TECHNICAL REPORT

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Lifts and escalators subject to seismic conditions — Compilation report

Ascenseurs et escaliers mécaniques soumis aux conditions sismiques — Rapport de compilation

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Foreword

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

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

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

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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

ISO/TR 25741 was prepared by Technical Committee ISO/TC 178, *Lifts, escalators and moving walks*.

0 Introduction

0.1 When an earthquake occurs, it releases energy in the form of waves that radiate from the earthquake source in all directions. The different types of energy waves shake the ground in different ways and travel through the earth at different velocities. The fastest wave, and therefore, the first to arrive at a given location, is called the P wave. The P wave, or compressional wave, alternately compresses and expands material in the direction in which it is travelling. The S wave is slower than the P wave and arrives next, shaking the ground up and down and back and forth perpendicular to the direction in which it is travelling. Surface waves follow the P and S waves. Source: NEIC [16].

0.2 Earthquake magnitudes are measured on different scales, namely, Richter and Modified Mercalli Intensity. The Richter Scale is considered more accurate. Approximate values are summarised in Table 1.

Sources: California Institute of Technology [17] and Wiegel [14].

Table 1 — The Richter Scale

Richter magnitude	Mercalli intensity	Acceleration	Approximate radius of perceptibility	Effect
8,5	XII	> 1,0g	—	Total damage
8	XI	0,8g	580 km	General damage
7	IX to X	0,5g	385 km	Considerable damage
6	VII to VIII	0,15g	210 km	Frightening; some broken chimneys; damage to weak buildings
5	VI to VII	0,05g	145 km	Felt by all; some fallen plaster; chimney damage
4	V	0,01g	130 km	Felt by most; some broken windows; cracked plaster
3	III	—	15 km	Quite noticeable indoors
2	I to II	—	0 km	Barely felt

0.3 The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. An increase of one magnitude unit on the Richter Scale corresponds to a ten times greater ground motion. An increase of two magnitude units corresponds to a 100 times greater ground motion, and so on, in a logarithmic series.

0.4 The strongest earthquakes, measured on the Richter Scale, over the last century include those shown in the worldwide map in Clause 5 and in Table 2 below.

Table 2 — The strongest earthquakes

Location	Year	Magnitude
Chile	1960	9,5
Alaska	1964	9,2
Russia	1952	9,0
Banda Aceh, Indonesia	2004	9,0
Alaska	1957	8,8
Kuril Islands	1958	8,7
Alaska	1965	8,7
India	1950	8,6
Chile	1922	8,5
Indonesia	1938	8,5
Great Kanto, Japan	1923	8,3
Gujrat, India	2001	8,1
Mexico	1985	8,0
Southern Peru	2001	7,9
San Francisco, CA, USA	1906	7,8
Bolivia	1994	7,7
El Salvador	2001	7,7
Taiwan	1999	7,6
Tangshan, China	1976	7,5
Sakhalin	1995	7,5
Taiwan	1935	7,4
Izmit, Turkey	1999	7,4
Southern Italy	1980	7,2
Fukui, Japan	1948	7,2
Miyagi, Japan	2005	7,2

Source: U.S. Geological Survey

0.5 Seismic-induced ground motions can have an adverse effect on the operational and physical integrity of building supports and vertical transportation equipment. Experience in the U.S. from the San Fernando, California, earthquake on February 9, 1971 with a magnitude of 6,6 on the Richter Scale resulted in significant damage to buildings and vertical transportation systems. The most notable damage included the following, shown in Table 3.

Table 3 — Damage to vertical transportations systems

Description	**Quantity** (Number of lifts)
Counterweights out of guide rails	674
Counterweights out of guide rails; damaged cars	109
Cars damaged	102
Rope systems damaged	100
Motor generators (moved; some damaged armatures)	174
Counterweight guide rail brackets broken/damaged	174
Roller guide shoes (broken or loose)	286

Source: Elevator World's Annual Study [13].

