



Mobile equipment for continuous handling of bulk materials

Part 1: General requirements for the design of steel structures



This Australian Standard® was prepared by Committee ME-043, Bulk Handling Equipment. It was approved on behalf of the Council of Standards Australia on 26 October 2017. This Standard was published on 5 December 2017.

The following are represented on Committee ME-043:

- Australasian Institute of Mining and Metallurgy
 - Australian Industry Group
 - Consult Australia
 - Engineers Australia
 - Minerals Council of Australia
 - Ports Australia
 - SafeWork NSW
 - University of Newcastle
 - University of Sydney
 - University of Western Sydney
 - University of Wollongong
 - Welding Technology Institute of Australia
-

This Standard was issued in draft form for comment as DR AS 4324.1:2017.

Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through the public comment period.

Keeping Standards up-to-date

Australian Standards® are living documents that reflect progress in science, technology and systems. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued.

Standards may also be withdrawn. It is important that readers assure themselves they are using a current Standard, which should include any amendments that may have been published since the Standard was published.

Detailed information about Australian Standards, drafts, amendments and new projects can be found by visiting **www.standards.org.au**

Standards Australia welcomes suggestions for improvements, and encourages readers to notify us immediately of any apparent inaccuracies or ambiguities. Contact us via email at **mail@standards.org.au**, or write to Standards Australia, GPO Box 476, Sydney, NSW 2001.

Australian Standard®

Mobile equipment for continuous handling of bulk materials

Part 1: General requirements for the design of steel structures

Originated as AS 4324.1—1995.
Second edition AS 4324.1:2017.

COPYRIGHT

© Standards Australia Limited

All rights are reserved. No part of this work may be reproduced or copied in any form or by any means, electronic or mechanical, including photocopying, without the written permission of the publisher, unless otherwise permitted under the Copyright Act 1968.

Published by SAI Global Limited under licence from Standards Australia Limited, GPO Box 476, Sydney, NSW 2001, Australia

ISBN 978 1 76035 956 0

PREFACE

This Standard was prepared by the Standards Australia Committee ME-043, Bulk Handling Equipment, to supersede AS 4324.1—1995, *Mobile equipment for continuous handling of bulk materials*, Part 1: *General requirements for the design of steel structures*.

This is the first part of what is planned to be a four-part series dealing with mobile equipment for continuous handling of bulk materials, with Part 2 to deal with mechanisms, Part 3 to deal with electricals and controls and Part 4 to deal with commissioning, operation and asset management. Parts 2, 3 and 4 are intended to be sequentially developed with the necessary revisions to Part 1 incorporated as the other Parts are published.

The development of the first edition of this Standard in 1995 was based largely on the German Code for structural design, BG—1986 Regulations, *Calculations and dimensioning of large machines in open cuts*, and the International Standard ISO 5049-1:1994, *Mobile equipment for continuous handling of bulk materials*, Part 1: *Rules for the design of steel structures*, but included a number of variations to provide coverage of a more comprehensive range of machinery and loading conditions.

The objectives of this revision are to achieve greater clarity in loading requirements and greater simplicity in the prescription of structural design requirements. This led to more emphasis being placed on specifying design requirements that are specific to the machine, and the recognition that effective controls, protective devices systems and load limiting devices play an integral part in the operation and limitation of applied loading to structures of this type. Duplication of requirements for structural materials and design rules has been avoided where possible by direct reference to established Australian or International Standards. Following structural reliability analyses, the ultimate limit state approach has been modified to accommodate the load factor (per primary load case) and resistance design/partial safety factor approach. The preferred method of structural design is a subject for agreement between the purchaser and the supplier or prescription via the technical specification.

Committee ME-043 recognizes that some load cases are based on general industry knowledge and other international precedents. For future revisions of specific values in certain clauses, co-ordinated field-testing or a significant level of research across a wide variety of machines and materials is likely to be required.

Explanatory notes on the drafting of this Standard are given in Appendix A.

Statements expressed in mandatory terms in notes to tables are deemed to be requirements of this Standard.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE.....	5
1.2 APPLICATION	5
1.3 INNOVATION	5
1.4 NORMATIVE REFERENCE	6
1.5 NOTATION.....	6
1.6 DEFINITIONS.....	6
1.7 BASIS OF DESIGN.....	9
1.8 TECHNICAL SPECIFICATION	9
1.9 BASIC DIGGING PARAMETERS FOR BUCKET WHEEL MACHINES	10
1.10 CORROSION PROTECTION AND MACHINE CONDITION	10
1.11 RELATIONSHIP TO PARTS 2, 3 AND 4.....	10
SECTION 2 MATERIALS	
2.1 GENERAL.....	11
2.2 LIMITATION ON USE OF BRITTLE MATERIALS	11
2.3 ALTERNATIVE MATERIALS AND FABRICATION STANDARDS	12
SECTION 3 LOAD ASSUMPTIONS	
3.1 GENERAL.....	13
3.2 LOAD GROUPS.....	14
3.3 MAIN LOADS	14
3.4 ADDITIONAL LOADS.....	20
3.5 SPECIAL LOADS	28
3.6 FATIGUE LOADS	38
3.7 LOAD CASES	40
SECTION 4 OVERTURNING AND DRIFTING	
4.1 STABILITY AGAINST OVERTURNING.....	47
4.2 RESISTANCE AGAINST DRIFTING	47
SECTION 5 DESIGN OF STRUCTURES	
5.1 LOADS AND LOAD CASES.....	48
5.2 FATIGUE DESIGN LIFE.....	48
5.3 STEELS HAVING A HIGH YIELD TO ULTIMATE TENSILE STRENGTH RATIO.....	48
5.4 DESIGN METHODS TO ALLOW FOR STRENGTH AND SERVICEABILITY	48
5.5 FATIGUE STRENGTH OF STRUCTURAL COMPONENTS AND JOINTS	53
5.6 BOLTING AND RIVETING	53
5.7 STEEL WIRE ROPES, STRAPS AND STAYS IN TENSION, AND HYDRAULIC CYLINDERS	54
5.8 SLEWING RACE SAFETY HOOKS TO PREVENT SEPARATION AT THE SLEW RACE	56
5.9 MASS AND CENTRE OF GRAVITY OF MACHINE	57
5.10 LIFTING BEAMS AND LUGS.....	58
SECTION 6 ANCILLARY STRUCTURES	
6.1 LOADS AND LOAD CASES.....	59
6.2 SUPPORTING STRUCTURES AND RAILS	59

	<i>Page</i>
6.3 TIE-DOWN AND RESTRAINTS	59
6.4 MAJOR MAINTENANCE WORKS	59
APPENDICES	
A EXPLANATORY NOTES.....	60
B INFORMATION TO BE SUPPLIED WITHIN THE TECHNICAL SPECIFICATION	88
C NORMATIVE REFERENCES	96
D QUANTITY SYMBOLS	97
E TYPICAL TYPES OF MOBILE CONTINUOUS BULK HANDLING EQUIPMENT	101
F BASIC DIGGING PARAMETERS FOR BUCKET WHEEL MACHINES	109
G LOOSE MEASURE VOLUMETRIC CAPACITY OF DIGGING ELEMENTS	116
H TYPICAL BULK DENSITIES OF HANDLED MATERIAL.....	119
I LIVE LOADS ON CONVEYORS.....	120
J PLATE BUCKLING.....	129
K FUNCTIONS FOR A DESIGN AUDIT ENGINEER DURING AUDIT OF A STRUCTURE	130
L ULTIMATE LIMIT STATE DESIGN.....	133
BIBLIOGRAPHY	135

STANDARDS AUSTRALIA

Australian Standard

Mobile equipment for continuous handling of bulk materials

Part 1: General requirements for the design of steel structures

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies general requirements, design loads and specific requirements for the design of structures of mobile equipment for continuous handling of bulk materials, including appliances and machines that are intended to carry out similar functions (e.g. excavators, stackers, reclaimers, ship loaders, ship unloaders, belt wagons, sizing rigs and spreaders).

This Standard may, in some instances, be applied to the design of certain stationary plants.

It is not intended that this Standard be applied to the following equipment, but may be applied to parts of such equipment:

- (a) Feeders, fixed conveyors, bucket elevators and storage structures with through flow of materials.
- (b) Intermittent operation bulk handling equipment (i.e. equipment that handles or excavates material on a cyclic basis, such as draglines and power shovels).

NOTE: Explanatory notes on the drafting of this Standard are given in Appendix A.

1.2 APPLICATION

It is not intended that this Standard be applied to equipment that was designed before the publication of this Standard (i.e. AS 4324.1:2017). This Standard should be used as part of a risk assessment process for assessment of existing machine structures for continued use, upgrade or modification.

The application, omission, or variation within the requirements of specific clauses of this Standard shall be in a documented technical specification (see Clauses 1.6.42 and 1.8), subject to the minimum requirements indicated in this Standard.

Specified omission or reduction of the requirements of this Standard shall only occur following the assessment of the risk of that load case occurring, with consideration of the effectiveness of the controls and protections that will be implemented to prevent the situation occurring and the consequences should the event occur. This risk assessment shall be documented with justifications provided as technically and practicably valid. Refer to AS/NZS ISO 31000.

Appendix B prescribes information that is required to be established within a technical specification for supply of a machine.

1.3 INNOVATION

This Standard shall not be interpreted so as to prevent the use of new or unusual materials or methods not specifically referred to herein, provided that the requirements of Section 5 are conformed to.

1.4 NORMATIVE REFERENCE

The normative documents referred to in this Standard are listed in Appendix C.

NOTE: Documents referenced for informative purposes are listed in the Bibliography.

1.5 NOTATION

The quantity symbols used in this Standard are listed in Appendix D. Where possible, the quantity symbols used are generally similar to those used in AS 4100 and AS 3990. Due to inconsistencies between the quantity symbols used in these Standards, equivalence is not possible.

1.6 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

1.6.1 Alternative Standard

An alternative (Standard) to that specified by this Standard or the Standards referenced by this Standard that are prescribed in the technical specification (see Appendix B).

1.6.2 Appropriate recognized Standard

A Standard that is recognized by the global industry and is conventionally used for the application so defined.

1.6.3 Approved

Approved, in writing.

1.6.4 Balance

Balance is the state of the machine masses, both dead load and operating loads in relation to the load's locations generally with reference to a pivoting point. This is generally assessed by review of luff system forces and slew bearing moments.

1.6.5 Bulk density

The weight of a unit volume of loose material, including moisture.

1.6.6 Constructor or erector

The party that conducts the site construction or erection of the machine. This party may not necessarily be the supplier (1.6.41) or the designer (1.6.9).

1.6.7 Crowding board

A board placed near the edge of a conveyor belt either to increase the carrying capacity or to prevent spillage. Crowding boards are sometimes referred to as skirt plates. Other devices (e.g. including closely spaced wire ropes, pipes or tube sections) that achieve the same effect are treated as though they are crowding boards.

1.6.8 Design audit engineer

A suitably qualified engineer who undertakes independent checks of the design (also known as a 'proof engineer' or a 'design verifier').

1.6.9 Designer/design engineer

The designer of the machine, including preparation of the necessary design calculations, drawings and fabrication/construction specifications.

1.6.10 Effective torque limited coupling

A torque limiting coupling that, upon activation, in any foreseeable operation scenario, ceases operation or reduces the transmitted torque and power across the coupling.

1.6.11 Excavator

A machine that digs in virgin ground, and sometimes in blasted material.

1.6.12 Fail-to-safety

A feature of a component mechanism or system that obviates any hazard to personnel and equipment in the event of power failure, malfunction of any component mechanism or system, or a device or design that in the event of failure reverts to a safe condition to prevent harm to personnel or further damage to equipment, or the like.

1.6.13 Fatigue

Damage caused by repeated fluctuations of stress leading to gradual cracking of a structural element.

1.6.14 Fatigue capacity

See 'fatigue strength' (1.6.15).

1.6.15 Fatigue strength

The stress range defined in AS 4100—1998, Clause 11.6 for each detail category varying with the number of cycles (see AS 4100—1998, Figures 11.6.1 and 11.6.2).

