not mandatory, loading arrangements are shown in the figures as follows :

7.3.1 Wheel loaders and wheel tractors : figures 1c), 1d).

7.3.2 Graders : figures 2c), 2d).

7.3.3 Tractor-scrapers : figures 3c), 3d).

7.3.4 Crawler tractors and crawler loaders : figures 4c), 4d).

7.4 Apparatus

7.4.1 General considerations

7.4.1.1 Assembly of the ROPS to the machine frame

The ROPS shall be attached to the machine frame as it would be on an operating machine. A complete machine is not required for the evaluation; however, the machine frame and ROPS mounting shall represent an operating installation. All normally detachable windows, panels, doors, and other non-structural elements shall be removed so that they do not contribute to or detract from the structural evaluation.

7.4.1.2 Attachment of the ROPS-machine frame assembly to the bedplate

The ROPS-machine frame assembly shall be secured to the bedplate so that the members connecting the assembly and bedplate experience minimal deflection when the ROPS is horizontally loaded. During side loading, the ROPS-machine frame assembly shall not receive any support from the bedplate, other than that due to the initial attachment.

7.4.1.3 Elimination of suspension elements and shock absorbers

The machine frame shall be secured and/or modified so that any machine suspension element that might be considered as a suspension element (rubber, gas, gas-oil, or mechanical spring) shall be effectively eliminated as an energy absorber. However, the ROPS-structural members as defined in 4.1 may include suspension or flexible shock absorbers which shall not be altered.

7.4.2 Specific considerations related to particular types of machine — Side loading

7.4.2.1 Wheel loaders, wheel tractors and graders

Connections to the bedplate shall be directly from the machine frame at or near the front-axle support and the rear drive support. For articulated machines, if both frames are used in the evaluation, the hinge shall be locked so that the attitude of the frames is in a straight line. If only that frame on which the ROPS is mounted is used, the connections shall be at or near the extreme ends of the frame. See figures 1a), 1b), 2a), 2b).

7.4.2.2 Tractor scrapers

Connection to the bedplate shall be directly from the machine frame at or near the drive tyre or axle location. See figures 3a), 3b).

7.4.2.3 Crawler tractors and crawler loaders

Connection to the bedplate shall be through the main housing or track frames. See figures 4a), 4b).

7.4.3 Vertical loading — All machines

For vertical loading there is no limitation on securing or supporting the ROPS-machine frame assembly.

7.5 Procedure

7.5.1 General

The test procedures shall consist of the operations specified in 7.5.2 and 7.5.3, in the order listed.

No repair or straightening of any ROPS-machine member shall be carried out during or between the side and vertical loading.

7.5.2 Side loading

7.5.2.1 The force-deflection characteristics shall be determined by side loading the top major longitudinal members of the ROPS.

For a ROPS having more than two posts, the side loading shall be applied through a load-distribution device having a length not greater than 80 % of the top member straight length L between the front and rear posts of the ROPS. See figures 5a), 5b), 5c).

7.5.2.2 For a ROPS having a two-post system, the side loading shall be applied to the top longitudinal member of the ROPS at a minimum distance of $L/3$ from the posts. See figure 5d), or the locating axis (LA) of the DLV, whichever distance is greater.

7.5.2.3 The initial direction of loading shall be horizontal and perpendicular to a vertical plane through the machine's longitudinal centre line.

7.5.2.4 As loading continues, the ROPS-machine frame deformations may cause the direction of loading to change; this is permissible.

7.5.2.5 Should the operator's seat be off the machine's longitudinal centre line, the loading shall be against the outermost side nearest the seat.

7.5.2.6 For on-centre line seats, if mounting of the ROPS is such that different force-deflection relations are obtained from loading from left or right sides, the side loaded shall be that which will place the most severe requirements on the ROPS-machine frame assembly.

7.5.2.7 The rate of deflection (application of load) shall be such that it can be considered static.

7.5.2.8 At deflection increments no greater than 25 mm (1 in) at the point of application of the resultant load, the force and deflection shall be recorded and plotted. See figure 6.

7.5.2.9 The loading shall be continued until the ROPS has achieved both the force and energy requirements. The area under the resulting force-deflection curve (figure 6) equals the energy.