0.6 In response to earthquake experience on different continents, some codes and standards organizations have included a level of seismic protection in their national standards. ISO/TC 178 recognised that it would be beneficial to promote worldwide guidance in order to ensure the safety of people, as well as equipment, taking seismic forces into consideration for design and construction. The experiences of those national codes and standards organizations that have already adopted seismic protection requirements would benefit the rest of the worldwide elevator community through the compilation of such design safeguards.

0.7 The scope of this effort is the compilation of special specifications for lifts and escalators situated in areas subject to seismic conditions in order to ensure safe operation of the vertical transportation equipment within commonly occurring, i.e. non-catastrophic, ground motion excitation.

0.8 ISO/TC 178 took a Resolution on May 15, 1998, as follows:

"Resolution 156 — Study Group for Lifts and Escalators Working Under Seismic Conditions. On a proposal by WG 6, ISO/TC 178 agreed to create a study group under the leadership of Mr. Gibson (USA) to establish the essential safety requirements and dimensional considerations for lifts and escalators working under seismic conditions. This is to be confirmed by an inquiry among ISO/TC 178 members."

0.9 A new work item proposal covering the preparation of a Compilation Report was issued in document No. ISO/TC 178 N319 on August 27, 1999. The results of the voting on this Item showed that 17 P-members supported the programme of work. These members included Australia, Austria, Belgium, Canada, France, Germany, India, Israel, Italy, Republic of Korea, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom and USA. The following P-members agreed to participate in the development of the work: Australia, Austria, Canada, Italy, Spain and USA.

0.10 ISO/TC 178 took a Resolution on March 25, 2004, as follows:

"Resolution 231/2004. ISO/TC 178 agreed WG 6 to submit a draft Technical Report (compilation of existing documents) by October 2004."

0.11 ISO/TC 178 has included a global essential safety requirement (GESR) in ISO/TS 22559-1 as follows:

> *"6.1.12 Effects of earthquake. In areas subject to earthquakes, means shall be provided to minimize the risk to users, when inside the LCU, and authorized persons, of the foreseeable effects of earthquakes on the lift equipment."*

NOTE 1 The effects on the safety of users and authorized persons need to be considered at all stages: during the earthquake (as much as possible), during rescue from a stalled LCU, and when the lift is returned to normal operation. This assumes that there is no major building failure.

NOTE 2 LCU refers to load-carrying unit (lift car).

0.12 This Compilation Report has been prepared to document current seismic design rules/specifications pertaining to vertical transportation equipment in different geographic regions, which regional experiences have shown to be effective in providing a reasonable degree of seismic protection. Only those requirements in lift safety standards are included.

0.13 Requirements in building codes are not included in this report; however, where applicable, references are given to some building codes.

Lifts and escalators subject to seismic conditions — Compilation report

1 Scope

This Technical Report provides a compilation of relevant safety standards pertaining to protection of the user and vertical transportation equipment during seismic activity.

2 United States

2.1 ASME A17.1-2004 [1]

The ASME A17.1-2004, which includes the ASME A17.1a-2005 Addenda1), specifies safety requirements for all elevators (lifts) with counterweights, and direct-plunger hydraulic elevators, including escalators and moving walks, where these systems are installed in buildings that are designed and built to meet seismic risk zone 2 or greater as defined by the applicable building codes. The requirements of Sections 8.4 and 8.5 are in addition to the requirements specified in other parts of the ASME A17.1 Code, unless otherwise specified. The outline of the seismic requirements are listed below, in terms of the ASME A17.1 rule/clause numbers and title. For the complete text, the reader should consult the ASME A17.1-2004 Code [1].

Under predecessor building codes, i.e. those in effect throughout the late 1990s, the United States was divided into five seismic zones, namely 0 to 4. The weakest seismic ground motion activity was designated 0, 4 indicated the strongest seismic activity in terms of magnitude. To put this into context with the ground-motion-producing accelerations, the ASME A17.1 rules indicate the magnitude of the associated accelerations.