1.6.16 Full load torque

The output torque generated at 100% of the rated power of the relevant drive.

1.6.17 Harrowing or raking motion

A typical action of a device to rake stockpile material to a bucket wheel or a scraper chain.

1.6.18 Limit state

Any limiting condition beyond which the structure ceases to fulfil its intended function. Ultimate limit state may also be used.

1.6.19 Load limiting device (or protective device)

A device or control that prevents a specific load or a combination of loads from exceeding a defined value.

1.6.20 Material in transit

Material that is in motion on a conveyor belt or within a reclaiming device or chute.

1.6.21 Minimum requirement

Indicates that requirements for specific load cases are mandatory to conform to this Standard. Clauses that contain minimum requirements are indicated by an introductory statement.

1.6.22 Mobile equipment for continuous handling of bulk materials

Equipment such as those illustrated in Appendix E as follows:

- (a) Bucket wheel excavators and bucket chain excavators in Figure E1.
- (b) Reclaimers in Figure E2.
- (c) Stacker-reclaimers in Figure E3.
- (d) Tripper-stackers in Figure E4.
- (e) Scraper-reclaimers in Figure E5.
- (f) Stackers in Figure E6.
- (g) Belt wagons in Figure E7.
- (h) Ship continuous loaders in Figure E8.

- (i) Ship unloaders in Figure E9.
- (j) Conveyor drive units in Figure E10.

These machine types that are diagrammatically illustrated are typical and are not intended to prevent the use of other types. Mobile equipment for continuous handling of bulk materials are referred to in this Standard also as 'equipment', 'machine' and 'plant'.

1.6.23 Normal operation

Operation of the machine that does *not* cause any loads to exceed—

- (a) their main load/Type I limiting value(s);
- (b) the initiation of any controls or limits; or
- (c) the loads in additional (excepting wind, W) or special load types being experienced.

1.6.24 Operating and maintenance manual(s)

The instructions and information to enable safe operation and maintenance of the machine.

1.6.25 Owner

A ultimate possessor/owner of the equipment.

1.6.26 Purchaser

A party (e.g. person, company) who ordinarily manages procurement actions for a machine that is to be supplied. The purchaser may be the owner or may be a party responsible to the owner.

1.6.27 Reclaimer

A machine that recovers material from a stockpile.

1.6.28 Regulatory authority

An authority having regulatory powers to control the design, manufacture, erection and operation of continuous operation bulk handling equipment within the relevant state or territory of Australia.

1.6.29 Safety device

A device, that through its operation, is considered a load limiting or protective device.

1.6.30 Shall

Indicates that a statement is mandatory.

1.6.31 Should

Indicates a recommendation.

1.6.32 Spreader

A machine for delivering material onto a stockpile or waste dump, similar to a stacker.

1.6.33 Stacker

A machine for delivering material onto a stockpile.

1.6.34 Stockpile

A quantity of the material in storage, either in the open (i.e. exposed to weather) or covered (i.e. located in a shed or building).

1.6.35 Storm park position

A location where equipment can be secured against winds exceeding safe operating limits.

1.6.36 Strap/Stay

Components in suspension/tension supporting booms and counterweight booms, generally comprising a steel plate or rod member/component, which may be segmented. The design actions experienced by straps/stays are primarily tensile, with minimal bending stresses.

1.6.37 Strength

The capacity of a member, component or assembly to resist failure, except where the context dictates otherwise, by mechanisms such as yielding, cleavage or buckling.

1.6.38 Stress range

The algebraic difference between two extremes of stress of a particular stress cycle.

1.6.39 Stress spectrum (design)

Histogram of stress cycles produced for the nominal loading events expected during the design life, relevant to the design fatigue assessment.

1.6.40 Structural calculations

The compilation of documented evidence that illustrates the loading used, the methods of analysis undertaken, the results obtained from the analyses and design verifications (to demonstrate conformance) of the design of the structure.

1.6.41 Supplier

The party (e.g. person, company) who supplies the machine design. The supplier may or may not be the constructor or erector.

1.6.42 Technical specification

A document that details the application, omission, or variation of requirements within specific clauses of this Standard. See Clause 1.8.

1.6.43 Tripper

A machine that is typically coupled to a stacker, so as to elevate the material and deliver it into the receiving chute of a stacker, from which it will be conveyed along a stacker boom and deposited on a stockpile.

1.7 BASIS OF DESIGN

The design of equipment to this Standard depends on the following principles:

- (a) Due care and skill, experience, supervision and quality control is provided during the design and execution of the work (during design, fabrication, construction, assembly, and commissioning).
- (b) The construction materials and products used are in accordance with the relevant Standards and are consistent with the design requirements.
- (c) The structure will be adequately maintained.
- (d) The structure will be used in accordance with the design requirements.

1.8 TECHNICAL SPECIFICATION

A technical specification for equipment to be procured under this Standard shall be prepared.

Information that shall be supplied with a technical specification is given in Appendix B.

1.9 BASIC DIGGING PARAMETERS FOR BUCKET WHEEL MACHINES

For bucket wheel machines, forces determined in accordance with this Standard are based on the actual torque/power ratings of drive equipment (i.e. motors and couplings). These ratings shall be determined for the equipment so that it is possible to dig the material at the specified rates.

However, this Standard does not provide performance characteristics for materials handling rates.

NOTE: In Appendices F and G, guidance is given on how to confirm that the equipment design can reasonably meet the long-term output goals when the geometry of the machine and the nature of the excavating process are taken into account. This may be found particularly useful for determining the numbers of slew and travel cycles for the overall design life.

1.10 CORROSION PROTECTION AND MACHINE CONDITION

Steel structures shall be adequately protected against corrosion in the working environment. Corrosion protection requirements are specified in AS 4100.

Corrosion allowances in defined regions of structure should be as prescribed within the technical specification.

1.11 RELATIONSHIP TO PARTS 2, 3 AND 4

1.11.1 General

At the time of publication of this Standard, there was no defined timeline to produce and publish AS 4324, Parts 2, 3 and 4 (referred to in the Preface).

Until publication of these parts, the following generic recommendations and requirements apply.

1.11.2 Part 2—Mechanisms

In the absence of AS 4324.2, Standards for the design of mechanisms shall be as defined in the technical specification, as indicated in Appendix B.

With regards to loading conditions that are reliant upon a mechanism, electrical or controls protection being in place, the required setting of the device/control should be clearly defined in the structural calculations and the operating and maintenance manuals.

It should be noted that the design criteria for mechanism design may vary from the design criteria for structures.

1.11.3 Part 3—Electrical and controls (including computer/programmable controls)

In the absence of AS 4324.3, Standards for the design of electrical and controls shall be as defined in the technical specification as indicated in Appendix B.

With regards to loading conditions that are reliant upon an electrical or controls protection being in place, the required setting of the device/control should be clearly defined in the structural calculations and relevant manuals.

1.11.4 Part 4—Commissioning, operation and asset management

In the absence of AS 4324.4, the commissioning, operation and asset management requirements affecting the design of the equipment should be carried out to Standards as defined by the technical specification, as indicated in Appendix B. Where no Standards are defined, the Standards used for, or referred to by, the design shall be used.

Commissioning requirements shall be as defined by the technical specification, as indicated in Appendix B.

NOTE: Operation and asset management (post-supply) should be carried out in accordance with the operating and maintenance manuals, as a minimum.

SECTION 2 MATERIALS

2.1 GENERAL

Unless otherwise nominated in the technical specification, structural materials, material properties and testing requirements for structural materials shall conform to any relevant Australian Standards, or an agreed alternative Standard (see Clause 2.3.5). The requirements of AS 4100 in respect of brittle fracture shall apply to all structural steel. Where structural materials cannot be shown to conform, e.g. by certification to an appropriate recognized Standard, their mechanical properties, chemical composition and, where applicable, weldability shall be established by testing.

Where a failure of a structural element could influence the safety of the machine as a whole or the safety of personnel, or where reliability is important, the properties of materials having an ultimate tensile strength in excess of 550 MPa or an actual yield strength in excess of 450 MPa shall be established by tests conducted on samples from the material actually to be used in manufacturing the element. These tests shall conform to relevant Australian Standards and shall include tests that are able to establish the following properties:

- (a) Charpy impact energy, at a temperature that is the lesser of $(T_{\text{design}} - 15)^{\circ}\text{C}$ and 0°C .
- (b) Percentage of ductile fracture area on Charpy test specimens, at a temperature that is the lesser of $(T_{\text{design}} - 15)^{\circ}\text{C}$ and 0°C .
- (c) Ultimate tensile strength at 20°C .
- (d) Yield strength at 20°C .
- (e) Percentage elongation at 20°C .
- (f) Percentage reduction of area at 20°C .

T_{design} is the lowest one day mean ambient temperature (LODMAT) determined for the area where the equipment will operate, based on appropriate Australian Bureau of Meteorology records or LODMAT isotherms in AS 4100.

Used test specimens shall be kept for the duration of the construction and commissioning periods, or such longer period as may be nominated in the technical specification, and shall be traceable to their respective components by means of a marking system.

Materials that fully conform to Standards referenced in AS 4100—1998, Clauses 2.1 and 2.2 do not require additional testing as listed in Items (a) to (f) above.

2.2 LIMITATION ON USE OF BRITTLE MATERIALS

2.2.1 General

The technical specification shall define the regions of structure where this Clause (2.2) shall apply.

2.2.2 Critical applications

Where a brittle fracture could cause a failure and influence the safety of the machine as a whole or the safety of personnel, brittle materials shall not be used. For such critical applications, materials shall be deemed to be brittle if the following properties are not achieved, with the orientation of test specimens selected so as to result in the least favourable test results:

- (a) The average of three Charpy impact test specimens, at a temperature that is the lesser of $(T_{\text{design}} - 15)^{\circ}\text{C}$ and 0°C , shall be greater than $1.4 \times (\text{ultimate tensile strength, in megapascals})^{0.5}$, in joules.
- (b) The minimum individual value of the three Charpy impact test specimens, at a temperature that is the lesser of $(T_{\text{design}} - 15)^{\circ}\text{C}$ and 0°C , shall be greater than $(\text{ultimate tensile strength, in megapascals})^{0.5}$, in joules.
- (c) The minimum ductile fracture area on any Charpy test specimen, at a temperature that is the lesser of $(T_{\text{design}} - 15)^{\circ}\text{C}$ and 0°C , shall be more than 75%.
- (d) The minimum elongation at 20°C is more than 10% and the minimum reduction in area is greater than 40%.

2.2.3 Non-critical applications

Where reliability is important with non-critical applications of brittle materials (as defined in Clause 2.2.2), the values in Items (c) and (d) of Clause 2.2.2 shall apply and 0.7 times the values in Items (a) and (b) of Clause 2.2.2 shall apply.

2.3 ALTERNATIVE MATERIALS AND FABRICATION STANDARDS

2.3.1 General

The use of alternative materials and fabrication Standards shall be as defined in the technical specification. See Clause 2.3.5.

NOTE: This should be the subject of agreement by the owner/purchaser and the supplier.

2.3.2 Basis of design

The design shall reflect the structural size, material (including strength grade and ductility sub-grade where appropriate) and other necessary properties as are required by the relevant structural design Standard, chosen in accordance with Section 5. Where possible, the designer should take into consideration the likely materials of fabrication and construction.

2.3.3 Material substitution

Where the use of a material specified in the design is not possible, a process of material substitution shall be carried out to ensure material with at least the properties of the design material is supplied for the fabrication.

Substitution shall consider all material characteristics pertinent to the use of that material including but not necessarily limited to mechanical properties, chemical composition and, where applicable, weldability, which may require establishment by testing. Statistical testing methods shall be used. The testing and permission to use substitute materials shall be documented in the technical specification, as indicated in Appendix B.

2.3.4 Fabrication practices and Standards

Use of fabrication practices and Standards other than Australian Standards may be permitted by the technical specification where structural performance requirements of this Standard are achieved as a minimum.

