

FINALIZED DRAFT

AUTOMOTIVE INDUSTRY STANDARD

**Performance Requirements and
Test Procedures of Braking Systems for
Wheeled High Speed Rubber Tracked Earth
Moving Machines and all types of
Construction Equipment Vehicles**

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INTRODUCTION

The Government of India felt the need for a permanent agency to expedite the publication of standards and development of test facilities in parallel when the work on the preparation of the standards is going on, as the development of improved safety critical parts can be undertaken only after the publication of the standard and commissioning of test facilities. To this end, the erstwhile Ministry of Surface Transport (MoST) has constituted a permanent Automotive Industry Standards Committee (AISC) vide order No. RT-11028/11/97-MVL dated September 15, 1997. The standards prepared by AISC will be approved by the permanent CMVR Technical Standing Committee (CTSC). After approval, the Automotive Research Association of India (ARAI), Pune, being the secretariat of the AIS Committee, would publish this standard. For better dissemination of this information ARAI may publish this standard on their Web site.

This standard addresses the general requirements, requirement of a service brake system, secondary brake system and a parking brake system. Additional requirements have also been specified for hydrostatic braking systems, systems with combined brake and steer function, performance and warning devices for stored energy sources, braking systems with electronic machine control systems, test conditions and performance tests. This standard is intended to replace the requirements currently notified under CMV(A)R, 1989.

While deriving this standard considerable assistance has been derived from the following:

- a) ISO:3450 – 2011 Earthmoving machinery – Wheeled or high-speed rubber – tracked machines – Performance requirements and test procedures for brake systems
- b) Rule 96 A of the Central Motor Vehicle Rules, 1989 already lays down certain technical prescriptions and requirements which have been suitably considered.

While finalising this standard in line with ISO 3450, the following deviations were necessary on account of the current braking requirements already notified under CMV(A)R, 1989.

- (i) The scope of the standard have been extended to all type of rubber tyred Construction Equipment Vehicles, which are currently covered under the scope of CMV(A)R, 1989.
- (ii) The word “mass” has been changed to “weight” in line with other Indian Standards published by BIS.
- (iii) The service brake requirements for all other Earth Moving Machines, including Towed Trailers with payloads and all Construction Equipment Vehicles (as defined under CMVR) have been kept at the same level of stringency as is currently notified and applicable under CMVR.

The AISC panel and the Automotive Industry Standards Committee (AISC) responsible for preparation of this standard are given in Annex-C and Annex-D respectively.

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Performance Requirements and Test Procedures of Braking Systems for Wheeled High Speed Rubber Tracked Earth Moving Machines and all types of Construction Equipment Vehicles

1.0 SCOPE

This standard specifies minimum performance requirements and test procedures for the service, secondary and parking brake systems of wheeled and high-speed rubber-tracked earth-moving machines, for the uniform assessment of those brake systems.

It is applicable to the following earth-moving machinery, operating on work sites or in mining, or travelling on public roads:

- a) self-propelled, rubber-tyred earth-moving machines,
- b) self-propelled, rubber-tyred construction equipment vehicles (as defined under CMV(A) R 1989),
- c) self-propelled rollers and landfill compactors,
- d) self-propelled scrapers,
- e) remote-control machines, wheeled or rubber-tracked;
- f) derivative earth-moving machines with rubber tyres;
- g) earth-moving machines with rubber tracks and a maximum machine speed ≥ 20 km/h.

It is not applicable to pedestrian-controlled earth-moving machinery (see ISO 17063:2003) or crawler earth-moving machines with steel or rubber tracks that travel at < 20 km/h (see IS/ISO 10265:2008). While purpose-built underground mining machines are not within the scope of this National Standard, its provisions can generally be applied to those machines with some braking performance modifications and additions (see Annex A).

2.0 REFERENCES

The standards listed below are necessary adjuncts to this standard. At the time of publication, the editions indicated were valid. All standards are subject to revisions and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated.

IS/ISO 6165:2006, Earth-moving machinery - Basic types - Identification and terms and definitions

IS/ISO 7133:1994, Earth-moving machinery- Tractor-scraper-Terminology and commercial specifications

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

IS/ISO 10265:2008 Earth moving machinery- Crawler machines - Performance requirements and test procedures for braking systems

IS/ISO 10968:2004, Earth-moving machinery- Operator's controls

ISO 6014: 1986, Earth-moving machinery-Determination of ground speed

ISO 6016::2008 Earth-moving machinery-Methods of measuring the weights of whole machines, their equipment and components

ISO 8811:2000, Earth-moving machinery-Rollers and compactors-Terminology and commercial specifications

ISO 15998:2008, Earth-moving machinery-Machine-control systems (MCS) using electronic components-Performance criteria and tests for functional safety

ISO 17063:2003, Earth-moving machinery- Braking systems of pedestrian-controlled machines- Performance requirements and test procedures

3.0 TERMS AND DEFINITIONS

For the purpose of this standard, the following definitions in addition to given in IS/ISO 6165 shall apply.

3.1 Braking System

All components which combine together to stop and/or hold the machine, including the brake control(s), brake actuation system, the brake(s) themselves and, if the machine is so equipped, the retarder

3.1.1 Service Brake System

Primary system used for stopping and holding the machine.

3.1.2 Secondary Brake System

System used to stop the machine in the event of any single failure in the service brake system.