ASME A17.1, Section 8.4
Elevator Safety Requirements For Seismic Risk Zone 2 or Greater

8.4.1	Horizontal Car and Counterweight Clearances.
8.4.1.1	Between Car and Counterweight and Counterweight Screen.
8.4.2	Machinery and Sheave Beams, Supports, and Foundations.
8.4.2.1	Beams and Supports.
8.4.2.2	Overhead Beams and Floors.
8.4.2.3	Fastenings and Stresses.
8.4.3	Guarding of Equipment.
8.4.3.1	Rope Retainers.
Fig. 8.4.3.1.3	Arc of Contact.
8.4.3.2	Guarding of Snag Points.
8.4.4	Car Enclosures, Car Doors and Gates, and Car Illumination.
8.4.4.1	Top Emergency Exits.
8.4.5	Car Frames and Platforms.
8.4.5.1	Guiding Members and Position Restraints.
8.4.5.2	Design of Car Frames, Guiding Members, and Position Restraints.

1) ASME is the registered trademark of the American Society of Mechanical Engineers. The A17.1 rule numbers and titles shown below are summarised from the ASME A17.1-2004 Safety Code for Elevators and Escalators; copyright © 2004 by the American Society of Mechanical Engineers. All rights reserved. It includes the ASME A17.1a-2005 Addenda; copyright © 2005 by the American Society of Mechanical Engineers. All rights reserved.

8.4.6	Car and Counterweight Safeties.
8.4.6.1	Compensating Rope Sheave Assembly.
8.4.7	Counterweights.
8.4.7.1	Design.
8.4.7.2	Guiding Members and Position Restraints.
8.4.8	Car and Counterweight Guide Rail Systems.
8.4.8.1	General.
8.4.8.2	Seismic Load Application.
Fig. 8.4.8.2-1	12 kg/m (8 lb/ft) Guide-Rail Bracket Spacing.
Fig. 8.4.8.2-2	16,5 kg/m (11 lb/ft) Guide-Rail Bracket Spacing.
Fig. 8.4.8.2-3	18 kg/m (12 lb/ft) Guide-Rail Bracket Spacing.
Fig. 8.4.8.2-4	22,5 kg/m (15 lb/ft) Guide-Rail Bracket Spacing.
Fig. 8.4.8.2-5	27,5 kg/m (18,5 lb/ft) Guide-Rail Bracket Spacing.
Fig. 8.4.8.2-6	33,5 kg/m (22,5 lb/ft) Guide-Rail Bracket Spacing.
Fig. 8.4.8.2-7	44,5 kg/m (30 lb/ft) Guide-Rail Bracket Spacing.
Fig. 8.4.8.2-8	Car and Counterweight Load Factor.
8.4.8.3	Guide-Rail Stress.
8.4.8.4	Brackets, Fastenings, and Supports.
8.4.8.5	Type and Strength of Rail Joints.
8.4.8.6	Design and Construction of Rail Joints.
8.4.8.7	Design and Strength of Brackets and Supports.
Table 8.4.8.7	Stresses and Deflections of Guide-Rail Brackets and Supports.
8.4.8.8	Type of Fastenings.
8.4.8.9	Information on Elevator Layouts.
Fig. 8.4.8.9	Guide-Rail Axes.
8.4.8.9.1	Force normal to the x-x axis of the guide rail.
8.4.8.9.2	Where normal to the y-y axis.
8.4.9	Driving Machines and Sheaves.
8.4.9.1	Seismic Requirements for Driving Machine and Sheaves.
8.4.10	Emergency Operation and Signalling Devices.
8.4.10.1	Operation of Elevators Under Earthquake Emergency Conditions.
8.4.10.1.1	Earthquake Equipment (see also Fig. 8.4.10.1.1).
Fig. 8.4.10.1.1	Earthquake Elevator Equipment Requirements Diagrammatic Representation.
8.4.10.1.2	Equipment Specifications.
8.4.10.1.3	Elevator Operation (see Fig. 8.4.10.1.3).
Fig. 8.4.10.1.3	Earthquake Emergency Operation Diagrammatic Representation.
8.4.10.1.4	Maintenance of Equipment.
8.4.11	Hydraulic Elevators.
8.4.11.1	Machinery Rooms and Machinery Spaces.
8.4.11.2	Overspeed Valve.
8.4.11.3	Pipe Supports.
Table 8.4.11.3	Pipe Support Spacing.
8.4.11.4	Counterweights.
8.4.11.5	Guide Rails, Guide-Rail Supports, and Fastenings.
8.4.11.6	Support of Tanks.
8.4.11.7	Information on Elevator Layouts.
8.4.11.7.1	Force normal to x-x axis of the rail (see 8.4.8.9).
8.4.11.7.2	Force normal to y-y axis of the rail (see 8.4.8.9).
8.4.12	Design Data and Formulae for Elevators.
8.4.12.1	Maximum Weight per Pair of Guide Rails.
8.4.12.1.1	Force Normal to x-x Axis of Rail (see 8.4.8.9).
8.4.12.1.2	Force Normal to y-y Axis of Rail (see 8.4.8.9).
8.4.12.2	Required Moment of Inertia of Guide Rails.
8.4.12.2.1	Force Normal to x-x Axis of Rail (see 8.4.8.9).
8.4.12.2.2	Force Normal to y-y Axis of Rail (see 8.4.8.9).
Table 8.4.12.2.2	Maximum Allowable Deflection.
8.4.13	Ground Motion Parameters.
8.4.13.1	For application to building codes of the United States.
8.4.13.2	For application to building code of Canada.

