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Information technology — Data centre facilities and infrastructures —

Part 30:
Earthquake risk and impact analysis

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 39, *Sustainability, IT and data centres*.

A list of all parts in the ISO/IEC 22237 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

Introduction

Parts 1, 3, 4 and 5 of the ISO/IEC 22237 series specify requirements and recommendations for the design of data centres to meet a given Availability Class. Parts 2 and 6 of the ISO/IEC 22237 series specify requirements and recommendations for the building construction and security systems for data centres.

Determination of the risk and scale of seismic activity should be included as part of the overall risk assessment approach found in ISO/IEC 22237-1. ISO/IEC TS 22237-2 requires a geographical risk analysis which includes seismic activity and relevant mitigation actions, but does not identify the specific actions to be applied. ISO/IEC TS 22237-6 addresses external environmental events but does not explicitly list earthquakes or seismic activity within that group of events (other than general vibration) or indicate the specific measures required.

Taking these points into consideration, this document provides requirements and recommendations for the type of risk assessment to be employed in the context of seismic activity and earthquakes in relation to data centres. It also describes design concepts that can be employed as mitigation actions within the construction, and other design elements, of data centres.

Information technology — Data centre facilities and infrastructures —

Part 30: Earthquake risk and impact analysis

1 Scope

This document specifies requirements and recommendations for the type of risk assessment to be employed concerning seismic activity and earthquakes in relation to data centres. In addition, it describes design concepts that can be employed as mitigation actions within the construction and other design elements of data centres.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1.1
availability
ability to be in a state to perform as required

[SOURCE: IEC 60050-192:2015, 192-01-23, modified — Note 1 to entry and Note 2 to entry deleted.]

3.1.2
computer room space
area within the *data centre* (3.1.3) that accommodates the data processing, data storage and telecommunication equipment that provides the primary function of the data centre

[SOURCE: ISO/IEC 22237-1:2021, 3.1.6]

3.1.3
data centre
structure, or group of structures, dedicated to the centralized accommodation, interconnection and operation of information technology and network telecommunications (NT) equipment providing data storage, processing and transport services together with all the facilities and infrastructures for power distribution and environmental control together with the necessary levels of *resilience* (3.1.8) and security required to provide the desired service *availability* (3.1.1)

Note 1 to entry: A structure can consist of multiple buildings and/or spaces with specific functions to support the primary function.

Note 2 to entry: The boundaries of the structure or space considered the data centre which includes the *information and communication technology equipment* (3.1.4) and supporting environmental controls can be defined within a larger structure or building.

[SOURCE: ISO/IEC 30134-1:2016, 3.1.4]

3.1.4
information and communication technology equipment
equipment providing data storage, processing and transport services

Note 1 to entry: This represents the "critical load" of the *data centre* (3.1.3).

3.1.5
peak ground acceleration
maximum ground acceleration occurring during earthquake shaking at a location

Note 1 to entry: Peak ground acceleration (PGA) is equal to the amplitude of the largest absolute acceleration recorded on an accelerogram at a site during a particular earthquake.

Note 2 to entry: Earthquake shaking generally occurs in all directions. Therefore, PGA is often split into horizontal and vertical components. Horizontal PGAs are generally larger than those in the vertical direction, but this is not always true, especially close to large earthquakes.

Note 3 to entry: The design basis earthquake ground motion (DBEGM) is often defined in terms of PGA.