3.1.3 Parking Brake System

System used to hold a stopped machine in a stationary position and which, if applicable, may also be part of secondary brake system.

3.1.4 Hydrostatic Brake System

Hydrostatic or other similar propel drive system used to meet one or more of the brake system requirements.

3.1.5 Braking System Components

3.1.5.1 Brake control

Component directly activated by the operator to cause a force to be transmitted to the brake(s).

3.1.5.2 Brake actuation system

All components between the brake control and the brake(s) which connect them functionally.

3.1.5.3 **Brake**

Component which directly applies a force to oppose movement of the machine

Note: The different types of brake include friction, mechanical, electrical, regenerative devices and hydrostatic or other fluid types.

3.1.5.4 **Common component**

Component that performs a function in two or more brake systems.

Example : Pedal, valve.

3.1.5.5 **Retarder**

Energy-absorption device normally used to control machine speed.

3.2 **Hydrostatic Drive System**

Hydraulic system where hydraulic motors form a direct drive to the wheels or track to propel the machine and slow machine movement.

3.3 **Machine Test Weight**

Operating weight of a machine which includes the heaviest combination of cab, canopy, operator protective structures (if required) with all their components and mountings, any combination of equipment approved by the manufacturer of the machine, including operator and full liquid systems in accordance with ISO 6016. (e.g. machine configuration and direction of travel having the most adverse effect on braking)

Note:

1. For rollers, the sprinkler water reservoir(s) shall be full.
2. For self-propelled scrapers with semi-trailed units, towed trailers and all types of dumpers, the machine test weight shall also include the maximum specified payload as per the machine manufacturer's specifications. For all other machines, the payload shall not be included.

3.4 **Stopping Distances**

Distance travelled by the machine from the point on the test course at which the machine brake control actuation begins (e.g. operator actuates the brakes) to the point on the test course where the machine is fully stopped.

Note:

- 1 It is expressed in metres (m).
- 2 It does not take into account the operator reaction time, unless stated, but does take into account the system reaction time.

3.5 **Mean Deceleration (a) :**

Average rate of change in the velocity of the machine from the instant the brake control actuation begins until a full stop is achieved

Note: It is expressed in metres per second squared (m/s²), calculated from:

$$a = \frac{v^2}{2s}$$

Where

v is the velocity of the machine immediately prior to the brake control being activated, in metres per second (m/s);

S is the stopping distance, in metres (m).

3.6 **Burnishing**

Procedure used to condition the frictional surfaces of a brake.

3.7 **Brake System Pressure**

Fluid pressure available to the brake control.

3.8 **Brake Application Pressure**

Measured fluid pressure used to actuate the brakes.

3.9 **Modulated Braking**

Ability to continuously and progressively increase and decrease the braking force by operation of the brake control

Example: A system allows the braking force to be increased and decreased over time, based on single or repeated movements of the brake control.

3.10 **Test Course**

Surface upon which the test is carried out.

Note: See 5.3.

3.11 **Cold Brakes**

(brake systems containing friction elements) condition of brakes

where

- a) the brakes have not been actuated in the previous hour except in accordance with the applicable performance test (see Clause 6),
- b) the brakes have been cooled to 100 °C or less when measured on the brake disc or the outside of the brake drum, or
- c) in the case of totally enclosed brakes, including oil-immersed brakes, the temperature measured on the outside of the housing closest to the brake is below 50 °C or within the brake manufacturer's specifications

3.12 **Maximum Machine Speed**

Maximum speed determined in accordance with ISO 6014, or equivalent.

3.13 **Back Throttling**

Action of applying slight forward or reverse power to a hydrostatic or other similar drive system in order to hold the machine stationary.

- 3.14 **Derivative Earth-Moving Machine**
Machine with a combination of features from other earth-moving machines, thereby creating different configurations or arrangements.
Example : Machine having the front-mounted equipment of a loader on a non-self-loading, rear-mounted dumper body.
- 3.15 **Safe State**
Condition in which, after a malfunction of the machine control system, the controlled equipment, process or system is automatically or manually stopped or switched into a mode that prevents unexpected performance or the potentially hazardous release of stored energy.
- 3.16 **Dumper:**
Self-propelled crawler or wheeled machine with an open body, which transports and dumps or spreads material, and where loading is performed by means other than the dumper [ISO 6165]
Note: For semi-trailed dumpers, see ISO 7132:2003, Figs 3, 16 and 20.
- 3.16.1 **Rigid-frame Dumper**
Dumper having a rigid frame and wheel or crawler steering [IS/ISO 6165]
Note: Rigid-frame and articulated-frame dumpers are illustrated in ISO 7132:2003, Figs 1 and 2, 8 and 9, 14 and 15, and 18 and 19.
- 3.16.2 **Articulated-frame Dumper**
(Wheeled machine) Dumper with an articulated frame which accomplishes the steering of the dumper [IS/ISO 6165]
Note: Rigid-frame and articulated-frame dumpers are illustrated in ISO 7132:2003, Figs. 1 and 2, 8 and 9, 14 and 15, and 18 and 19.
- 3.17 **Trailer**
Transport machine with one or more axles which, according to its design, is suitable and intended for coupling to a self-propelled machine.
- 3.18 **Fully Developed Deceleration Rate**
Maximum continuous deceleration rate which the machine is capable of developing on a specified constant slope, with a specific machine test weight and surface condition and an initial (prior to deceleration) machine travel speed.
- 3.19 **Purpose-Built Underground Mining Machine**
Specialized earthmoving machine designed for underground use which may have a lower height profile and trailer attached.
Example: Underground dump trucks, tele-dumpers, load haul dumps, scoops, coal haulers, power trams, chock carriers, personnel carriers, loading machines.
- 3.20 **Machine Control System (MCS)**
Components needed to fulfill the function of the system, including sensors, signal processing unit, monitor, controls and actuators or several of these.