ASME A17.1-2004, Section 8.5
Escalator And Moving Walk Safety Requirement For Seismic Risk Zone 2 or Greater

8.5.1	Balustrade Construction.
8.5.2	Truss Members.
8.5.2.1	Lateral forces.
8.5.2.1.1	The Seismic Zone and NEHRP Maps.
8.5.2.2	Vertical Forces.
8.5.2.3	Truss Calculations.
8.5.3	Supporting Connections Between the Truss and the Building.
8.5.4	Earthquake Protective Devices.

2.2 Seismic safety for buildings

The following abbreviations are defined:

FEMA	Federal Emergency Management Agency
NEHRP	National Earthquake Hazards Reduction Program
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NSF	National Science Foundation
USGS	United States Geological Survey

The Model Building Codes in the U.S. have a greater impact on the quality of construction and how structures will withstand the forces of nature than any other NEHRP activity.

Over the past twenty years, the NSF and the USGS have accumulated a significant body of basic research work in the areas of earthquake engineering, geoscience and seismology. This fundamental research work and the use of earthquake monitoring networks by USGS have allowed the development of detailed seismic hazard maps by USGS and the development of significant earthquake engineering knowledge by NSF.

Concurrently, FEMA and NIST have developed and continued to refine the NEHRP Recommended Provisions, a guidance document for the seismic design of structures, directly incorporating the results of scientific advances of NIST, NSF and USGS. The seismic hazard maps developed by USGS are directly referenced in the NEHRP Recommended Provisions, and NSF research results are used throughout the document. This guidance document within the engineering profession is regarded as the state of the art in earthquake design guidance.

National implementation of new design standards is done through the adoption and enforcement of building codes. FEMA and USGS work with state and local governments and multi-state consortia to improve hazard identification and to promote the adoption of building codes in seismically at-risk communities and states. In addition, the NEHRP Recommended Provisions was selected by model code organizations as the basis for the seismic design provisions of the *International Building Code* [5] and the *International Residential Code*, and the *NFPA 5000: Building Construction and Safety Code* [6].

2.3 The seismic maps

The NEHRP is the U.S. Federal Government's programme to reduce the risks to life and property from earthquakes. The National Earthquake Hazards Reduction Program agencies are the Federal Emergency Management Agency, the National Institute of Standards and Technology (the lead agency), the National Science Foundation and the United States Geological Survey.