2.3.5 Demonstration of adequacy of alternative Standards used

Where Standards other than Australian Standards are to be used, a documented assessment and justification shall be prepared and included in the technical specification.

SECTION 3 LOAD ASSUMPTIONS

3.1 GENERAL

3.1.1 Technical specification and design loading

The application of the requirements of specific clauses of this Section shall be via a documented technical specification in accordance with Appendix B.

The technical specification shall define whether a load case is required to be considered, is permitted to be omitted, and/or where deviations to the values specified by this Standard are to be incorporated in the design.

Specified omission or reduction of requirements within this Standard shall only occur following formal assessment of the risk, of that load case occurring, with consideration and documentation of the effectiveness of the controls, protections and load limiting devices that will be implemented to prevent the load occurring. The risk assessment should follow the principles and guidance set out in AS/NZS ISO 31000.

3.1.2 Loads and load limiting devices

Many loads applied to this type of equipment can be controlled and excess loading prevented by the use of controls, electrical protective devices and mechanical protective devices.

Where the limit of loading is reliant upon a protective device or function, their use shall be as defined in the technical specification in accordance with Appendix B. The provided protection and its setting shall be defined in the structural calculations and be included in the operating and maintenance manual. The protective device should be able to be tested to the setting so defined.

Where there is the possibility of significant damage to the machine due to an upper bound load being exceeded, consideration should be given to providing protection prior to the upper bound load being reached.

An appropriate and recognized Standard for the design and installation of controls and devices to an adequate level of integrity and reliability should be used. The design of protective devices and systems should incorporate progressive limits [e.g. operational (primary), secondary (alarm), final cutout].

3.1.3 Bulk density (γ)

Calculations of the strength and the stability of a machine shall be based on the maximum specified bulk density of the material to be handled, γ . Calculations of volumetric capacity shall be based on the minimum specified bulk density of the material to be handled. The specified bulk density for encrustation shall be used for encrustation loads.

Bulk density values for design shall be nominated in the technical specification in accordance with Appendix B. These values should include—

- (a) a bulk density value to be used for 'structural' load;
- (b) a bulk density value to be used for 'encrustation' load calculations, which may be the same or higher than the 'structural' bulk density;
- (c) a bulk density value to be used for 'power' calculations;
- (d) a bulk density value to be used for 'volumetric' calculations; and
- (e) a bulk density value to be used for 'fatigue' calculations.

3.2 LOAD GROUPS

The equipment shall be designed to withstand all relevant loads, including the following loads, which have been grouped according to their frequency of occurrence:

- (a) Main loads, that are listed in Tables 3.7(A) and 3.7(B) and described in Clause 3.3.
- (b) Additional loads, that are listed in Tables 3.7(A) and 3.7(B) and described in Clause 3.4.
- (c) Special loads, that are listed in Tables 3.7(A) and 3.7(B) and described in Clause 3.5.

Where it is intended to use the equipment to handle different materials at different speeds, in varying machine configurations or under other varying design parameters, the design for strength and stability shall allow for the most adverse combinations of loadings and configurations.

3.3 MAIN LOADS

3.3.1 Grouping

Main loads is a grouping that comprises permanent (i.e. steady) loads and variable loads that occur whenever the equipment is used under normal operating conditions.

3.3.2 Dead loads (*E*)

This load case is a minimum requirement of this Standard for all machine types. The method of design dead load estimation and assessment shall be as defined in the technical specification in accordance with Appendix B.

Dead loads shall comprise the sum of the masses (that are always present in operation) of the fixed and moving parts of the machine as built, clean and ready for service, and in the finished condition, including ballast, liquid fillings, protective coatings, and auxiliary and spare components permanently installed on the machine.

3.3.3 Encrustation (*V*)

This load case is a minimum requirement of this Standard for all machine types.

The following requirements apply to loads due to encrustation, such as accumulation of spillage or material that is sticking to digging devices:

- (a) On conveying devices, allowances shall be not less than 10% of the theoretical design material loading uniformly distributed along the conveyor, as calculated according to Clause 3.3.5 for live loads carried on a conveyor.
- (b) For bucket wheels, allowances shall be not less than the weight of a 50 mm thick layer of material acting at the centre of the bucket wheel, that shall be considered to be a solid disc up to the cutting circle and at 'Encrustation' density. For sticky materials, the thickness of the layer shall be increased to not less than 100 mm.
- (c) For bucket chains, allowances shall be not less than 10% of the theoretical live load uniformly distributed over the total length of the ladder, as calculated according to Clause 3.3.5 for mass of material in digging devices.
- (d) For scrapers, allowances shall be not less than 10% of the theoretical live load uniformly distributed over the total length of the scraper supporting structure, as calculated according to Clause 3.3.5 for mass of material in digging devices.
- (e) At specific locations where additional spillage occurs (e.g. near hoppers, near loading points, along walkways, in washdown launders, around bucket-wheel areas, chutes, etc.), consideration shall be given to increasing the encrustation load to account for the actual degree of buildup possible, unless the structural integrity and stability of the machine is protected by installation of appropriate load limiting devices.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

- (f) Where spillage and material build-up or abnormal encrustation could occur during a loading event attributable to a special load (e.g. a wear hole in a transfer chute), the portion of encrustation above that defined as 'normal' encrustation shall be considered in the special load combination.
- (g) Encrustation that may occur within chutes shall be taken into account.

Special allowances for encrustation shall be as defined in the technical specification in accordance with Appendix B.

NOTE: For 'sticky' material, or structures with large flat areas or chutes, consideration should be given to increasing these allowances.

3.3.4 Inclination (*N*)

This load case is a minimum requirement of this Standard for all machine types.

Design loads due to inclination of the working level shall be based on the maximum inclination for normal operation (i.e. excluding ramps or while in transit), as nominated in the technical specification in accordance with Appendix B.

3.3.5 Live loads (*F*)

This load case is a minimum requirement of this Standard for all machine types.

Live loads are due to the weight of handled material and caused by the material flow.

Live loads carried on a conveyor shall be determined in accordance with the principles contained in Appendix I and as defined in the technical specification in accordance with Appendix B. For structural design purposes, live loads on conveyors shall be based on a minimum surcharge angle for the carried material of 20°.

For bucket chains and scrapers, the mass of material in digging devices shall be considered and shall be based on not less than the following:

- (a) For bucket chains—
 - (i) the lower one-third of all the buckets in contact with the face being one-third full;
 - (ii) the middle one-third of all the buckets in contact with the face being two-thirds full; and
 - (iii) the top one-third of buckets up to the tumbler being full.
- (b) For scrapers (all types)—the scraper flights on the material carrying length of the scraper chain being two-thirds full.

Where applicable, live loads arising from material in transit through chutes and spouts shall be considered (either globally, locally or both), including impact, inertia and change of velocity.

The consideration of dynamic resonance/excitation due to material flow may also be required.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

3.3.6 Basis for normal digging and lateral resistance determination

This load case is a minimum requirement of this Standard for reclaiming and excavating machines.

Calculations of forces due to normal digging (see Clause 3.3.7) and to normal lateral movement (see Clause 3.3.8) of the digging element shall be based on concentrated loads acting at—

- (a) for bucket wheels, the most unfavourable point of the cutting circle for each load case being considered;
- (b) for bucket chains, a point one-third along the ladder length in contact with the face, measured from the outboard end of the ladder; and
- (c) for scrapers, the most unfavourable point for each load case.

Drives for bucket wheels, bucket chains and lateral motions of bucket wheels and bucket chains (i.e. slew and travel) shall each be provided with two or more levels of protection to prevent overloading. The nature of such levels of protection should be as nominated in the technical specification in accordance with Appendix B; provided that at least two levels of protection are achieved by independent means. At least two levels of protection shall be provided to control the loads due to the operation of the digging and slewing devices.

It is intended that the protection/load limiting device that is set to the lowest value will influence the calculation of U and S , as further described by Clauses 3.3.7 and 3.3.8. The load limiting/protection device that is set to the highest value, or the value of the maximum load expected to be experienced shall influence the calculation of abnormal digging resistances UU and SS , as further described by Clauses 3.4.4 and 3.4.5.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual. The first level of protection may restrict or control loading, whereas the second level shall cease operation to prevent further loading being experienced.

3.3.7 Normal digging resistance (U)

This load case is a minimum requirement of this Standard for reclaiming and excavating machines.

The calculated force due to normal digging of the digging element, as determined in accordance with Clause 3.3.6, shall be determined as a force tangential to the wheel cutting circle or parallel to the bucket or scraper chain, and shall be based on the rating of the drive motor, while taking into account the cut-off torque of any torque limiting coupling, the setting of any load limiting/protection device and the efficiency of the drive gear reducer and the speed at the bucket lips.

The minimum design torque/digging force shall be based on 1.1 times the lesser of—

- (a) the load limiting/protection device setting; and
- (b) the nominal coupling limit; and
- (c) the hydraulic drive limit;

subject to a minimum of 1.1 times the motor rated torque for reclaimers and a minimum of 1.3 times the motor rated torque for excavators.

Where a load limiting/protection device is present but does not cease the operation, or reduce the transmitted torque or force, of the digging element, this device shall not be considered for calculation of the digging force U .

For bucket wheels, the full drive torque shall be used, without deducting contributions associated with lifting material in the buckets.

For bucket chains, the torque needed to lift material in the buckets (see Clause 3.3.5) shall be deducted for the purpose of calculating the digging force.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

3.3.8 Normal lateral digging resistance (S)

3.3.8.1 General

This load case is a minimum requirement of this Standard for reclaiming and excavating machines that experience lateral loading due to digging.

3.3.8.2 Bucket wheel machines

Unless otherwise specified, the calculated force due to lateral movement of the digging element, as determined in accordance with Clause 3.3.6, shall be—

- (a) where a torque limiting coupling or clutch is used as the first level of protection of lateral digging force, not less than the greatest of the following:
 - (i) 0.3 times the normal digging force (U) calculated as if all of the drive power was available for digging (i.e. without deducting the power needed to lift the material in the buckets).
 - (ii) the force derived from 1.1 times the lesser of the cut-off torque of the torque-limiting coupling or clutch and the lowest overload protection device limit on the relevant lateral drive (e.g. travel or slew); minus the frictional losses in the slewing or travel drive system between coupling and digging element.
- (b) where a torque limiting coupling or clutch is not fitted to the slew or travel drive, a lateral digging force not less than the greatest of the following:
 - (i) 0.3 times the normal digging force (U) calculated as if all of the drive power was available for digging (i.e. without deducting the power needed to lift the material in the buckets).
 - (ii) 1.3 times the force derived from the rated torque of the relevant lateral drive (e.g. travel or slew); minus the frictional losses in the relevant drive system (e.g. travel or slew) between drive motor and digging element.

Fatigue loading shall use a value of 0.3 times the normal digging force (U) unless a greater value is specified in the technical specification in accordance with Appendix B. Load reversal shall be considered where applicable.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

3.3.8.3 Other reclaiming machines/Fixed boom type machine

The same principles and requirements as defined in Clause 3.3.8.2 shall be applied to other reclaiming machines, unless varied by the technical specification in accordance with Appendix B.

3.3.9 Permanent dynamic effects (*D*)

This load case is a minimum requirement of this Standard for all machine types.

Permanent dynamic load effects, such as inertia forces due to acceleration and deceleration of components and overall machine movements, shall be allowed for as main loads. In general, dynamic effects from impact of falling material at the transfer points, rotating mechanical parts, vibrating feeders, etc. need only be considered as acting locally. However, variations in digging resistance at bucket passing frequency need to be considered as a particular fatigue loading for the design of buckets, bucket wheels and bucket wheel shafts and for assessing possible resonant excitation of the overall machine structure.

Permanent dynamic loads shall be taken as the greater of the following:

- (a) Loads calculated from linear and angular acceleration or deceleration of the structure, resulting from operation (including braking) of the main drives (e.g. travel, slew, luff, steering).
- (b) Vertical and horizontal loads as calculated by applying the dynamic effects factors given in Table 3.3.9 to the relevant structural sub-assemblies.