Note : The extent of the system is not limited to the electronic controls, but is defined by the machine-related function of the complete system. It therefore consists generally of electronic, non-electronic and connection devices. This can include mechanical, hydraulic, optical or pneumatic components/systems.[ISO 15998]

4.0 GENERAL REQUIREMENTS

The requirements of this clause apply to all machines within the scope of this National Standard.

All brake systems shall be designed, constructed and installed such that contamination and/or its effects are minimized.

4.1 Required Brake Systems

4.1.1 All machines shall be equipped with,

- a) a service brake system,
- b) a secondary brake system, and
- c) a parking brake system.

Service, secondary and parking brake systems may share common components or functions and do not have to be three independent and separate systems.

4.1.2 No brake system (including hydrostatic systems) shall contain a disconnecting device such as a clutch or shiftable gear-box which allows disabling of the brake, except for systems in accordance with a) and/or b), as follows:

- a) any device designed to disconnect the service or secondary brake power source for cold weather starting shall require application of the parking brake before disconnection can take place;
- b) a parking brake disconnect (release) designed to allow movement of disabled machines shall be located outside the operator's station unless it can be reapplied immediately.

4.1.3 All machines shall have service brakes of an equal nominal capacity rating applicable to each of the wheels (or equivalent) of at least one axle. Dumpers and self-propelled scrapers with semi-trailed unit(s) shall have service brakes applicable to at least one axle of the towing machine and one axle of each semi-trailed unit.

4.1.4 For rollers, the service and secondary brakes shall apply to all power-driven drums and wheels. Each drum of a split drum shall have the same nominal brake torque. The brake of a single-drum roller and a combined roller shall apply to all wheels and to the drum.

4.1.5 If the parking brake is intended to stop creep movement, the parking brake system shall permit actuation of the parking brake during travel.

4.2 Common Components

Service, secondary and parking brake systems can share common components. Where common components are used, the machine's braking performance shall meet the requirements for secondary brake systems given in 4.5 and 4.7, as applicable. If there is a failure in any single component within the brake system — except for tyres, drum or track — braking performance shall be in accordance with Table 3.

Acceptable performance is achieved for common brake control failure as follows. If there is a failure with a common brake control (lever, pedal, etc.) used to actuate the combined service and secondary brake systems, and there is another dynamic braking capability provided with the machine (e.g. parking brake with dynamic braking capability), the dynamic braking capability shall stop the machine after the failure within 120 % of the stopping distance for secondary brakes (under secondary test conditions) in accordance with Table 3. This dynamic braking capability may be applied automatically and without modulation. An indication should be given to the operator simultaneous with, or before, application of the brake system, if applied automatically.

4.3 **Brake Control Systems**

All brake system controls shall be capable of being applied by an operator from the operating position. Parking brake system controls shall be arranged so that, unless immediately reapplied, they cannot be released once applied. Unintended brake control activation can be avoided through compliance with IS/ISO 10968.

Brake control systems should be designed to avoid any unintended application or release of brakes during normal operation. This does not preclude the automatic application of a brake system due to intended design conditions that also meet the requirements of this National Standard.

The arrangement of the brake system controls should be in accordance with IS/ISO 10968. If not, an instructional sign shall be provided (e.g. using symbols) explaining the control arrangement. Brake pedals and hydrostatic brake system controls are obvious and may not require machine instructions.

A brake control system shall prevent or minimize any uncontrolled braking performance (random brake applications, releases or sporadic braking performance, etc.) during normal operation (start, stop or normal travel operation of the machine, etc.).

Electric, electronic and electronic machine control systems (MCS) for service, secondary or parking brakes shall comply with ISO 15998.

The operator should be able to apply the service or secondary brake while retaining control of the steering device on the machine with at least one hand.

4.4 **Service Brake Systems**

All machines shall meet the service brake performance requirements given in 6, as applicable. The service brake system shall have modulated braking for machines designed for maximum machine speeds greater than 6 km/h. If a travel mode that limit the maximum machine speed to 6 km/h or less can be selected, modulation is not required in this mode.

If other systems receive power from the service brake system, any failure in those systems that reduces service brake system performance shall be considered as a failure in the service brake system.

4.5 Secondary Brake Systems

All machines shall meet the secondary brake performance requirements given in 6, as applicable. The secondary brake system shall have modulated braking for maximum machine speeds greater than 20 km/h.

4.6 Parking Brake Systems

All machines shall meet the parking brake requirements of 6.0, as applicable.

After application of the parking brake, the parking brake system shall not depend on an exhaustible energy source or continuous operator action (e.g. hand or foot effort). The parking brake system may use common components, provided the requirements of 6.4 and Table 2 are met. The parking brake, operating according to the manufacturer's specifications, shall be in accordance with Table 2, regardless of any contraction of the brake parts or leakage of any kind.