7.5.2.10 The deflection(s) used in calculating energy shall be that of the ROPS along the line(s) of action of the force(s). The deflection should be measured at the mid-point of the loading. See figures 5b), 5c), 5d).

7.5.2.11 Any deflection of members used to support load-application devices shall not be included in deflection measurements used for calculation of energy absorption.

7.5.3 Vertical loading

7.5.3.1 After removal of the side load, a vertical load shall be applied to the top of the ROPS.

7.5.3.2 There are no limitations on the manner of distributing this load on ROPS having more than two posts. See figures 1c), 2c), 2d), 3c), 3d), 4c), for typical vertical loading arrangements.

7.5.3.3 For ROPS having a two-post system, the vertical load shall be applied at a minimum distance of $L/3$ from the supporting posts [see figures 1d), 4d)], or the vertical plane containing the centre line of the locating axis (LA) of the DLV, whichever distance is greater.

NOTE — The figures referred to in 7.5 are illustrative and are not intended to restrict the design of loading devices.

8 Performance requirements

8.1 General

8.1.1 During each test, no part of the ROPS shall enter the DLV (see ISO 3164). Also, deformation of the ROPS shall not allow the SGP, as defined in 8.1.2, to enter the DLV.

NOTE — It is not required that the included volume of a ROPS having four or more vertical members entirely enclose the positioned DLV, nor is it intended that a simple (two-post) frame be excluded as a ROPS.

8.1.2 ROPS deflection during each test shall not cause the load side planes of the DLV (figure 7) to extend beyond or intersect the SGP (see figure 7) defined as follows :

a) upper member to which load is applied;

b) outermost point in end view of above member;

c) vertical line through above point;

d) vertical plane parallel to vehicle's longitudinal centre line through the above line;

e) rotate plane described in d) above, 15° away from the DLV about an axis which is perpendicular to the vertical line given in c) above and also passes through the point described in b) above; this establishes the SGP;

f) the SGP shall be established on an unloaded ROPS and shall move with the member to which the load is applied.

8.1.3 The ROPS shall not break away from the machine frame due to failure of the machine frame.

8.2 Force-energy and vertical load requirements

8.2.1 These requirements shall be met within the deflection(s) permitted in 8.1.1. The requirements are related to M, the machine manufacturer's "maximum recommended mass", in kilograms (pounds). See 5.4.

8.2.2 The side-load force attained during the representative side loading test shall be at least that given by the equations set forth in table 1.

If the required force is attained or exceeded before the energy requirement is met, the force may decrease but shall attain the required force when the energy is achieved or exceeded.

8.2.3 The energy absorbed during the representative side loading test shall be at least that given by the equations set forth in table 2.

8.2.4 After removal of the side load, the ROPS-machine frame assembly shall support a vertical load of 2 M (the maximum recommended mass) for a period of 5 min or until any deformation has ceased, whichever is shorter.

8.3 Temperature-material requirements

8.3.1 The laboratory evaluations should be performed with all ROPS and machine frame members soaked to − 18 °C (0 °F) or below.

8.3.2 If the evaluations are not performed at this temperature, the following minimum material requirements shall be met.

8.3.2.1 Bolts and nuts used to attach the ROPS to the machine frame and to connect structural parts of the ROPS shall be property class 8.8 or 10.9 bolts (see ISO 898/1) and 8 or 10 property class nuts (see ISO/R 898/2).

8.3.2.2 Structural members of the ROPS made from steel shall have one of the following Charpy V-notch impact strengths :

10 mm × 10 mm specimen : 10,8J at − 30 °C (8 lbf·ft at − 20 °F)

10 mm × 7,5 mm specimen : 9,5J at − 30 °C (7 lbf·ft at − 20 °F)

10 mm × 5 mm specimen : 7,5J at − 30 °C (5,5 lbf·ft at − 20 °F)

10 mm × 2,5 mm specimen : 5,5J at − 30 °C (4 lbf·ft at − 20 °F)

Structural members of the ROPS made from materials other than steel shall have equivalent low temperatures impact resistance.

NOTES

1 Specimens are to be "longitudinal" and taken from flat stock, tubular, or structural sections before forming or welding for use in the ROPS. Specimens from tubular or structural sections are to be taken from the middle of the side of greatest dimension and shall not include welds.

2 In those countries using the inch system, the grade of bolts or nuts used shall be of an equivalent grade (i.e. equal to the ROPS material).