Permanent dynamic effects are to be applied to the relevant sub-assembly dead weights and live loads. Permanent dynamic effects should be applied to E, V and F loads as a minimum.

On equipment whose motion varies in linear acceleration/deceleration/velocity (i.e. due to slewing) along its length, dynamic effects may be considered as a triangular distribution, with the values in Table 3.3.9 considered at the extremity of the equipment.

For assessment of fatigue [load case F/I, see Table 3.7(A) or Table 3.7(B)], stress cycles determined due to dynamic effects shall be included at a frequency that takes into account operational circumstances and the possibility of a number of oscillations at a relevant structural natural frequency, each time a motion is initiated or stopped. In general, the effects of inclination as defined in Clause 3.3.4 will need to be accounted for separately within any Miner's Rule calculation at a lesser frequency than for permanent dynamic effects.

For strength load combinations, the simultaneous occurrence of dynamic effects and the effects of inclination as prescribed by Clause 3.3.4, shall be considered.

The dynamic factors for cabins for operators are only required to be applied to the cabin itself and the localized structural design of its immediate supporting structure back to the supporting main sub-assembly. These factors need not be applied for the global structural assessment.

Where load-limiting devices are used to control this loads, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual. This includes maximum speeds, 'ramp times' and associated accelerations and decelerations for normal operating motions.

For the purposes of stability and wheel load calculations, the design shall use one of the following methods:

- (i) Permanent dynamic effects shall be considered as loads calculated from linear and/or angular acceleration or deceleration of the structure, resulting from operation (including braking) of the main drives (travel, slew, luff or other as appropriate) multiplied by a factor of 1.2 (to account for dynamic amplification effects).
- (ii) By addition of the applicable dynamics effects factor from Table 3.3.9 to the (overall) overturning moment.

TABLE 3.3.9
DYNAMIC EFFECTS FACTORS

Machine	Machine part	Dynamic effects factors		
		Vertical	Horizontal	
			Transverse	Longitudinal
All rail mounted machines	Without digging element	1/10	1/30	1/30
	With digging element	1/8	1/30	1/30
Crawler mounted machines and equipment with mechanical or hydraulic lifting feet	Bucket wheel boom	1/5	1/30	1/30
	Discharge boom	1/5	1/10	1/30
	Counterweight boom	1/5	1/15	1/30
	Tower or central structure	1/5	1/30	1/30
	Connecting bridges	1/5	1/10	1/15
All machines	Cabins for operators	1/2	1/2	1/2

3.3.10 Forces associated with conveyor elements (*G*)

This load case is a minimum requirement of this Standard for machines with conveying elements.

Structures shall be designed to withstand the effects of forces associated with conveyor elements arising from belt tension, chain tension, etc. The maximum load resulting from belt tensions occurring during starting, stopping or normal running with live loads as specified in Clause 3.3.5 for a conveyor shall be used. The de-tensioned belt case shall also be considered.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and the operating and maintenance manual.

3.3.11 Friction (*R*)

This load case is a minimum requirement of this Standard for all machine types.

For structural design purposes, calculations of resistance force due to friction shall use coefficients (μ) of not less than—

- (a) for pivots and ball shaped socket bearings 0.15; and
- (b) for structural parts with sliding friction.....0.25.

3.3.12 Travel (*L*)

This load case is a minimum requirement of this Standard for all machine types.

This Clause is subject to the requirements of Clauses 4.1 and 4.2.

Calculations of resistance force due to travel, for structural design purposes (strength and stability), shall use friction coefficients (μ) of not less than the following:

- (a) For rail-mounted machines, due to—
 - (i) rolling resistance of wheels 0.03; and
 - (ii) traction forces between driven wheels and rails 0.25.
- (b) For crawler-mounted machines, due to—
 - (i) track wheels 0.10; and

- (ii) traction forces between crawler pads and operating surfaces during travelling, steering and slewing of the machine—
 - (A) during normal and abnormal operation 0.6; and
 - (B) while crawlers are bogged 0.9.

There exists a special case for crawler-mounted machines when required to relocate down a slope or drive. In this case, due consideration of the regenerative power or mechanical braking requirements shall be made by the designer in sizing load banks, dynamic braking resistors, or other such braking mechanisms used to restrain the forward motion of the machine. The technical specification, in accordance with Appendix B, should nominate the appropriate friction factor for the purposes of design of the travel components in this instance as this value will vary dependent on site specific parameters and conditions, however, this value should not be more than 0.3.

3.4 ADDITIONAL LOADS

3.4.1 Grouping

Additional loads are a grouping that comprises loads that occur infrequently. They may occur during operation of the equipment or while the equipment is not working. These loads may either replace certain main loads or add to the main loads.

3.4.2 Wind during operation (*W*)

This load case is a minimum requirement of this Standard for all machine types.

Where a machine is not completely shielded from the wind, calculations of the wind load on the machine in operation shall be in accordance with AS/NZS 1170.2 using a wind speed (based on the permissible stress design method, see Clause 5.4.2) in the most adverse direction of not less than 20 m/s.

A wind speed for relocation (generally greater than 20 m/s) shall also be considered in the design, as an additional load. The relocation (e.g. travelling but not handling material) wind speed shall be defined in the technical specification in accordance with Appendix B.

The most adverse wind direction shall be taken into account for determining wind loads; although it is normally sufficient to consider wind directions along the main axis of the structure, at right angles to the main axis of the structure and at 45° to the main axis of the structure, in each possible configuration.

In addition to uniform wind loading, non-uniform wind loading (e.g. due to partial shielding of the machine, variability of gust behaviour over the entire machine) or other possible effects shall be considered. The wind direction and machine configuration shall be varied, to determine the worst case of wind loading for stability and design of structures and mechanisms.

Where a variability of gust behaviour across the extent of a machine is the only apparent reason for wind loading on the machine being non-uniform, any resultant torque that is exerted on any rotatable or slewable portion of the machine shall be calculated, assuming the wind loading on one side of the rotating or slewing axis to be reduced to 50% of the full load on that side. The wind direction and the side of the axis that is reduced by 50% shall be chosen to give the maximum possible torque.

Alternatively, wind tunnel testing and/or computational fluid dynamics are permitted for the determination of wind loading.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

3.4.3 Temperature (*T*)

This load case is a minimum requirement of this Standard for all machine types.

Loads due to temperature effects need to be considered in certain cases (e.g. where materials with very different expansion coefficients are used within the same component; where a significant temperature difference can exist throughout a structure).

3.4.4 Abnormal digging resistance (*UU*)

This load case is a minimum requirement of this Standard for reclaiming and excavating machines.

The calculated abnormal digging force shall be determined as the force tangential to the wheel cutting circle or parallel to the bucket or scraper chain that results from the maximum torque of the motor (e.g. during stalling or starting, including breakdown torque under no power), taking into account the second or final cut-off torque of any effective torque limiting coupling, the setting of any load limiting/protection device, the efficiency of the drive gear reducer and the speed at the bucket lips.

Where an effective torque limiting coupling or hydraulic drive is not fitted, the design torque before consideration of frictional and efficiency losses shall be not less than the maximum torque of the drive motor (i.e. during starting or stalling including breakdown torque under no power), subject to a minimum of 2.0 times the motor full load torque.

Where an effective torque limiting coupling or hydraulic drive is fitted, the limiting design torque at the output of the coupling or hydraulic drive shall be based on the greatest of—

- (a) 1.1 times the greatest load limiting/protection device limit setting; and
- (b) a minimum of 1.5 times the motor full load torque for an electric motor drive.

For design purposes, the maximum abnormal digging force on a bucket wheel shall be an equivalent force acting at the bucket lips, without deduction for the force needed to lift material in the buckets. Thus the force needed to lift material in the buckets is included as part of the digging force. The effect of friction and efficiency losses in the drive system shall be included so as to increase (i.e. rather than to decrease) the design torque, since during an abnormal digging event, the bucket wheel or bucket chain friction can decelerate the drive system. The friction and efficiency factor shall be not more than 0.95. Therefore, the maximum torque shall be increased by a factor of not less than 1.05.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

3.4.5 Abnormal lateral digging resistance (*SS*)

3.4.5.1 General

This load case is a minimum requirement of this Standard for reclaiming and excavating type-machines that experience lateral loading due to digging.

3.4.5.2 Slewing or bucket wheel machines

The provision of a load limiting/protection coupling or clutch on slewing machines is a minimum requirement of this Standard.

The abnormal lateral digging resistance shall be taken as:

- (a) Where a safety coupling or clutch is fitted to the slew or travel drive, the force derived from the sum of—
 - (i) 1.1 times the highest value of the cut-off torque of the load limiting/protection coupling or clutch and the load limiting/protection device limit on the relevant drive (i.e. slew or travel); plus

- (ii) the frictional losses in the relevant drive system (i.e. slew or travel) between coupling and digging element (that shall be added to increase the design resistance).
- (b) Where a safety coupling or clutch is not fitted to the slew or travel drive, the force derived from the sum of—
 - (i) the maximum torque (i.e. during starting or stalling) of the relevant lateral drive motor (i.e. slew or travel); plus
 - (ii) the frictional losses in the relevant drive system (i.e. slew or travel) between drive motor and digging element (that shall be added to increase the design resistance).

Where a torque limiting device (e.g. a slew clutch) is fitted, the design cut-off torque shall be not less than 1.1 times the sum of the torques due to inclination of the machine (see Clause 3.3.4) plus the design wind load for the machine during operation or relocation (see Clause 3.4.2).

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

3.4.5.3 Other reclaiming machines/Fixed boom type machines

The same principles and requirements as defined in Clause 3.4.5.2 shall be applied to other reclaiming machines, unless varied by the technical specification in accordance with Appendix B.

3.4.6 Travel skew forces (LS)

3.4.6.1 Crawler-mounted machines

This load case is a minimum requirement of this Standard, but may be limited or controlled by a skew control system (with at least two levels of protection achieved by independent means).

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

For crawler-mounted machines, the travel skew force to be taken into account for the structural design of the machine shall be as determined from the friction coefficients as specified in Clause 3.3.12(b).

3.4.6.2 Rail-mounted machines—General

This load case is a minimum requirement of this Standard, but may be limited or controlled by a skew control system (with at least two levels of protection achieved by independent means).

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

For rail-mounted machines, the total travel skew force at a wheel to rail contact shall be the sum of the skew reaction determined for oblique travel (see Clause 3.4.6.3) plus the skew reaction determined for forward travel with the driving force not coincident with the centre of mass (see Clause 3.4.6.4).

3.4.6.3 Rail-mounted machines—Skew reactions due to oblique travel

For rail-mounted machines, such as travelling conveyor gantries, skew reactions transverse to the rail due to oblique travel can occur due to skewing or unintended deviation from the direction of travel [see Figure 3.4.6(a)]. These reactions are in addition to those due to wind and forces of inertia. Skew reactions due to oblique travel shall be calculated from the following equation:

$$H_{yij} = V_{ij\max} \times K_G$$

where

H_{yij} = skew force acting horizontally transverse to the rail (i) on the wheel or bogie (j)

$V_{ij\max}$ = maximum vertical load on each rail (i) or on each wheel or bogie (j), computed for the machine centre of mass in its most unfavourable position

K_G = $K_O \times K_F$

K_F = reduction factor that allows for the flexibility of the rail mounted structure as a function of the lowest horizontal natural frequency (or torsional natural frequency about a vertical axis) for the whole structure

= 1.0, if natural frequency (f_n) > 5.0 Hz

= 0.83, if natural frequency (f_n) > 3.2 Hz and ≤ 5.0 Hz

= 0.66, if natural frequency (f_n) > 2.4 Hz and ≤ 3.2 Hz

= $0.426 \times (f_n)^{0.5}$, if natural frequency (f_n) ≤ 2.4 Hz

with f_n to be not less than 1.0 Hz for calculation purposes

K_O = skew reaction coefficient, whose value is given in Table 3.4.6 as a function of the oblique travel gradient ($\bar{\alpha}$)

$K_{G\min}$ = minimum permissible value of K_G

= $0.025 (p/a)$

p = rail gauge, in metres

$\bar{\alpha}$ = oblique travel gradient, in millimetres per metre = c/a

c = design clearance between wheel flange or guide roller and side of rail, in millimetres [see Figure 3.4.6(c)]

≥ the sum of 10% of the rail head width (to allow for wear) plus the greater of 10 mm and 75% of actual maximum initial clearance

a = centre distance between track wheels, track wheel groups or bogies, in metres

= centre distance between rollers, in metres, where horizontal guide rollers are used

TABLE 3.4.6
SKEW REACTION COEFFICIENT

$\bar{\alpha}$ mm/m	K_O
≤1.5	0.094
2	0.118
3	0.158
4	0.196
5	0.214
6	0.233
7	0.248
8	0.259
9	0.268
10	0.275
12.5	0.287
15	0.293
>15	0.300

NOTE: Where $K_O < K_{Gmin}/K_F$, the value for K_G to be used in the calculations shall be set equal to K_{Gmin} .