Note: Mechanical springs are not considered to be an exhaustible energy source. Back throttling by a hydrostatic drive system does not meet the parking brake requirements, as back throttling requires continuous operator action. The parking brake shall require an action by the operator prior to release of the parking brake control. The parking brake shall not automatically release during normal start up or upon loss of power to the parking brake system or parking brake MCS.

A parking brake may be applied automatically (e.g. spring- or control-system-activated), in which case it shall be applied or remain applied after the machine is in a stopped condition and the engine shut down.

Machines with the capability for a self test of the parking brake shall include design provisions that the machine does not propel unless there is a propel activation by the operator during the self test.

4.7 Hydrostatic Brake Systems

For a machine fitted with a hydrostatic brake system, the service and secondary brakes shall be in accordance with 4.4 and 4.5, respectively.

Typical hydrostatic brake systems have an exhaustible power supply and would not be able to meet the requirements for parking brakes given in 4.6.

Service brake application shall be obtained by one of the following means:

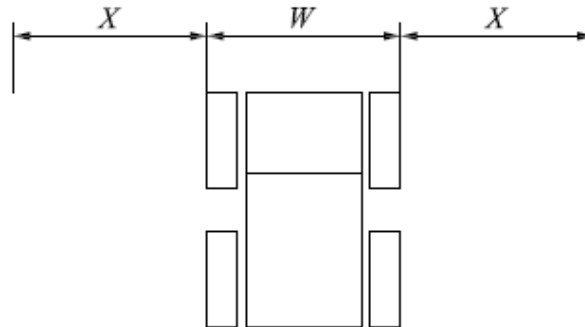
- a) operation of a single control;
- b) moving the foot from the drive pedal to the brake pedal;
- c) at the start of the braking sequence, releasing the drive control(s) and moving to the neutral or reverse propel position using hand or foot.

A brake system additional to the service brake may be used to hold the machine when there is creep movement. A machine may be held stationary, regardless of the grade, using the throttle of the hydrostatic or similar propel drive system (back throttling).

4.8 Systems With Combined Brake And Steer Function

If the braking system has a combined brake and steer function and is used as the secondary brake system, the machine shall maintain controllability during secondary brake stopping distance testing in accordance with 6.

While remaining within the applicable secondary brake stopping distance specified in Table 3, the machine shall not veer outside a boundary lane, X , on either side of the machine, in accordance with Fig. 1.



For $W \leq 2$, X shall be $1,25W$.

For $W > 2$, X shall be 2 m. This is intended to limit the machine veering outside the required public road traffic lane width.

Key

W width of machine over wheels or tracks, m

X width of boundary lane, m

Figure 1 - Boundary conditions for secondary braking

4.9 Performance And Warning Devices For Stored Energy Sources

If stored energy (e.g. reservoirs, accumulators) is used for the service brake system, the stored energy system shall be equipped with a low-energy warning device. The remaining pressure on the third service brake application after the warning signal shall have sufficient energy to provide secondary brake performance in accordance with Table 3, as applicable to the machine.

The warning device shall readily attract the operator's attention by providing a continuous (e.g. steady or pulsating) visible and/or audible warning. Gauges indicating pressure or vacuum do not meet this requirement.

4.10 Braking Systems With Electronic MCS

The electronic control system for a braking system shall meet safe state requirements as determined by the manufacturer using a risk assessment methodology. An electronic MCS complying with ISO 15998 meets such safe state requirements.

If the maximum machine speed is limited by design to less than 6 km/h, these safe state requirements are fulfilled when any of the braking systems can bring the machine to a stop within the brake stopping distances given Table 3.

Braking systems on machines that meet the requirements of this National Standard also achieve the safety concept of ISO 15998 for earth-moving machinery braking systems. A risk assessment of the brake MCS needs to be carried out to determine if functional braking after any single failure involving an electrical and/or electronic MCS meets the braking performance requirements of this National Standard.

Note: ISO 15998 also requires additional testing of the MCS to verify its performance and modes of failure.

- 4.11 All performance requirements given in this National Standard that apply to the service, secondary and parking brakes of a machine also apply to the combination of a machine and trailer(s).

The trailer or trailed unit(s) do not require brakes if the towing machine's brakes meet the service, secondary and parking brake requirements when tested with the combined machine and trailer weight, including the specified trailer payload. The trailer brakes should be evaluated for protection against jack-knifing, if applicable.

4.12 **Machine Instructions And Labels**

- 4.12.1 Operational limitations of the brake control system according to the manufacturer's specifications, if applicable, shall be included in one or the other of the following:

- a) operator's manual;
- b) instructional sign;
- c) machine monitor displays.

Example: Operating precautions for braking system default conditions where the brake or retarding operating characteristics may be automatically changed creating new brake performance characteristics such as automatic shift of the transmission to neutral or potential damage to the parking brake due to propelling through the parking brake.

If brake burnishing is recommended by the brake or machine manufacturer, the brake burnishing procedure shall be included in the operator's or maintenance manual for the machine.

The manufacturer of any machine equipped with a retarder shall provide the following instructions:

- a) in the operator's manual, the maximum machine speed and/or the transmission gear to be engaged when the loaded machine descends specific slopes as specified by the machine manufacturer;
- b) an instruction sign or machine monitor display containing the information specified in a), located in the operator's compartment and readily visible to the operator.

Instructional signs or machine monitor displays showing the retarding ability for slopes shall not exceed the minimum brake holding performance of the service and parking brakes as a percentage holding slope (see 6.4.2).