3.1.6
probable maximum loss
ratio (expressed as a percentage) of the *restoration cost* (3.1.9) to the *re-procurement cost* (3.1.7) taking into account the degree of earthquake risk, the stability of ground, the earthquake resistance of the building and the earthquake resistance of the facilities

3.1.7
re-procurement cost
total cost required to reconstruct the assets damaged at the time of evaluation

3.1.8
resilience
capacity to withstand failure in one or more of the information and communication technology (ICT) equipment or *data centre* (3.1.3) infrastructures

3.1.9
restoration cost
cost required to recover the damage caused by seismic activity (earthquake)

3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

DBEGM	design basis earthquake ground motion
FL	liquefaction index
ICT	information and communication technology
IT	information technology
LPI	liquefaction potential index
NT	network telecommunications
PGA	peak ground acceleration

PL probability of liquefaction

PML probable maximum loss

PTFE polytetrafluoroethylene

SIS seismic intensity scale

SLA service level agreement

4 ISO/IEC 22237-1 Availability Classes

ISO/IEC 22237-1 defines four classes of overall availability of the set of facilities and infrastructures of the data centre, described as Classes 1 to 4, which are intended to provide increasing levels of availability.

The desired Availability Class is supported by design solutions for:

a) power supply and distribution systems (ISO/IEC 22237-3),

b) environmental control systems (ISO/IEC 22237-4),

c) telecommunications cabling infrastructure (ISO/IEC TS 22237-5).

If the data centre is to be located in a region of seismic activity, then mitigation actions are necessary in order to maintain the desired Availability Class (but not further define it).

The intention of these actions is to provide the data centre of a desired Availability Class with aseismic performance.

5 Overview of risk associated with seismic activity

5.1 Direct risk of seismic motion

5.1.1 Short-period ground motion

Ground motion denotes the positional change of an area of ground relative to objects or other areas of ground nearby in both horizontal and vertical directions.

Short-period (high frequency) ground motion can cause the structural damage generally associated with earthquakes.

A number of mitigation techniques can be employed, including rack isolators within computer room spaces and the application of base isolation techniques for the structure accommodating the facilities and infrastructures of the data centre.

5.1.2 Long-period ground motion

Long-period (low frequency) ground motion is motion with a period typically between 1 and 5 seconds. This type of ground motion can occur at significant distances from an earthquake epicentre.

Long-period ground motion can cause the structural damage generally associated with earthquakes. Mitigation techniques should be employed to support the facilities of the data centre by using base isolation techniques.

In addition, long-period ground motion and can have unexpected consequences which are not directly constructional. For example, fuel storage tanks subject to long-period ground motion are at risk of fire due to “sloshing” of the fuel contained within them.

5.1.3 Ground liquefaction

Ground liquefaction resulting from ground motion results in a significant reduction in the load-bearing capacity of the ground. This can result in the uneven settlement (or unequal settlement) of buildings comprising the facilities of the data centre.

5.2 Indirect risk initiated by seismic motion

5.2.1 Fire and toxic or damaging effluent

Even if a data centre has employed mitigation measures and is unaffected structurally during an earthquake, the data centre can be affected by fire in the local areas. These fires can produce effluent which is toxic or damaging to the equipment within the data centre.

5.2.2 Explosion

Even if a data centre has employed mitigation measures and is unaffected structurally during an earthquake, the data centre can be affected by explosions of other facilities in the local area.

5.2.3 Flooding

Even if a data centre has employed mitigation measures and is unaffected structurally during an earthquake, the data centre can be affected by flooding from damaged water supplies or from surges in natural water sources.

5.2.4 Utilities

5.2.4.1 General

Even if a data centre has employed mitigation measures and is unaffected structurally during an earthquake, the data centre can be affected by failures of utility supply including electricity, gas, water and sewerage.

5.2.4.2 Electricity

For electrical power, data centres of Availability Class 2 and above feature design solutions to provide an additional supply to support the primary supply (see ISO/IEC 22237-3). Following an earthquake, the primary supply can be subject to multiple outrages and ongoing restrictions. Where the additional supply is fuel-based then the continued supply of the fuel is critical.

5.2.4.3 Gas

Following an earthquake, damage to gas supply piping infrastructure at or in the vicinity of the data centres (typically installed underground and subject to ground instability as described in 6.3), and also to the gas supply facilities, can result in disruption to supply.