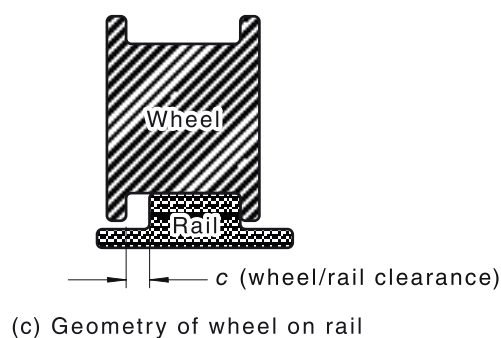
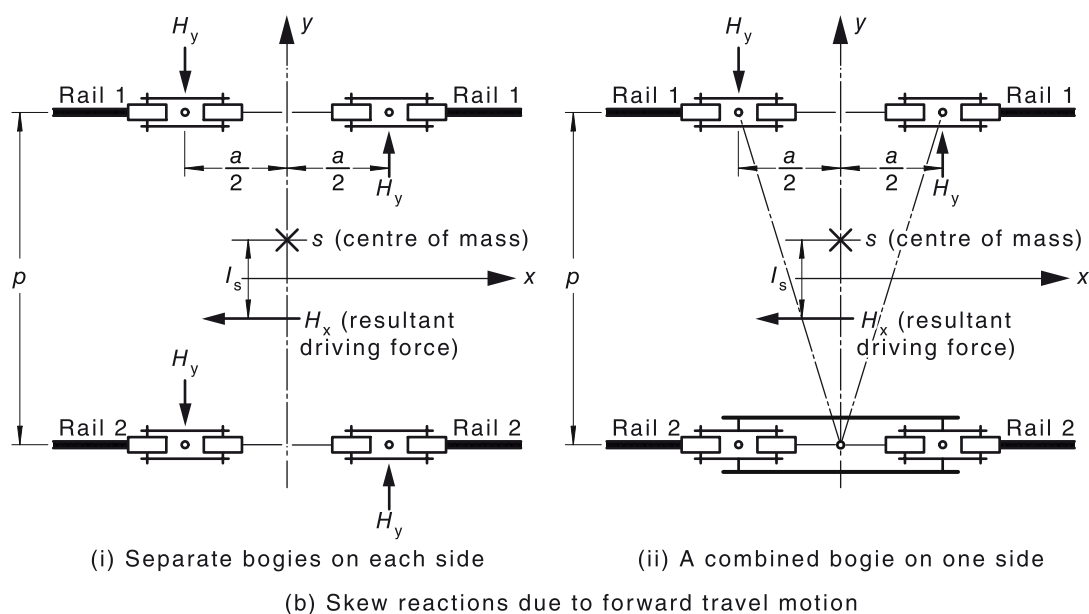
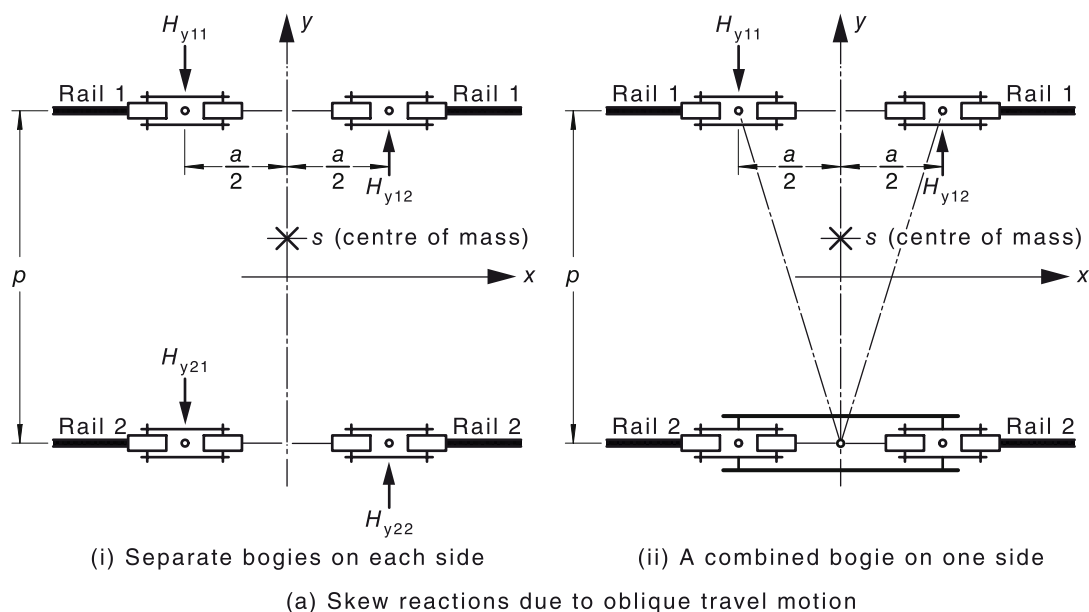


FIGURE 3.4.6 LATERAL SKEW REACTIONS FOR MACHINES ON RAILS

3.4.6.4 Rail-mounted machines—Skew reactions due to forward travel

Where the driving force H_x is not coincident with the centre of mass of the machine, the calculations of skew reactions due to forward travel motion shall assume, where appropriate, that all H_{yij} are equal and that they resist an inertial moment equivalent to $M_d \times H_x \times l_s$ [see Figure 3.4.6(b)]. The values so calculated may be reduced if an adequate skew control system is incorporated; but not below 30% of the calculated values,

where

M_d = dynamic factor

≥ 1.5

H_x = maximum total travel force available from the drives

= sum of the drive forces associated with individual driver wheels

$\leq \mu \times (\text{sum of all the vertical reactions on the driver wheels})$

μ = limiting coefficient of friction between the driver wheels and the rails

≥ 0.25 for steel wheels on steel rails

l_s = distance between line of action of driving force H_x and the centre of mass, in metres

Thus, for the example shown in Figure 3.4.6(b)(i)—

$$H_y = \frac{M_d \times H_x \times l_s}{2a}$$

and for the example shown in Figure 3.4.6(b)(ii)—

$$H_y = \frac{M_d \times H_x \times l_s}{a}$$

3.4.7 Non-permanent dynamic effects (DD)

This load case is a minimum requirement of this Standard for all machine types.

Inertia forces due to non-permanent dynamic load effects, such as abnormal acceleration and braking of moving parts of the machine (e.g. emergency braking), shall be classified as additional loads. They may be disregarded where their effect is in the same direction and less than that of the wind force during operation, as calculated in accordance with Clause 3.4.2. Where these non-permanent dynamic effects are in the same direction and exceed the wind force, the wind effect may be disregarded.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual. This includes maximum velocities and calculation of associated accelerations/decelerations under activation of controls/devices.

3.4.8 Snow, ice and hail loads (K)

Where applicable, or where prescribed by the technical specification in accordance with Appendix B, the design shall include the effects of loads due to snow, ice and hail. The amount of additional loading that needs to be taken into account will depend on the area where such material can collect to a degree in excess of the encrustation loading already taken into consideration (see Clause 3.3.3) and shall conform to AS/NZS 1170.3. The annual probability of exceedance for these loads shall be as nominated in the technical specification and in accordance with AS/NZS 1170.0:2002 Appendix F, when they are required to be considered.

Snow, ice and hail loads that may be present at the location of fabrication and during construction and/or delivery should be included.

3.4.9 Access ways (*P*)

This load case is a minimum requirement of this Standard for all machine types.

Access ways, such as stairs, platforms, walkways and guardrails, shall be designed in accordance with AS 1657 and, in addition, shall be able to support a concentrated load of 3 kN at any point. The local area of the main structure of the machine that supports stairs, platforms, walkways, guardrails, access ways and the like shall be designed to withstand the concentrated and distributed loads as required above, as if these loads are applied locally. These loads need not be considered for the purposes of assessing overall machine strength and stability unless indicated otherwise in the technical specification in accordance with Appendix B.

Where stairs, platforms, walkways, access ways or the like may temporarily support an additional load that may be in excess of the loads required in the foregoing paragraph (e.g. material build-up, maintenance personnel, equipment), they shall be designed and sized accordingly.

3.4.10 Erection, dismantling and weighing (*Y*)

This load case is a minimum requirement of this Standard for all machine types.

Loads that can be applied as a result of erection, dismantling or weighing shall be taken into account. During erection, machines shall be secured against movement caused by winds having a strength as set out in AS/NZS 1170.2.

Wind loading shall be in accordance with Clause 3.5.10 (i.e. *WW*) unless varied by the technical specification in accordance with Appendix B.

The technical specification should define the extent to which these loads and associated structural configurations are subject to review by the design audit.

3.4.11 Maintenance loads (*X*)

This load case is a minimum requirement of this Standard for all machine types.

Loads that can arise during any special maintenance operations (e.g. replacement of slew bearing, replacement of bogie) shall be taken into account. During maintenance, machines shall be secured against movement caused by wind speeds as set out in AS/NZS 1170.2.

Where wind loading less than that defined for load *WW* is to be considered, this shall be explicitly defined by the technical specification in accordance with Appendix B.

3.4.12 Abnormal inclination (*NN*)

This load case is a minimum requirement of this Standard for all machine types.

Abnormal loads due to extreme inclination of the working level shall be based on the following:

- (a) For machines in operation:

$$NN_1 = 1.2 \times (\text{maximum slope for normal operation as specified in the technical specification in accordance with Appendix B})$$

- (b) For crawler mounted machines in transit:

$$NN_2 = 1.2 \times (\text{maximum in transit slope as specified in the technical specification in accordance with Appendix B})$$

3.5 SPECIAL LOADS

3.5.1 Grouping

Special loads are a grouping that comprises loads that do not normally occur while the machine is operating or idle, but may occur in exceptional circumstances and shall be considered in the design.

3.5.2 Grounding of a bucket wheel, ladder or discharge boom

3.5.2.1 General

This load is a minimum requirement of this Standard for machine types with a bucket wheel, ladder or discharge booms.

Machines that have only one level of protection against grounding shall conform to both Clauses 3.5.2.3 and 3.5.2.4.

This load shall be considered for both operational (i.e. live loads present) and non-operational (i.e. dead load only present) conditions.

Whilst this Clause (3.5.2.1) generally requires consideration of grounding at the boom tip, the design may need to consider the possibility of grounding at locations along the boom.

The consideration of grounding of counterweight booms shall only be required if defined by the technical specification in accordance with Appendix B.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the required action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

3.5.2.2 Slight (A1)

To allow for grounding of a bucket ladder, bucket wheel or boom that would cause the force in its support system (i.e. ropes or hydraulic cylinder) to fall to 10% below the lowest nominal support load in normal operation, allowance shall be made for 1.1 times the resultant force acting at a bucket ladder or up through the centre of a bucket wheel in the case of an excavator or reclaimer, or through the centre of the conveyor end pulley on the boom of a machine such as a stacker. This corresponds to a first level setting of the support load limiting/protection device that shall be set at 1.0 times the resultant force defined above and prevent load applied above that value.