4.12.2 **Braking System And Periodic Verification Instructions**

Information on brakes may be provided in manuals, labels or other means readily available to the operator while in the operator's station along with precautions about the limitation of this information. If braking system and periodic verification instructions are provided by the machine manufacturer, they should include the following:

- a) daily brake check method instructions:
 - i. a method for verifying the functionality of the service and parking brakes;
 - ii. provisions for verifying the functionality of the secondary brakes if the service and/or parking brake check method does not verify functionality of the secondary brakes;
- b) in-service, periodic or post-maintenance brake verification instructions:
 - i. a method for verifying the functionality of the service and parking brakes including acceptance criteria;
 - ii. a means of verifying the functionality of the secondary brakes.

The instructions are to include a notice to the user that the machine is to be immediately taken out of service until corrected if the service, secondary or parking brakes do not operate within specifications or performance requirements as defined by the daily brake check method, in-service, periodic or post-maintenance brake verification.

Instructions for the periodic verification of braking systems may give test conditions different than those prescribed in this National Standard in order to permit testing or other verification by the user.

4.12.3 **Additional Instructions For Machines Designed To Tow Trailers**

If applicable, information on the machine's allowable trailer towing capacity shall be provided in machine manuals or labels along with any other applicable trailer towing instructions or precautions by the earth-moving machinery manufacturer. The information, if provided, should include the maximum un-braked trailer towing load and the maximum combination of payload and towing load for the earth-moving machinery.

4.13 **Estimating Brake Slope Capability**

The estimated brake slope capability defines the ability of a braking system to stop and hold a machine on a slope. Other factors, such as ground conditions, side-slopes, speed, payload retention or the need to maintain the machine within the earth-moving machinery manufacturer's specifications can limit the machine's operating slope capability to slopes less steep than those where the brakes are actually able to stop and hold the machine. Annex A gives one method for estimating brake slope capability.

5.0 TEST CONDITIONS

5.1 Overall Test Parameters :

The manufacturer's operational precautions shall be observed when carrying out the performance tests. All machine parameters related to braking systems shall be within the machine manufacturer's specifications, including tyre size and pressure, brake adjustment, warning actuation points and braking system pressures, which shall be within the machine manufacturer's specification range. No manual adjustment, such as readjustment to prevent diminished or improved braking performance, shall be made to the braking system during any single performance test.

The instruments used to carry out the measurements shall be of an accuracy and be measured in units in accordance with IS/ISO 9248.

The performance requirements given in Tables 2 and 3 shall be achieved from single-stop and hold testing at the service limit condition for the braking systems. These requirements shall be validated by physical testing or alternative means, including calculation and extrapolation from physical test data. The validation means shall be recorded in the test report in accordance with Clause 7.

See 6.4.3 and 6.6 for alternative braking system performance test methods.

Note: Hydrostatic brake systems typically are not materially affected by brake wear limits.

5.2 General Test Conditions

When the machine transmission provides a selection of gear ratios, the stopping tests shall be conducted with the transmission in the gear corresponding to the test speed specified. The power train may be disengaged prior to completing the stop.

Retarders shall not be used during the service brake performance tests, but may be used during the secondary brake performance test. A hydrostatic or similar propel drive system is not considered to be a retarder.

Machines with operator-selectable, multiple-drive axles shall be brake-performance tested with the non-braked selectable axle(s) disengaged.

Equipment (blades, buckets, dozers, etc.) shall be in the transport position recommended by the manufacturer.

Burnishing or conditioning of brakes before testing is permissible. The burnishing procedures shall be verified by a review of the supplied instructions or in consultation with the machine or brake manufacturer.

Immediately prior to testing, the machine shall be operated until the engine, transmission and machine fluids are at normal operating temperature(s) as specified by the manufacturer.

The machine test speed shall be that speed measured immediately prior to the brake control being applied.

Brake-holding performance tests shall be performed with the power train disengaged and the engine at worst case (e.g. idle or stopped) except for hydrostatic or similar propel drive systems, which shall be engaged to the power train.

When testing a vibratory roller, all tests shall be conducted without vibration.

On machines where hydrostatic braking is used as the service brake, the stopping and holding performance (e.g. back throttling) of the service brake system shall be tested with the engine running.

At minimum, all data required for completion of the test report in accordance with 7 shall be recorded.

5.3 **Test Course**

The test course shall consist of a hard, dry surface with a well-compacted base. Ground moisture may be present to the extent that it does not adversely affect the braking test.

The test course shall not have a slope of more than 3 % at right-angles to the direction of travel.

Slope in the direction of travel shall be no greater than 1 percent, or as specified for the test being carried out. The exceptions to this are rigid-frame dumpers, articulated-frame dumpers and tractor-scrapers of over 32 000 kg machine test weight, for which the test course shall have a downward slope of (9 ± 1) percent in the direction of machine travel. The approach to the test course shall be of sufficient length, smoothness and uniformity of slope to ensure the required machine speed is reached before the brakes are actuated.

5.4 **Machine Test Configuration**

Service brake and secondary brake system stopping distance tests — except for those carried out on hydrostatic brake systems — shall be conducted with cold brakes.

For rigid-frame dumpers, articulated-frame dumpers and tractor-scrapers of over 32 000 kg machine test weight, the transmission shall be engaged in a gear in which the engine does not exceed the maximum engine rotational speed, in revolutions per minute (r/min) or frequency (min^{-1}), specified by the manufacturer.