2.4 NEHRP and FEMA seismic criteria applicable to new buildings

The *NEHRP Recommended Provisions for Seismic Regulations for New Buildings* [18][19].

Guide to Application of the 1991 Edition of the *NEHRP Recommended Provisions in Earthquake Resistant Building Design* [20].

A Non-Technical Explanation of the NEHRP Recommended Provisions [21].

Seismic Considerations for Communities at Risk [22].

Seismic Considerations: Apartment Buildings [23].

Seismic Considerations: Elementary and Secondary Schools [24].

Seismic Considerations: Health Care Facilities [25].

Seismic Considerations: Hotels and Motels [26].

Seismic Considerations: Office Buildings [27].

Societal Implications: Selected Readings [28].

2.5 NEHRP and FEMA seismic criteria applicable to existing buildings

NEHRP Guidelines for the Seismic Rehabilitation of Buildings [29] [30].

Case Studies: An Assessment of the NEHRP Guidelines for the Seismic Rehabilitation of Buildings [31].

Planning for Seismic Rehabilitation: Societal Issues [32] and *Example Applications of the NEHRP Guidelines for the Seismic Rehabilitation of Buildings* [33].

NEHRP Handbook of Techniques for the Seismic Rehabilitation of Existing Buildings [34].

NEHRP Handbook for the Seismic Evaluation of Existing Buildings [35].

An Action Plan for Reducing Earthquake Hazards of Existing Buildings [36].

2.6 Civil engineering design criteria

ASCE 7-02 [3] gives current requirements for dead, live, soil, flood, wind, snow, rain, ice and earthquake loads and their combinations, which are suitable for inclusion in building codes and other documents.

The earthquake load provisions in that edition of ASCE 7-02 for the first time are now referenced in the *2003 International Building Code* [5] and the *NFPA 5000: Building Construction and Safety Code* [6]. All other ASCE 7 provisions continue to be referenced in the *2003 International Building Code*. Also included is a detailed commentary on the standard, containing explanatory and supplementary information designed to assist building code committees and regulatory authorities.

Architects, structural engineers and those engaged in preparing and administering local building codes will find the structural load requirements provided by this standard essential. The document uses both SI units and Imperial units.

2.7 Reference publications

ASME A17.1-2004/ASME A17.1a-2005 Addenda [1]. Available from the American Society of Mechanical Engineers.

AISC Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings [2]. Available from the American Institute of Steel Construction.

ASCE 7-02, Minimum Design Loads for Buildings and Other Structures [3]. Available from the American Society of Civil Engineers.

NEHRP Maps [4]. Available from the Building Seismic Safety Council and the U.S. Federal Emergency Management Agency.

2003 International Building Code [5]. Available from the International Code Council.

2002 NFPA 5000, Building Construction and Safety Code [6]. Available from the National Fire Protection Association.

2.8 Procurement information

2.8.1 American Institute of Steel Construction
1 East Wacker Drive, Suite 3100
Chicago, IL 60601
USA
Tel: ++ 312-670-2400
Web: http://www.aisc.org

2.8.2 American National Standards Institute, Inc.
25 West 43rd Street
New York, NY 10036
USA
Tel: ++ 212-642-4900
Web: http://www.ansi.org

2.8.3 American Society of Civil Engineers
ASCE Publications
1801 Alexander Bell Drive
Reston, VA 20191
USA
Tel: ++ 800-548-2723
Web: http://www.asce.org

2.8.4 American Society of Mechanical Engineers
ASME Order Department
22 Law Drive
Box 2300
Fairfield, NJ 07007-2300
USA
Tel (US & Canada): 800-843-2763, ext. 848
Tel (Outside North America): ++ 973-882-1167, ext. 848
Tel (Mexico): ++ 95-800-843-2763, ext. 848
E-mail: infocentral@asme.org
Web: http://www.asme.org/catalog