3.5.2.3 Partial (A2)

To allow for grounding of a bucket ladder, bucket wheel or boom that would cause the force in its support system to fall to 20% below the lowest nominal support load in normal operation, allowance shall be made for 1.1 times the resultant force acting at a bucket ladder, or up through the centre of a bucket wheel in the case of an excavator or reclaimer, or through the centre of the conveyor end pulley on the boom of a machine such as a stacker. This corresponds to a second level setting of the support load limiting/protection safety device that shall be set at 1.0 times the resultant force defined above and prevent load applied above that value.

3.5.2.4 Full (AA)

Where safety devices required by Clauses 3.5.2.2 and 3.5.2.3 are not installed, or do not limit applied loads to below the defined values, the machine shall be designed to permit full grounding of the bucket wheel, bucket ladder or boom.

For machines with safety load limiting/protection devices as required in Clauses 3.5.2.2 and 3.5.2.3, the technical specification may prescribe a failure of the safety device leading to full grounding.

A possible full-grounding situation for a reclaimer rehandling stockpiled material, where a slip of the face would create an uplift of the wheel, is illustrated in Figure 3.5.2.4.

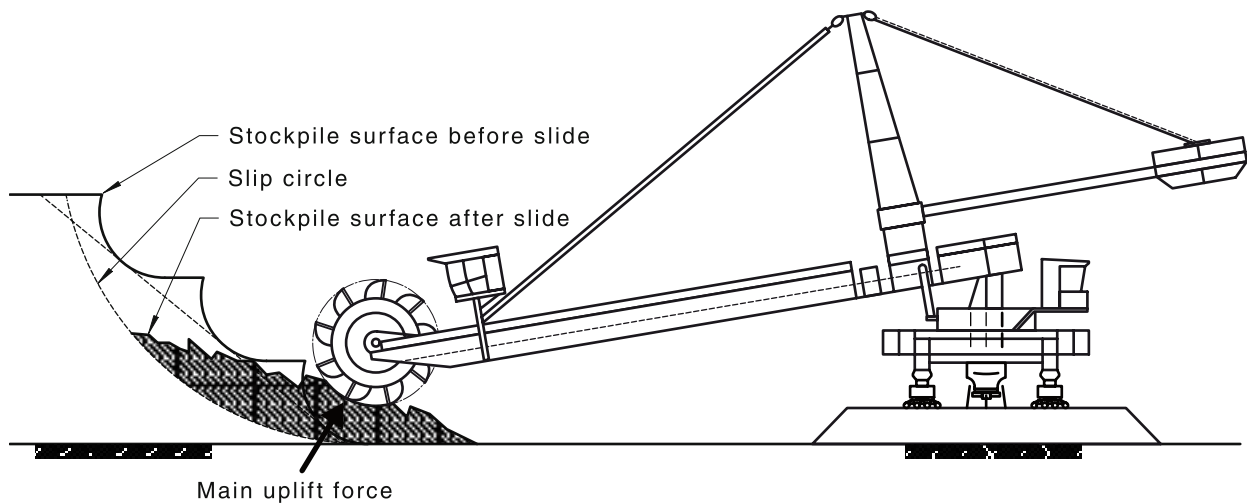


FIGURE 3.5.2.4 TYPICAL UP-LIFT OF A BUCKET WHEEL

3.5.3 Uneven support where rail-mounted (QQ)

This load case is a minimum requirement of this Standard for all machine types that are rail mounted.

Strength and stability calculations for rail-mounted machines shall allow for the machine orientation that represents the most adverse case of tipping. Where uneven support, such as variations in flatness of travel rails, could cause unloading of a group of travel wheels, loading of remaining wheels shall not exceed that needed to maintain a stability ratio for the overall machine of not less than 1.2, for the most adverse configuration of the machine in relation to the loaded wheels. Maximum wheel loads shall be less than the limits contained in the technical specification, in accordance with Appendix B.

3.5.4 Uneven support where crawler-mounted (QQ)

This load case is a minimum requirement of this Standard for all machine types that are crawler mounted.

Strength and stability calculations for crawler-mounted machines shall allow for the most adverse case of tipping or travel over uneven ground that may occur. Dimensions and geometry of crawler systems shall be such as to prevent the crawler ground pressure from exceeding the maximum specified.

Unless stated otherwise in the technical specification in accordance with Appendix B, the factor of safety between actual crawler ground pressures and permissible ground pressures shall be calculated on the basis that the maximum supporting area of a crawler is the plan area of the crawler, calculated from the distance between the first and the last track wheels $\times$ crawler track width.

However, for crawlers that are effectively rigidly connected to the undercarriage, the pressure distribution over the length of a crawler due to the effect of the machine centre of mass not coinciding with the centroid of the supporting crawler area shall be calculated on the basis that at the limiting condition, the pressure distribution would be uniform, but the crawler would be loaded over a length of less than the full distance between first and last track wheels.

Load cases to be evaluated shall include but not necessarily be limited to the following loading arrangements:

- (a) For fully equalized crawlers having the maximum load supported as two concentrated loads, one at each end tumbler and with a take-up tumbler in its outer position.
- (b) For two-crawler machines having the crawler main frames rigidly connected to the underframe, a loading situation that allows for the entire machine weight and the applied loads to be supported on two points, one point being on each crawler at a position corresponding to a tumbler or an equalized wheel group. The support points shall be determined from consideration of overall equilibrium of the machine under the loads applicable to the load case being considered.
- (c) For two-crawler machines having the crawler main frames rigidly connected to the underframe that is a loading situation that allows for the entire machine weight and the applied loads to be supported on three points, one point being a tumbler or equalized wheel group on one crawler and the other two points corresponding to either a tumbler or an equalized wheel group on the other crawler. The support points shall be determined from consideration of overall equilibrium of the machine under the loads applicable to the load case being considered.

NOTE: The maximum load to be supported at one of the points for the most adverse loading situation corresponding to Item (b) or (c) above may typically be found to be two-thirds to three-quarters of the total load to be supported.

- (d) For two-crawler machines having each of their crawler main frames pivoted to the underframe, a loading situation that allows for the entire machine weight and the applied loads to be supported on four points, two points being on each crawler and being either a tumbler or an equalized wheel group. The support points shall be determined from consideration of overall equilibrium of the machine under the loads applicable to the load case being considered.
- (e) For steered crawlers that are shearing material that has built-up against the side of the pads, the resistance shall be the greater of that derived from the shear strength of the ground material or that based on a coefficient of friction of 0.9.
- (f) Loads arising from cross-sliding of the crawlers when loads on the underframe are the most unfavourable under Cases I and II loads (see Clause 3.7), without steering, and with a coefficient of friction of 0.6 between the crawler pads and the operating surface.

Crawler mounted machines shall be designed to be able to traverse the nominated range of terrain and gradients, under relocation conditions, during the course of their operational life.

During abnormal load combinations in these configurations, where the potential for a two-crawler configuration machine to rock forward onto the crawler tumblers, the strength and stability of the relevant components and structures of the machine shall ensure the machine is able to safely recover from this position.

If such a possibility exists, the forward rocking motion and in particular, the severity of the return oscillation should be limited, or eliminated as far as is practicable within the constraints of the design. Where it is not practicable to stipulate a specific machine relocation configuration to alleviate this load case, strength and stability requirements shall be as prescribed in the technical specification, in accordance with Appendix B.

3.5.5 Blocked chutes and hoppers (VV)

This load case is a minimum requirement of this Standard for all machine types.

Calculations of the mass of material in blocked chutes, ship loader spouts, hoppers, etc. shall be based on the bulk density of the material (see Clause 3.1) multiplied by the sum of the following:

- (a) The volume of the chute or hopper.
- (b) The volume of any possible surcharge on the chute or hopper, taking into account the angle of repose of the material.
- (c) The volume of any possible overflow material resting on secondary structures or surfaces, taking into account the angle of repose of the material.

The mass of material in the chute or hopper during normal operation may be deducted from the total mass of material in the chute or hopper for the purposes of determining the additional mass present during a blockage, but only where it has been included as part of the live load (see Clause 3.3.5).

The calculations shall use an angle of repose of the material of not less than 35°.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the required action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

3.5.6 Excess material on conveyors (*FF*)

This load case is a minimum requirement of this Standard for all machine types.

Where a failure of load-limiting devices, blocking of chutes or anything else may cause material loads in excess of those specified in Clause 3.3.5, such excess loads shall be calculated as special loads.

Extreme live loads (*FF*) carried on a conveyor shall be determined in accordance with the principles contained in Appendix I. Unless varied by the technical specification in accordance with Appendix B, for structural design purposes, the live load shall be based on the maximum possible cross-section of material (S_m) as defined in Paragraph I3 of Appendix I (i.e. corresponding to zero edge distance and surcharge angle of at least 35°, subject to a minimum of the angle of repose of the material, and including allowance for any crowding boards).

Where load limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the required action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

3.5.7 Travelling device obstructed (*LL*)

This load case is a minimum requirement of this Standard, but the load may be limited or controlled by a skew control system (with a minimum of at least two levels of protection achieved by independent means) for machines with large rail gauge distances.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the required action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

The method of application or omission of this Clause (3.5.7) in relation to equipment with a large rail gauge distance shall be defined in the technical specification in accordance with Appendix B.

To allow for the obstruction of travelling devices, such as bogies of rail-mounted equipment becoming locked (e.g. by derailment or rail fracture), calculations of loads occurring under such conditions shall be based on the sum of the stall torque of the drive motors plus the inertial loading associated with decelerating the machine at the rail from maximum velocity at a constant rate of deceleration over a distance of 300 mm (this distance may be varied by the technical specification in accordance with Appendix B), except that loads imposed by driven wheels need not be taken as greater than would occur for a coefficient of friction (μ) between driven wheels and rails of 0.33. The case where driven wheels on one rail are blocked completely but driven wheels on the other rail are free to drive the machine into skew shall be considered. The most adverse combinations of loading from obstructed bogies shall be considered. Pairs of travel wheels on a crawler-mounted machine shall be treated similarly with a coefficient of friction (μ) of not less than 0.33. It shall be assumed that the machine is both slewing and travelling at the maximum velocity for each drive motion; unless interlocks prevent both motions occurring simultaneously, in which case the worst loading situation for either slewing or travelling at the maximum velocity for that drive alone shall apply.

3.5.8 Lateral collision of boom (FS)

This load case is a minimum requirement of this Standard for equipment with slewing motion capability. This load case shall also be applied to the counterweight boom as specified by the technical specification in accordance with Appendix B.

The application or omission of this Clause (3.5.8) in relation to equipment that has non-slewing or fixed boom type arrangements shall be defined in the technical specification in accordance with Appendix B.

Calculations of the maximum lateral resistance of a boom colliding against an obstruction while slewing or travelling shall be based on the sum of—

- (a) the maximum slew torque or travel drive torque for the motors during starting or at stall (or as limited by the safety load limiting/protection coupling, slip clutch or brake but factored by 1.1) divided by the efficiency of the slewing or travel drive; and
- (b) the inertial loading associated with decelerating the outermost extremity of the boom from maximum velocity at a constant rate of deceleration over a distance of 300 mm.

It shall be assumed that the machine is both slewing and travelling at the maximum velocity for each drive motion, unless interlocks prevent both motions occurring simultaneously, in which case the worst loading situation for either slewing or travelling at the maximum velocity for that drive alone shall apply. The efficiency factor shall be not greater than 0.95. Therefore, the maximum torque shall be increased by a factor of not less than 1.05.

The force calculations should be based on a simulation of the deceleration of the machine while travelling and slewing, taking account of the distributed inertia of the machine superstructure. It should be noted that the machine may still be travelling forward after the forward motion of the boom tip has been arrested. For non-slewing machines, it may be necessary to account for the flexibility of the structure, to obtain a realistic estimate of the inertial loading during a collision.