3 The requirements of 8.3.2.2 are set forth as information until such time as ISO develops an International Standard.

8.3.3 Materials used shall be processed in such a manner as to eliminate sharp corners and edges that are adjacent to the operator or service personnel work areas.

9 Labelling

9.1 A label shall be applied to every ROPS with or without a FOPS.

9.1.1 Label specifications

9.1.1.1 The label shall be of a permanent type and permanently attached to the structure.

9.1.1.2 The label shall be located on the structure so that it can be easily read and is protected from environmental defacing.

9.1.2 Label content

9.1.2.1 Name and address of the manufacturer or fabricator of the ROPS (and FOPS if integral with the ROPS).

9.1.2.2 ROPS and FOPS identification number, if any.

9.1.2.3 Machine make, model(s), or series number(s) the structure is designed to fit.

9.1.2.4 Maximum machine mass M for which the ROPS structure meets all of the performance requirements of this International Standard.

9.1.2.5 The International Standard number(s) for which the structure meets all of the performance requirements (for example, ISO 3471, ISO 3449). Other performance requirements may be included.

9.1.2.6 The manufacturer may include such other information as deemed appropriate (for example, installation, repair or replacement information).

10 Reporting of results

10.1 A test report shall include the results of the test and be presented in a typical test report as presented in annex A. Additional information presented in annex B shall be reported only to the test initiator.

Table 1 — Minimum force F attained during side loading

Machine	Equation	
	Si Units[1]	Imperial Units[2]
Wheel loaders and wheel tractors	$F = 60\,000 \left[\frac{M}{10\,000}\right]^{1,20}$	$F = 5\,220 \left[\frac{M}{10\,000}\right]^{1.20}$
Graders	$F = 70\,000 \left[\frac{M}{10\,000}\right]^{1,10}$	$F = 6\,600 \left[\frac{M}{10\,000}\right]^{1.10}$
Tractor-scrapers[3]	$F = 95\,000 \left[\frac{M}{10\,000}\right]^{1,20}$	$F = 8\,270 \left[\frac{M}{10\,000}\right]^{1.20}$
Crawler-tractors and crawler loaders	$F = 70\,000 \left[\frac{M}{10\,000}\right]^{1,20}$	$F = 6\,090 \left[\frac{M}{10\,000}\right]^{1.20}$

1) F expressed in newtons
M expressed in kilograms

2) F expressed in pounds-force
M expressed in pounds

3) Includes articulated steer dumpers, trailers and wagons.

Table 2 — Minimum energy U absorbed during side loading

Machine	Equation	
	SI Units[1]	Imperial Units[2]
Wheel loaders and wheel tractors	$U = 12\,500 \left[\frac{M}{10\,000}\right]^{1,25}$	$U = 41\,180 \left[\frac{M}{10\,000}\right]^{1.25}$
Graders	$U = 15\,000 \left[\frac{M}{10\,000}\right]^{1,25}$	$U = 49\,410 \left[\frac{M}{10\,000}\right]^{1.25}$
Tractor-scrapers[3]	$U = 20\,000 \left[\frac{M}{10\,000}\right]^{1,25}$	$U = 65\,880 \left[\frac{M}{10\,000}\right]^{1.25}$
Crawler-tractors and crawler loaders	$U = 13\,000 \left[\frac{M}{10\,000}\right]^{1,25}$	$U = 42\,830 \left[\frac{M}{10\,000}\right]^{1.25}$

1) U expressed in joules
M expressed in kilograms

2) U expressed in pounds-force inches
M expressed in pounds

3) Includes articulated steer dumpers, trailers and wagons.

The arrangements shown are typical but not mandatory

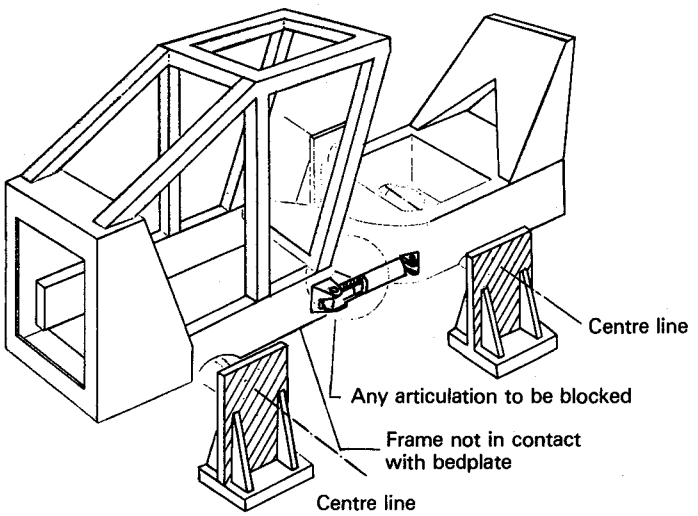

Figure 1a)