All brake tests shall be performed using the machine configuration (excluding the service limit requirements given in 5.1) having the most adverse effect on braking and with the machine test weight applicable to the machine type.

Note : As stated in the definition of 3.3, the machine test weight for all dumpers and self-propelled scrapers also include the maximum payload specified by the machine manufacturer.

Record the axle load distribution as applicable and report the results in the test report (see 7.0).

6.0 PERFORMANCE TESTS

6.1 General

The following performance tests shall be performed on all machines within the scope of this National Standard and on all braking systems, as applicable, under the test conditions given in 5.0. The brake holding and control forces shall be measured and reported in accordance with 7.0.

Note: The provisions of 6.3 are not applicable to service brake systems not fitted with stored energy sources (e.g. reservoirs or accumulators).

6.2 Braking System Controls

During the performance tests, the control forces shall not exceed the values given in Table 1.

Table 1
Maximum force levels for braking system controls
during performance tests
(Clause 6.2& 6.3.2)

S. No	Type of control	Max. force to be applied N
1.	Finger grasp (flip levers and switches)	20
2.	Hand grasp	
3.	— upwards	400
4.	— downwards, sideways, fore-aft	300
5.	Foot treadle (ankle control)	350
6.	Foot pedal (leg control)	600

6.3 Stored Energy Sources

6.3.1 Service Brake System Recovery Capacity

Set the engine speed control to obtain the maximum engine rotational speed (r/min) or frequency (min⁻¹). Measure the brake application pressure near the brake. The service brake system's stored energy sources shall have the capacity to deliver at least 70 % of the pressure measured during the first brake application after the service brakes have been fully applied:

- a) for dumpers, self-propelled scrapers and wheeled excavators, 12 times at the rate of four applications per minute;
- b) for all other machines, 20 times at the rate of six applications per minute.

6.3.2 Secondary Brake System Capacity

If the service brake system's stored energy sources are used to apply the secondary brake system, the stored energy source capacity shall meet the following requirement with the energy source disconnected and the machine stationary.

The remaining capacity of the service brake system's stored energy sources shall meet the secondary brake stopping requirements specified in Table 3, as applicable, after five full service brake applications at a rate of ≤ 1 s on and 1 s off. The full service brake applications shall be within the force level requirements of Table 1.

6.3.3 **Test Performance**

The stored energy system for the service brakes shall be tested to and shall achieve the requirements given in 4.9.

The warning device shall activate prior to automatic application of a secondary brake system during the test.

The service brake system's stored energy may be reduced by any suitable means for testing.

6.4 **Holding Performance**

6.4.1 General

All machines shall be tested in both the forward and reverse directions.

For hydrostatic or similar propel drive systems, back throttling may be used to meet the holding performance criteria for service brake systems and, if used, shall be reported in the test report.

6.4.2 Service And Parking Brakes

With the machine's power train as specified in 5.2, the service and parking brake systems shall be capable of holding the machine motionless on a slope in accordance with Table 2.

6.4.3 Brake Holding Performance Tests

Brake holding performance tests may be carried out either

- a) at a test site with the specified slope and slip-resistant surface,
- b) on a tilt platform with a slip-resistant surface, and
- c) by applying a pulling force to the stationary machine with the brake applied and the transmission in neutral on a test course with a slope of no more than 1 % slope in the direction of travel.

Table 2
Service and parking brake holding performance
(Clause 6.3.2 & 6.4.3)

S. No	Brakes	Machine type	Slope %
1.	Service Brake	Rigid-frame dumpers and articulated-frame dumpers having a machine test weight >32 000 kg	20
		Rollers (self-propelled, ride-on vibratory steel-wheeled, static-wheeled and rubber-tyred)	20
		Rigid-frame dumpers, articulated-frame dumpers, semi-trailed dumpers and their combinations with towed trailers having a machine test weight ≤32 000 kg	25
		All other earth-moving machinery, including self-propelled scrapers	25
2.	Parking brake	Rigid-frame dumpers, articulated-frame dumpers, self-propelled scrapers and their combinations with towed trailers	15
		Rollers (self-propelled, ride-on vibratory steel-wheeled, static-wheeled and rubber-tyred)	20
		Semi-trailed dumpers	20
		All other earth-moving machines	20

For alternative c), the pulling force shall be applied horizontally near the ground to achieve a minimum force equivalent to the slopes specified in Table 2. The equivalent force, expressed in newtons, shall be

- a) 1.46 times the machine test weight in kilograms for a 15 % slope,
- b) 1.92 times the machine test weight in kilograms for a 20 % slope, and
- c) 2.38 times the machine test weight in kilograms for a 25 % slope.

Pulling force testing has limitations versus testing on a slope. The machine's holding capacity on a slope can change due to a change in axle weight distribution and all the wheels might not be restrained by the brakes.

Another alternative, d), is to use the machine's propel system to simulate a static grade equivalent and demonstrate holding performance as required in Table 2 by conducting a propel stall test as follows.

Place the machine on a horizontal surface. Energize the propel system to a level that generates the equivalent brake holding requirements given in Table 2 for the applicable machine while simultaneously engaging the brake holding system being tested. Record the propel system output during the test simultaneously with the wheel speed in order to demonstrate that there was no motion during the brake holding test.