Stresses in the boom and superstructure resulting from such a collision may be calculated using a statically equivalent set of forces and moments, in which case the inertial loading should be represented by a number of distributed forces and lumped forces having the same effect as the mass items that they represent at their respective distances from the centre of rotation and travelling at the constant rate of angular deceleration. By way of example, Figure 3.5.8 illustrates an acceptable representation for a stacker-reclaimer that is slewing but not travelling.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

Where this load case is omitted, or a lower value is used in the design, the protection system should consider the level of deflection of the boom that would cause structural nonconformance and/or damage.

The consideration of this load case for collisions at locations other than at the end of the boom shall be as specified by the technical specification in accordance with Appendix B.

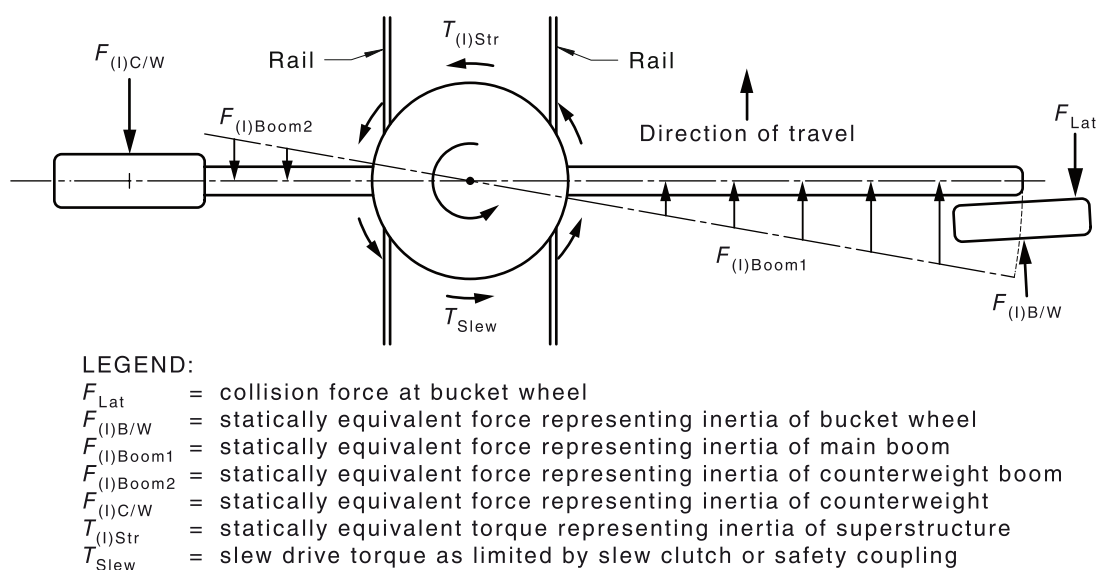


FIGURE 3.5.8 REACTIONS FROM A LATERAL COLLISION OF A STACKER-RECLAIMER BOOM

3.5.9 End-on collision of boom (FT)

This load case is a minimum requirement of this Standard for equipment with slewing motion capability. This load case is not required to be considered for equipment that does not have a motion capability (nearing) parallel to the boom, unless so defined by the technical specification in accordance with Appendix B. This load case shall be applied to the counterweight boom only as specified by the technical specification in accordance with Appendix B.

The application or omission of this Clause (3.5.9) in relation to equipment that has fixed boom type arrangement shall be defined in the technical specification in accordance with Appendix B.

A loading situation that allows for an end-on collision of the boom of a slewable machine while the machine is travelling shall be considered. For the purpose of determining the resulting loads, the boom shall be taken to be slewed at an angle of 20° to the direction of travel at the moment of collision. The forces so induced shall include a lateral force (F_{Lat}) normal to the boom axis and a longitudinal force (F_{Long}) along the boom axis. These forces shall be calculated as follows:

F_{Lat} = the sum of—

- (a) the force at outermost extremity of the boom, normal to the axis of the boom so as to just cause slippage of the slew clutch or slew brake, whichever is appropriate for the manner in which the machine operates;

- (b) the efficiency losses in the drive system due to the deceleration of the drive by the collision force where the efficiency factor shall be not greater than 0.95. Therefore, the maximum torque shall be increased by a factor of not less than 1.05; and
- (c) the inertial loading associated with bringing the end of the boom to rest in the direction of travel over a distance of 300 mm in the direction of travel.

In determining when slippage might reasonably be expected to occur for a clutch or brake, a minimum factor of 1.1 shall be applied to the rated slew clutch torque, and a minimum factor of 1.35 shall be applied to the nominal torque capacity of the brake to allow for setting inaccuracies and variability in performance.

F_{Long} = force at outermost extremity of the boom, aligned in the direction of the boom axis and equal to $F_{Lat} \cot 20^\circ$

The force calculations should be based on a simulation of the deceleration of the machine in travel and slew, taking account of the distributed inertia of the machine superstructure. It should be noted that the machine may still be travelling forward after the forward motion of the boom tip has been arrested.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

Figure 3.5.9 illustrates this loading situation for a rail-mounted stacker-reclaimer by way of example.

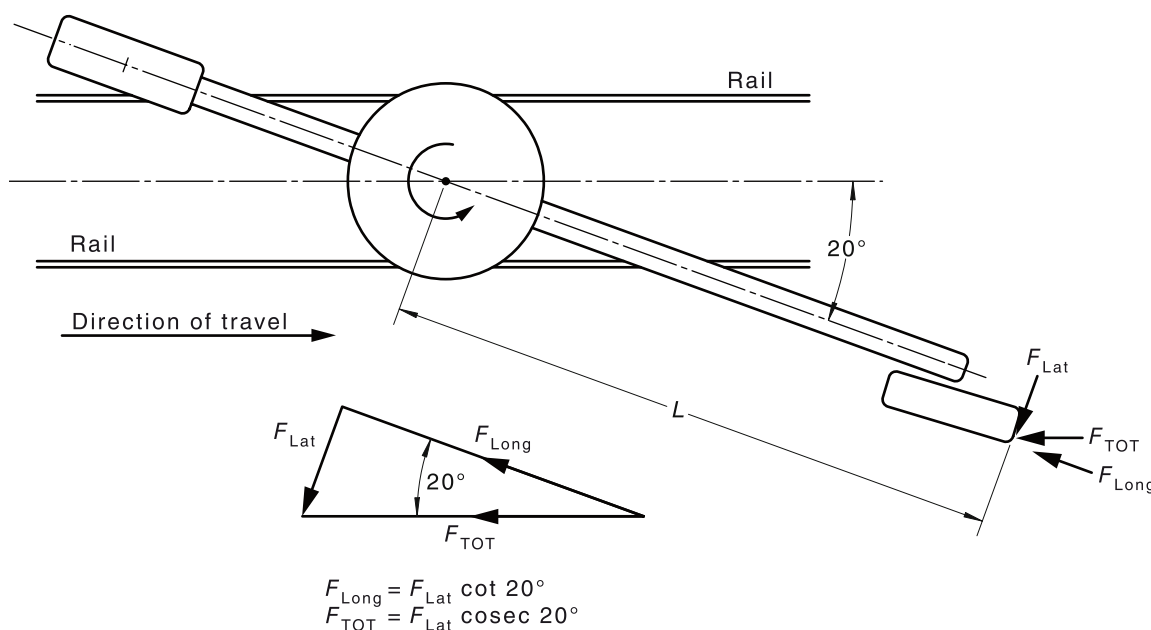


FIGURE 3.5.9 REACTIONS FROM AN END-ON COLLISION OF A STACKER-RECLAIMER BOOM DURING TRAVELLING

3.5.10 Wind while idle (WW_p and WW_u)

This load case is a minimum requirement of the Standard for all machine types.

Wind loads calculated according to the permissible stress design method shall be designated WW_p .

Wind loads calculated according to the ultimate limit state design method shall be designated WW_u .

Where machines are not completely shielded from the wind, the wind load on an idle machine shall be calculated in accordance with AS/NZS 1170.2, based on the basic wind speed (V_p) for the permissible stress design method. Determination of the basic wind speed (V_p) for the permissible stress design method shall be based upon the (ultimate limit state) V_{500} (or greater) regional wind speed divided by the square root of 1.5.

The most adverse wind direction shall be taken into account for determining wind loads; although it is normally sufficient to consider wind directions along the main axis of the structure, at right angles to the main axis of the structure and at 45° to the main axis of the structure.

Where a machine is parked only in the one configuration, wind loads for only that configuration need be considered.

In addition to uniform wind loading, non-uniform wind loading (such as may arise due to partial shielding of the machine or variability of gust behaviour over the entire machine) or from other possible effects shall be considered. The wind direction and machine configuration shall be varied to determine the worst case of wind loading for stability and design of structures and mechanisms.

Where the only apparent reason that wind loading on a machine would be non-uniform is due to a variability of gust behaviour across the extent of the machine, any resultant torque that would be exerted on any rotatable or slewable portion of the machine shall be based on a 50% reduction of the full wind loading on that side of the rotating or slewing axis. The wind direction and the side of the axis that is reduced by 50% shall be chosen to give the maximum possible torque.

Wind tunnel testing and/or computational fluid dynamics are permitted for the determination of wind loading.

3.5.11 Buffers (OO)

This load case is a minimum requirement of this Standard, for relevant motions for all machine types.

For rail-mounted machines, any buffers shall be capable of absorbing the total energy of the moving masses (including the rotational energy of the drive system) under full power at rated travelling velocity, and at uniform deceleration to zero speed from the point of contact to the full combined compression of the buffers. The energy to be absorbed by the buffers shall include not only the kinetic energy of the moving masses, but also the work done by the travel drive motors acting over the distance of combined buffer compression (the actual travel drive torques determined from the motor torque-speed characteristic should be used).

The resulting loads imparted to the structure shall be based on the retardation imparted by the buffers and the linear and rotational inertias of the moving parts.

Special cases should be as set out in the technical specification in accordance with Appendix B (e.g. a tripper locked onto a belt while it is travelling at rated speed).

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual. These principles shall also be applied to other moving sub-assemblies where buffers are installed.

3.5.12 Earthquakes (EQ_p and EQ_u)

This load case is a minimum requirement of this Standard for all machine types.

Earthquake loads calculated according to the permissible stress design method shall be designated EQ_p .

Earthquake loads calculated according to the ultimate limit state design method shall be designated EQ_u .

Loads arising from the effects of earthquakes shall be calculated in accordance with AS 1170.4. The ultimate limit state design loading, EQ_u , shall be calculated using an annual probability of exceedance of 1/500 (i.e. a probability factor, k_p , of not less than 1.0), or a more onerous value as defined by the technical specification in accordance with Appendix B.

The permissible stress design earthquake loading EQ_p shall be calculated as $EQ_u/1.4$.

3.5.13 Burying (ZZ)

This load case is a requirement of this Standard where the load, burying, is explicitly specified in the technical specification in accordance with Appendix B.

Where collapse of a stockpile or slippage of the bank could cause the reclaiming or excavating component of an operating machine to become partially or fully buried, it may be appropriate to consider this as a special load case.