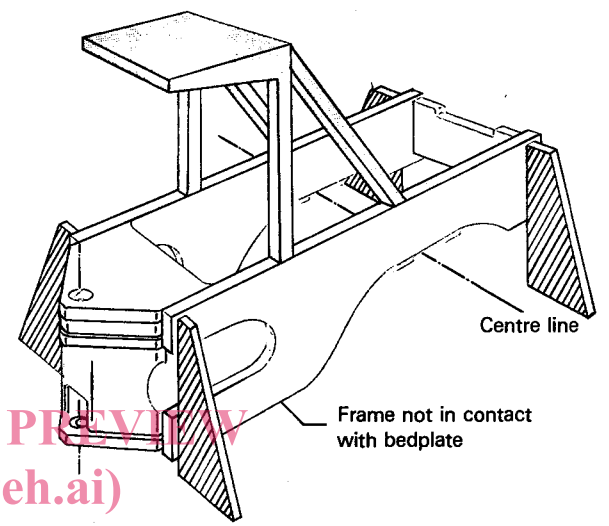

Figure 1b)

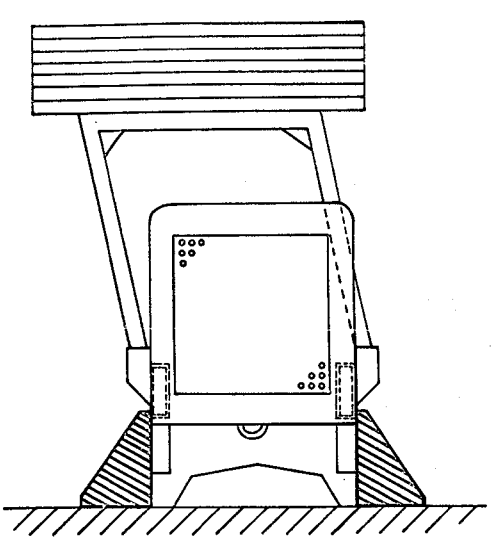

Figure 1c)

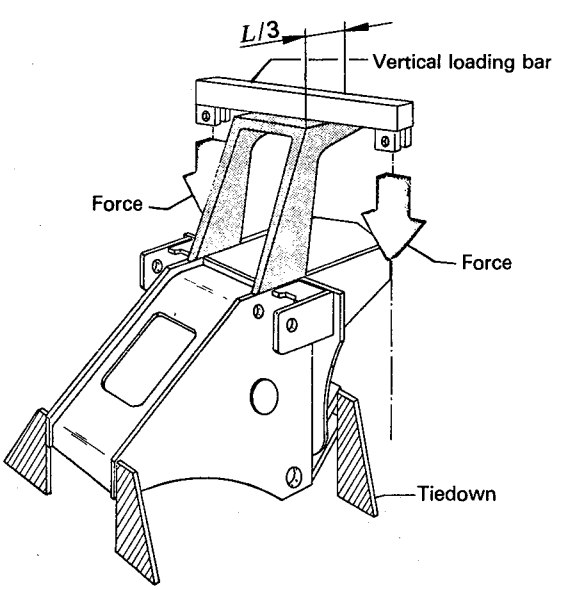

Figure 1d)