Measurement of indirect parameters such as torque/pressure/current may be used with the accompanying calculations (e.g. gear ratio, tyre size) to determine ground force output. The calculations related to measured parameters and brake holding performance shall be included in the brake test report. Holding performance is considered to have been successfully verified when the braking holding system resists movement during propel system application of the tractive force equivalent to the holding requirements of Table 2. Tyre or track movement during the test and before meeting the holding performance requirements of Table 2 shall be considered a failure of brake holding performance.

6.4.4 Durability Test Of Parking Brake When Used As Secondary Brake

If the parking brake system is used as part of the secondary brake system, the parking brake shall meet the holding performance requirements of Table 2 following one dynamic stop from the machine test speed in accordance with 6.5, with the machine test weight appropriate to the machine (see 3.3), and on a level surface with no adjustment of the parking brake. For rollers, the parking brake durability test requires the roller to be subjected to five stops. Locking-up of the tyres is permitted when applying the parking brake.

6.5 Stopping Performance

6.5.1 General

All machines shall be tested to the stopping distances given in Table 3.

Stopping shall be from one of the following machine test speeds, as applicable, within a tolerance of ± 2 km/h:

- a) for rigid-frame dumpers and articulated-frame dumpers of machine test weight $\leq 32\,000$ kg, stopping from either 80 % of the maximum machine speed or 32 km/h, whichever is the greater (see 6.5.5 for those dumpers having a machine test weight $> 32\,000$ kg);
- b) for all other machines stopping from 80% of the maximum machine speed.

Beginning with cold brakes, except for hydrostatic brake systems, the service and secondary brake system stopping distance tests shall be conducted twice - once in each direction of the test course - with the machine travelling forward and with at least 10 min between stops.

The measured stopping distance and machine speed shall be the average of the two tests (one in each direction of the test course) for the service and secondary brake systems, and shall be reported in the test report in accordance with 7.0.

6.5.2 Service Brake Systems

The service brake system shall stop the machine within the stopping distance for the applicable machine type specified in Table 3.

6.5.3 Secondary Brake Systems

The secondary brake system shall stop the machine within the stopping distance for the applicable machine type in accordance with Table 3.

Note: National or other regulations, which could be more stringent, can apply.

If the machine is equipped with a retarder, it may be used prior to and during the test.

The secondary brake system shall be tested to measure the stopping of the machine in the event of any single failure in the service brake system. During this test, modify the service brake system or use equivalent means to simulate the most adverse single failure of the service brake system.

Table 3
Stopping performance
(Clause 6.3.2, 6.5.1, 6.5.2, 6.5.3, 6.5.5)

S. No	Machine Type	Maximum stopping distance s, m	
		Service brake	Secondary Brake
1.	Scrapers, rigid-frame dumpers and articulated-frame dumpers with machine test weight ≤32 000 kg and semi-trailed dumpers of any weight	$\frac{v^2}{44} + 0.1(32 - v)$	$\frac{v^2}{30} + 0.1(32 - v)$
2.	Scrapers, rigid-frame dumpers and articulated-frame dumpers with machine test weight >32 000 kg	$\frac{v^2}{46 - 2.6\alpha}$	$\frac{v^2}{34 - 2.6\alpha}$
3.	Rollers	$\frac{v^2}{150} + 0.2(5 + v)$	$\frac{v^2}{75} + 0.4(5 + v)$
4.	All other earth-moving machines, including towed trailers with payloads & All Construction Equipment Vehicles (as defined under CMVR)	$\frac{v^2}{130} + 0.15(v)$	$0.4(v + 5) + \frac{v^2}{80}$

v initial speed, in km/h.

α test slope as a percentage between 8 % and 10%.

a The term $0,1(32 - v)$ is deleted from the formula for speeds over 32 km/h.

6.5.4 Heat Fade Test For All Machines Except Rigid-Frame And Articulated-Frame Dumpers With Machine Test Weight >32 000 kg

This test shall be performed on all machines except rigid-frame and articulated-frame dumpers of machine test weight >32 000 kg.

Apply and release the service brakes to complete four consecutive stops at, or as near as possible to, the maximum deceleration of the machine without sliding of the tyres or tracks. After each stop, the machine test speed according to 6.5.1 shall be regained as quickly as possible using maximum machine acceleration. A fifth consecutive stop shall be measured which shall not exceed 125 percent of the service brake stopping distance according to Table 3.

6.5.5 Brake Tests For Rigid-Frame And Articulated-Frame Dumpers With Machine Test Weight >32 000 kg

The test shall be performed on rigid-frame dumpers and articulated-frame dumpers of over 32 000 kg machine test weight, on the test course for those machines as specified in 5.3. The transmission shall be engaged in a gear in which the engine does not exceed the maximum engine rotational speed, in revolutions per minute (r/min) or frequency (min⁻¹), specified by the manufacturer.

The service brake system shall be tested by means of five stopping tests at 10 min to 20 min intervals between stops from a machine speed of $\geq (50 \pm 3)$ km/h or the maximum machine speed if less than 50 km/h. The stopping distance shall not exceed that specified in Table 3.

The secondary brake system shall be tested by means of a single stopping test carried out from a machine speed of (25 ± 2) km/h. If the machine is equipped with a retarder, it may be used prior to and during this test. The stopping distance shall not exceed that specified in Table 3.