Figure 3.5.13 illustrates a typical burying situation. A possible load description for a burying that could be included in a technical specification is given in Table B1 of Appendix B.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

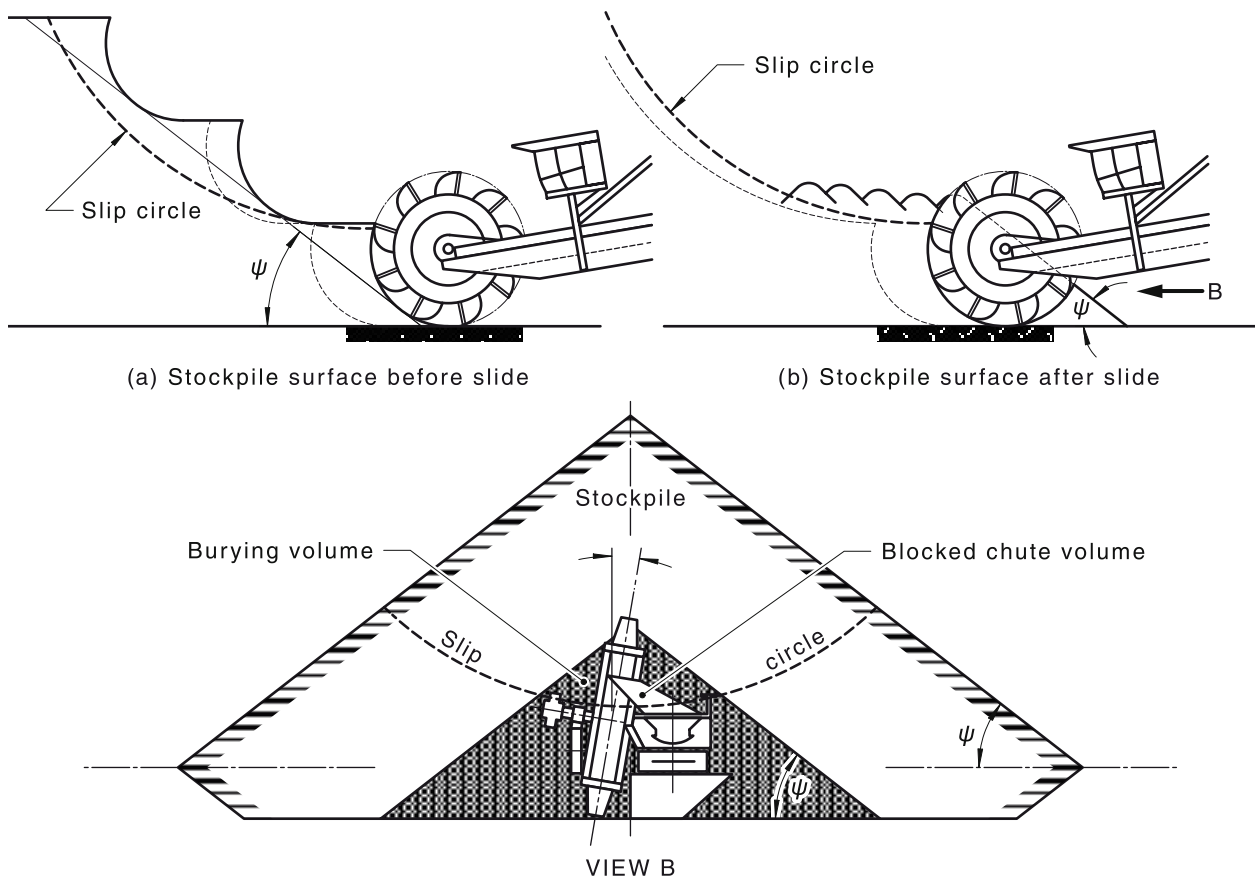


FIGURE 3.5.13 TYPICAL BURYING OF A BUCKET WHEEL

3.5.14 Bucket wheel and gearbox loss (*BL*)

This Clause (3.5.14) shall be considered for bucket wheels and/or drive assemblies that are not contained or captured by the structure upon failure of the shaft (i.e. such as cantilever bucket wheel shafts), or as defined in the technical specification in accordance with Appendix B.

This applies to bucket wheel machines, where the bucket wheel is mounted at the end of a boom. The load case involves the bucket wheel, bucket wheel shaft assembly and bucket wheel drive unit separating and falling from the end of the boom.

On machines where the bucket wheel is contained in such a case, but the drive unit is not, a loss of the drive unit shall be considered unless the drive unit is similarly contained by means of a catchment structure or system.

For this situation, the design shall be such that either the slew bearing or slew race safety hooks will hold the superstructure, preventing separation at the slew race. Dynamic effects associated with the bending oscillation of the boom following release of the bucket wheel, bucket wheel shaft and bucket wheel drive gearbox shall be considered.

3.5.15 Abnormal friction (*RR*)

This load case is a minimum requirement of this Standard, when specified by the technical specification in accordance with Appendix B.

A load case should be considered for each pivot (e.g. pinned joint or spherical seat) where it is assumed to be seized to such an extent that the abnormal friction coefficient is as much as 0.85, while all other pivots exhibit normal friction as specified by Clause 3.3.11. Allowance need not be made for more than one pivot seizing at the one time.

3.5.16 Extra loads (*EL*)

Other special loading situations may occur due to the particular or peculiar circumstances associated with a machine design or operating environment. A particular example is a failure of safety devices that are provided specifically to limit the loads on the machine. The technical specification, in accordance with Appendix B, shall identify any such further special loads required to be included in the design. The appropriate load case combinations, stability ratios, and factors of safety shall be as defined in the technical specification, so as to provide an acceptable level of risk under the circumstances.

Where load-limiting devices are used to control this load, their use shall be as defined in the technical specification in accordance with Appendix B. The device/control, its setting and the required action upon activation of the device/control shall be defined in the structural calculations and be included in the operating and maintenance manual.

3.6 FATIGUE LOADS

3.6.1 General

The load cases in this Clause (3.6) are minimum requirements of this Standard for all machine types.

Fatigue loading shall be determined by considering variations of the main loads as discussed in Clauses 3.6.2 to 3.6.10.

For any given machine, this will generally result in one or more cyclical loadings that will occur repetitively throughout the operational life of the machine. For each such cyclical load component, a load range (i.e. maximum to minimum) and a corresponding number of load cycles that will occur during the design life of the machine shall be determined. Where there are two or more cyclical loading components, the combined effect shall be assessed using a Miner's Rule summation.

For assessing the capability of a structure or parts thereof (e.g. welded joints) to resist fatigue based on the fatigue load cases defined in Table 3.7(A) or Table 3.7(B), the loads used shall be based on representative working loads (i.e. without inclusion of limit state load multiplying factors or factors of safety) so that calculated stress ranges may be compared directly with the fatigue strength for the appropriate joint configuration. Fatigue load modifying factors are specified in Table 3.6 for certain loading components that allow for these loads being unlikely to reach their maximum value on every cycle.

Unless otherwise nominated in the technical specification in accordance with Appendix B, Clauses 3.6.2 to 3.6.10 shall be used to calculate fatigue load components. The symbols used for fatigue loads have the following meanings:

- (a) $\pm$ indicates a change in load from one extreme to the other where the direction of load changes.
- (b) $+0$ indicates a change in load from zero to some maximum value.
- (c) $++$ indicates a change in load due to geometry or load variation.

3.6.2 Dead loads and encrustation ($+/+E$ and $+/+V$)

Changes in machine configuration that occur during the machine's operational cycle (e.g. geometry changes that occur as a result of slew, luff, travel or boom shuttling motions) shall be considered in terms of how these geometry changes alter loads on the machine or loads on the components of the machine. Variation in loads and cycle numbers shall be determined from consideration of motion limits and frequencies occurring during normal operation of the machine.

3.6.3 Inclination (+/- N)

Loads due to inclination apply to machines that slew during operation. They shall be calculated in accordance with Clause 3.3.4, but taking account of the slew angle and the combined longitudinal and cross slopes on which the machine operates.

Load cycles shall be taken to be the same as those used for normal digging (see Clause 3.6.5).

3.6.4 Live loads on conveyors (+0 $C_F.F$)

For conveyors on machines having a digging element, the variation in live load considered shall be the difference from zero to the maximum as calculated in Clause 3.3.5 multiplied by the factor C_F . The values of C_F for different machines are listed in Table 3.6. In the case of bucket wheel excavators or reclaimers, this variation will occur once every slew pass.

For machines without digging elements, the same load variation shall be considered, but the number of cycles shall be based on operational factors that control the loading and unloading of conveyors.

3.6.5 Normal digging resistance (+0 $C_U.U$)

Digging resistance load cycle components apply only to machines with digging elements. Variation of this loading shall be from zero to $C_U.U$, where C is calculated as in Clause 3.3.7. The values of C_U for different machines are listed in Table 3.6. For bucket wheel excavators and reclaimers, this variation will occur at least every digging pass of the machine (slew or travel).

3.6.6 Lateral digging resistance (+/- $C_S.S$)

For machines with digging elements, lateral digging resistance load components shall be $C_S.S$ where S is as calculated in Clause 3.3.8 with allowances for the fact that the direction of application reverses on each digging pass. The values of C_S for different machines are listed in Table 3.6. Cycle numbers will generally be one-half the number calculated for normal digging resistance.

3.6.7 Permanent dynamic effects (+/- D)

Variation of permanent dynamic cyclical components shall assume these loads are applied at a value D , as calculated in Clause 3.3.9 in either direction. Cycle numbers shall be determined from a consideration of operational circumstances. For machines with a luffable boom or a slewable boom, cycle numbers shall be taken at least as frequent as in Clause 3.6.5, however, consideration shall be given to the number of cycles of oscillation that may occur at a relevant structural natural frequency, each time a motion is initiated or stopped.

3.6.8 Conveyor elements (+/+ G)

Forces on conveyor elements shall be assumed to vary from the situation of loading on the belt being zero to the conveyor element loads G for a conveyor loaded at the F load magnitude, as calculated in accordance with Clause 3.3.5, and the number of load cycles shall be the same as specified in Clause 3.6.4.

3.6.9 Friction (+/- R)

Cyclical loads resulting from changes in magnitude and direction of friction at pivots of booms and similar shall be considered, with magnitude calculated in accordance with Clause 3.3.11. Cycle numbers shall be determined from operational considerations.

The extent that resistance due to travel or for friction effects at pivots are to be considered in the fatigue design of a machine should be defined in the technical specification in accordance with Appendix B.

3.6.10 Travel (+/-L)

For rail-mounted machines, the extent the resistance to travel (+/-L) shall be treated as a fatigue load and shall be as defined in the technical specification in accordance with Appendix B.

TABLE 3.6
FATIGUE LOAD MODIFYING FACTORS

Machine type	C_F	C_U	C_S
Rail-mounted			
Stackers	0.9	—	—
Ship loaders	0.9	—	—
Reclaimers	0.8	0.7	0.7
Crawler-mounted (e.g. BWEs, spreaders, belt wagons)	0.7	0.7	0.7

3.7 LOAD CASES

For the purpose of assessing fatigue, strength or stability, the total effect from the simultaneous application of various possible combinations of loads shall be considered, including those set out in Table 3.7(A) or 3.7(B). These combinations are grouped into four classes, as follows:

- (a) Load Case F/I that are combinations of the fatigue loads.
- (b) Load Case I that is a combination of the main loads.
- (c) Load Case II that are combinations of the main and additional loads.
- (d) Load Case III that are combinations of the main, additional and special loads.

Changes in the point of application of each of the loads arising from each of the possible equipment configurations shall be considered for the various load case combinations nominated in Table 3.7(A) or 3.7(B). For each strength or stability assessment, the worst case of these alternatives shall be adopted. Assessments of each particular part of the structure shall take account of non-permanent loads that increase stresses in the part, but not non-permanent loads that decrease stresses in the part. A similar philosophy shall be adopted for determinations of load combinations for stability assessments.

In particular, the determination of design loads for all of the load case combinations considered for strength and stability shall be based on the worst possible arrangement for the support of the machine due to uneven ground conditions in the case of crawler-mounted equipment, and due to deviations of the rail top surfaces from a true plane for rail-mounted equipment. This may be particularly important for crawler-mounted machines with a rigid connection between the undercarriage and the crawler beams. In such cases, it is possible for the entire weight of the machine to be carried on as few as three or sometimes two effective support points, each support point being an equalized crawler group or tumbler (refer especially to Items (a), (b), (c) and (d) of Clause 3.5.4, which shall be deemed to also apply to load cases I, II and III in respect of support assumptions).

For some specific machines, it might not be possible for some of the load combinations nominated in Table 3.7(A) or 3.7(B) to occur simultaneously in practice. In these cases, only those load components that can occur simultaneously shall be considered. In determining design loads for fatigue and the corresponding cycle numbers, the worst case arrangement for support of the machine shall be taken into account for such a period of operation as is likely under such support conditions.