Figure 1 — Wheel loaders and wheel tractors

The arrangements shown are typical but not mandatory

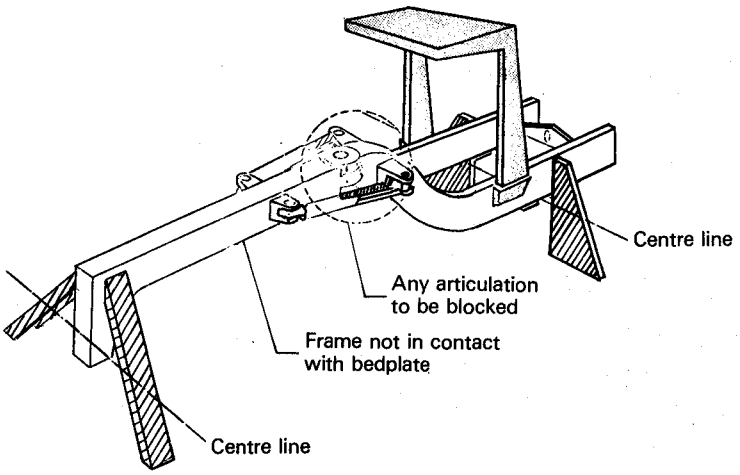

Figure 2a)

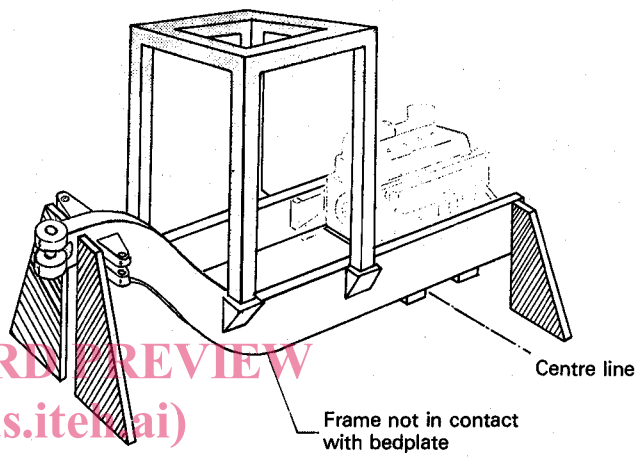

Figure 2b)

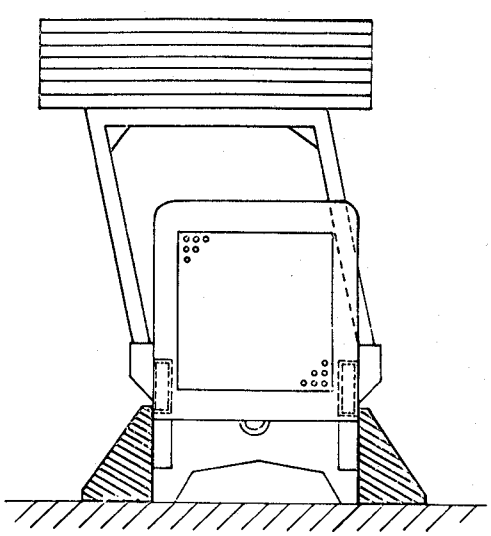

Figure 2c)

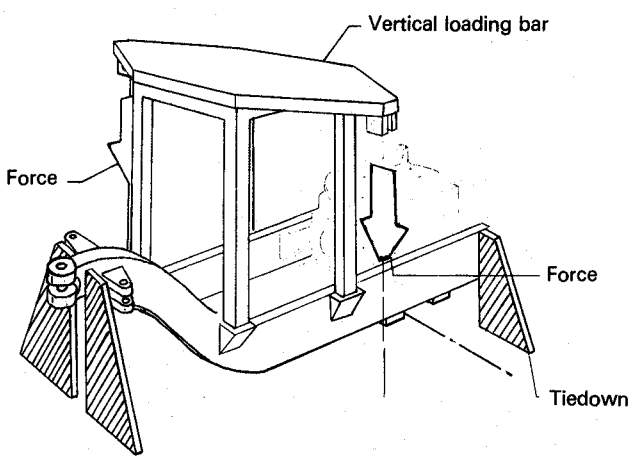

Figure 2d)