2.8.5 Building Seismic Safety Council
National Institute of Building Sciences
1090 Vermont Avenue, N.W., Suite 700
Washington, D.C. 20005
USA
Tel: ++ 202-289-7800
Fax: ++ 202-289-1092
Web: http://www.nibs.org
E-mail: bssc@nibs.org

2.8.6 Federal Emergency Management Agency (FEMA)
500 C Street, SW
Washington, DC 20472
USA
Tel: ++ 202-566-1600
Web: http://www.fema.gov

2.8.7 International Code Council
5203 Leesburg Pike
Suite 600
Falls Church, VA 22041
USA
Tel: ++ 703-931-4533
Web: http://www.iccsafe.org

2.8.8 National Fire Protection Association (NFPA)
1 Batterymarch Park
P. O. Box 9101
Quincy, MA 02269-9101
USA
Tel: ++ 617-770-3000
Web: http://www.nfpa.org

2.8.9 National Institute of Standards and Technology (NIST)
100 Bureau Drive, Stop 3460
Gaithersburg, MD 20899-3460
USA
Tel: ++ 301-975-6478
Email: inquiries@nist.gov
Web: http://www.nist.gov

2.8.10 U.S. Geological Survey (USGS)
Web: http://www.usgs.gov

3 Japan

3.1 Guide for Earthquake Resistant Design & Construction of Vertical Transportation [7]

This guide applies to elevators (lifts) and escalators to be installed in buildings. The text of the provisions were translated into English by the Japan Elevator Association for use as a reference document. The outline of the seismic requirements are listed below, in terms of the rule/clause numbers and title.

1	Basic Provision
1.1	The Application Scope
1.2	The Object of Earthquake Resistance
1.3	The Earthquake Resistant Design and Construction
1.4	The Allowable Stress
Table 1-2	Design Safety Rate of Anchor Bolt

2	Seismic Force for Design
2.1	The Calculation of the Seismic Force for Design
2.2	The Horizontal Seismic Intensity for Design
Table 2-1	Standard Seismic Intensity, K_s
Table 2-2	Coefficient of Usage, I
Fig. 2-2	Coefficient in Consideration to the Amplification Rate of Elevator Equipment
2.3	Guide Rail
Table 2-4	Reduction Rate, β
Table 2-5	Reduction Rate, α
Fig. 2-4	Engagement Dimension between Guide Shoe (Off-Stopper) and Rail
Table 2-7	Section Performance & Stress Intensity, Allowable Value of Deflection of Guide Rail
Fig. 2-5	Load Given to the Tie Bracket
2.4	The Equipment of the Machine Room
Fig. 2-6	Load and Dimensions of Equipment
2.5	The Structure of Sheave
Table 2-9	Earthquake Resistant Class and Sheave Structure
Fig. 2-62	Installation Standard of Rope Guard
Fig. 2-63	Relation between Sheave Rope Groove and Rope Radius
2.6	The Hoistway Equipment
Table 2-10	Protection Measures to the Projections
Fig. 2-70	Hoistway Equipment & Protection Measures against the Projections
2.7	The Control Operating Device in the Occurrence of an Earthquake
Table 2-12	Setting Value of Earthquake Sensor
4	Others
5	The Earthquake Measures for the Existing Elevators

3.2 Anti-earthquake design and construction in Japan [8]

This document outlines and explains the important requirements contained in the Guide for Earthquake Resistant Design & Construction of Vertical Transportation [7]. The followings points are covered:

— summary of modification;

— anti-earthquake classification and requirements;

— classification and standard seismic intensity for design, K_s;

— equations for horizontal seismic force, F_H, and horizontal seismic coefficient, K_H;

— coefficient of usage, I, and horizontal seismic coefficient, K_H;

— engagement dimension between guide shoe (off-stopper) and rail;

— installed position of intermediate stopper;

— structure of sheave;

— rope guard installation standard;

— classification height;

— protection measures;

— structure for preventing drop-out of counterweight blocks;

— anti-earthquake standard of hydraulic piping for hydraulic elevators;