6.6 **Alternative Testing**

6.6.1 Lab Testing

For braking system functions capable of being reproduced in a lab environment, alternative lab testing may be used to determine service, secondary and parking brake performance. The lab test equipment should be capable of producing the same operating environment as the brake would see in the machine. The test system shall be set up to resist and measure torque to the brake at a torque level capable of driving through the brake holding force and brake retarding force. The lab test system shall be validated by correlation with prior historical machine test data.

For service brake and secondary brake systems, the dynamic load on the brakes shall be duplicated in order to meet the cold brake stopping performance requirements of this National Standard. This data shall be measured and recorded in the test report as specified in 7.0.

For parking brake systems, the maximum brake holding torque should be measured and recorded in the test report as specified in 7.0.

6.6.2 Alternative Secondary Brake Testing For Hydrostatic Or Similar Propel Drive Machines

On machines using secondary brakes other than hydrostatic or similar propel drives, the retarding force of the propel motors shall be removed from the drive train. Alternatively, the motors and gear final drives may be disengaged from the drive train before stopping distance tests are run.

However, if it is difficult to remove the propel drive motor retarding force or disengage the motor and gear final drive from the drive train, the secondary brake system may be tested as follows.

With the machine stationary, including any movement for drive train tolerance, and with the variable motors set to maximum displacement and any mechanical transmissions set in the lowest speed range, apply the secondary brake and engage the propel drive system at the full rated pressure, alternately in forward and reverse. The machine shall remain stationary with creep movement of less than 30 mm/s other than drive train tolerance in the brake/drive train components.

7.0 TEST REPORT

The test report shall contain the following information:

- a) reference to this National Standard;
- b) place and date of measurement;
- c) type of machine;
- d) make of machine;
- e) model and serial number of the machine;
- f) condition of the braking system (new, in operation for 1 000 h, within manufacturer's specifications, etc.);
- g) weight and axle distribution of the machines as tested, in kilograms;
- h) manufacturer's approved maximum machine test weight and maximum axle distribution, in kilograms;
- j) as applicable, drum size, track size, tyre size, ply rating, tread pattern and pressure, in Newton per square metres ;
- k) description of the brakes (e.g. disc or drum, hand or foot control);
- l) type of braking system (e.g. mechanical or hydraulic);
- m) surface of the test course (e.g. asphalt, concrete or soil);

- n) longitudinal and cross slope of the test course;
- o) results of all stopping and holding tests and, if applicable, alternative brake holding calculations or methods;
- p) percentage of the service brake system stored energy after the brake application test calculated from (see 6.3.1):

$$p = \frac{P_2}{P_1} \cdot 100$$

Where

P is the residual pressure as a percentage;

P₁ is the brake application pressure during the first brake application;

P₂ is the lowest brake application pressure measured during subsequent brake applications.

- q) force levels applied to the controls (see 4.3 and 6.2);
- r) machine maximum speed and if applicable, machine test speed, in kilometres per hour;
- s) which tests were carried out using the hydrostatic brake system as one of the braking systems;
- t) parking brake durability test results if applicable (see 6.4.4);
- u) if applicable, a statement of evaluation and supporting information to the effect that maximum brake wear does not materially affect brake performance results;
- v) if applicable for estimating brake slope capability, type of tyres, tyre pressure, measured tyre rolling radius, and fully developed deceleration rate.

ANNEX A
(see 4.13)

BRAKE SLOPE CAPABILITY CALCULATION METHOD

Brake slope capability (BSC) can be calculated using the fully developed deceleration rate, measured with an accelerometer during the brake stopping performance testing. BSC is a measure of the brake's ability to stop and hold the machine, not of the machine's operating slope capability. Other factors need to be considered when determining the machine slope capability on the specific area where the machine is intended to work (see 4.13).

BSC, the percent slope on which the brakes stop a machine, can be calculated using Equation (B.1) and the measured fully developed deceleration rate, DR: $BSC = \frac{[(DR+b) \cdot MR \cdot TR] - SR}{100} \cdot 100 \dots (B.1)$

Where,

DR is the brake deceleration rate, the fully developed deceleration rate, in gs, where g is defined as the deceleration rate in metres per second squared divided by 9.8;

b is the slope on which the machine is evaluated or tested; it is divided by 100 for the equation;

SR is the brake stopping rate, the desired deceleration rate, in gs, on a slope (typical desired deceleration rates are 0.06g ~ 0.08g for primary brakes and 0.03g ~ 0.04g for secondary brakes);

MR is the machine weight ratio, the ratio of the weight of a machine during testing according to this National Standard divided by the machine weight on the work site, the actual machine weight including payloads and any options for or modifications to the machine;

TR is the tyre radius ratio, the ratio of the machine tyre radius during testing according to this National Standard to the machine tyre radius on the work site, thereby allowing for different tyre options.

Equation (B.1) can be applied to both primary and secondary brake systems using the appropriate desired deceleration rate for the particular brake system.

ANNEX- B
(See Introduction)

**COMPOSITION OF AISC PANEL ON PERFORMANCE
REQUIREMENTS AND TEST PROCEDURES OF BRAKING SYSTEMS
FOR WHEELED HIGH SPEED RUBBER TRACKED EARTH MOVING
MACHINES AND ALL TYPES OF
CONSTRUCTION EQUIPMENT VEHICLES***

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* At the time of approval of this Automotive Industry Standard (AIS)

ANNEX- C
(See Introduction)
COMMITTEE COMPOSITION*
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