Figure 2 — Graders

The arrangements shown are typical but not mandatory

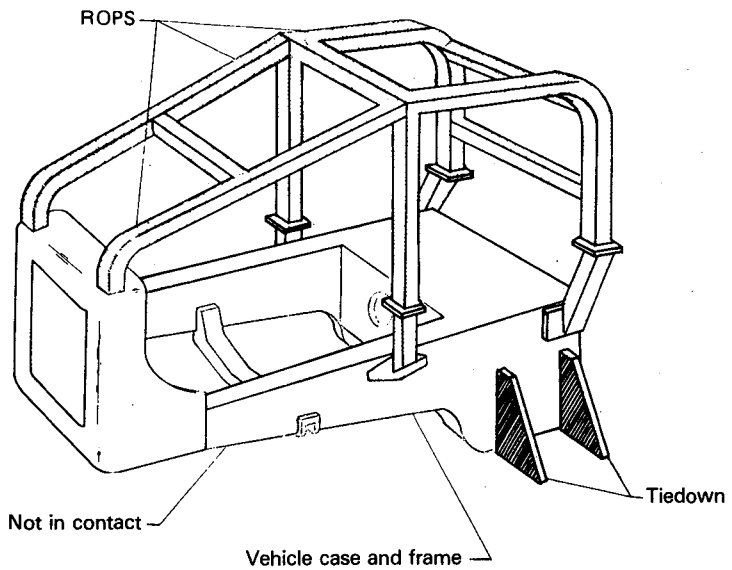

Figure 3a)

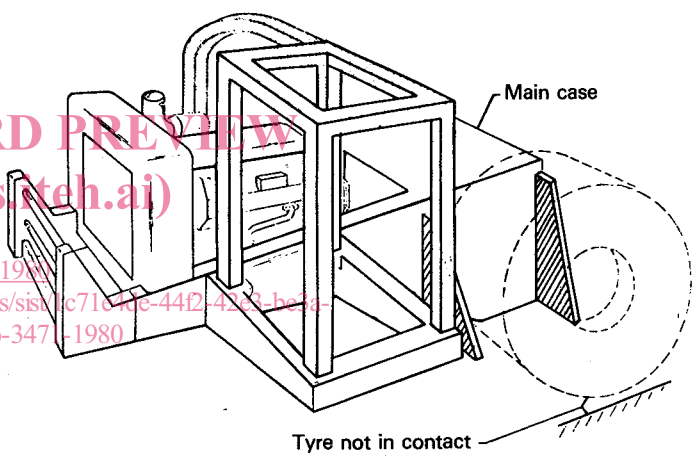

Figure 3b)

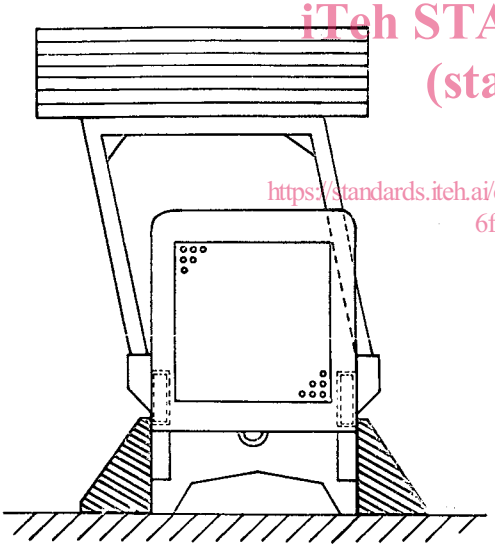

Figure 3c)

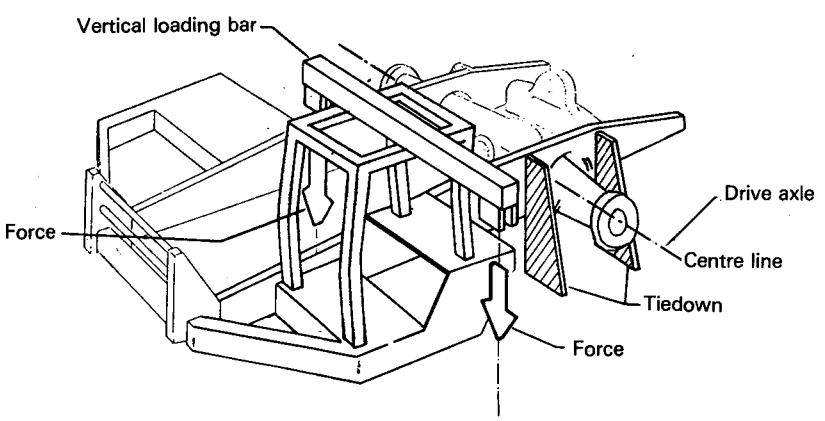

Figure 3d)

Figure 3 — Tractor scrapers