In addition, even if damage has not occurred, if a seismograph installed at a supply facility detects a certain level of earthquake motion, the supply can be automatically shut down.

In both cases, the supply will not be provided until safety has been confirmed. The length of disruption can extend from days to weeks, depending on the scale of damage and repair actions found to be necessary.

5.2.4.4 Water

Following an earthquake, damage to water supply piping infrastructure at or in the vicinity of the data centres (typically installed underground and subject to ground instability as described in 6.3), and also to the supply facilities (for water intake, water purification and water distribution) can result in disruption to supply.

In addition, even if damage has not occurred, the primary power supply to the facilities can be disrupted. Where a data centre relies on the continual provision of water, the alternative provision of power to supply facilities should be assessed.

The length of disruption can extend from days to weeks, depending on the scale of damage and repair actions found to be necessary. Extreme situations have been known to extend this period to months.

5.2.4.5 Sewerage

Following an earthquake, the impact of damage to sewerage piping infrastructure and facilities serving the data centre should be considered to be similar to that of the water supply.

5.2.5 Access

Even if a data centre has employed mitigation measures and is unaffected structurally during an earthquake, the roads surrounding and leading to the data centre can be damaged and even destroyed.

This can restrict access for:

a) emergency services to address events (e.g. fires) in the local area which can increase associated for the operation of the data centre; and

b) the ongoing provision of consumables to the data centre.

5.2.6 Transport

Even if a data centre has employed mitigation measures and is unaffected structurally during an earthquake, the road and rail infrastructure surrounding and to the data centre can be damaged and even destroyed. In addition, local regulations can restrict the type of vehicles allowed to use that infrastructure to emergency and authorized vehicles.

This not only affects supply of consumables to the data centre but can restrict the availability of personnel to operate the data centre.

Even if access to the data centre is unaffected, the earthquake can reduce the availability of appropriate vehicles e.g. a lack of fuel tankers can limit the provision of fuel for additional power supplies.

5.2.7 Security systems

Measures intended to prevent unauthorized access and intrusion across the Protection Class boundaries of the data centre (see ISO/IEC TS 22237-6) can be damaged.

6 Seismic activity risk assessment

6.1 General

Determination of the risk and scale of seismic activity should be included as part of the overall risk assessment approach that assesses the risks and events that potentially impact the data centre. Further guidance in relation to the risk assessment approach can be found in ISO/IEC 22237-1.

Following the determination of the risk and scale of seismic activity, appropriate mitigation actions should be employed.

Subclause 6.2 addresses ground motion.

Subclause 6.3 address ground stability (liquefaction).

6.2 Ground motion

The basis of the risk assessment can be the various national and regional seismic hazard maps which typically show the probability of an earthquake in a given geographic area, within a given time period, and with ground motion intensity exceeding a given threshold.

The time periods and thresholds vary from country to country but are typically in the region of 30 to 50 years with PGA in the range of 0,3 g (3 m/s^2) to 0,5 g (5 m/s^2) respectively.

For a given earthquake, the PGA will differ for the locations affected depending on a number of parameters, the most obvious of which is distance. Table 1 shows the range of PGA values associated with recognized seismic intensity scales (SIS).

Table 1 — PGA and SIS

PGA m/s^2	0,25 to 0,80		0,80 to 1,40	1,40 to 2,50	2,50 to 3,15	3,15 to 4,00	> 4,00
Mercalli SIS	V to VII		V to VIII	VI to IX	VIII to X	IX to X	X to XII
Japanese shindo SIS	4		5		6		7
			5 lower	5 upper	6 lower	6 upper	
	3,5 to 3,9	4,0 to 4,4	4,5 to 4,9	5,0 to 5,4	5,5 to 5,9	6,0 to 6,4	> 6,5

A SIS is associated with the probable type of damage. Table 2 indicates the type of damage associated with a given PGA value.

Table 2 — PGA and typical damage

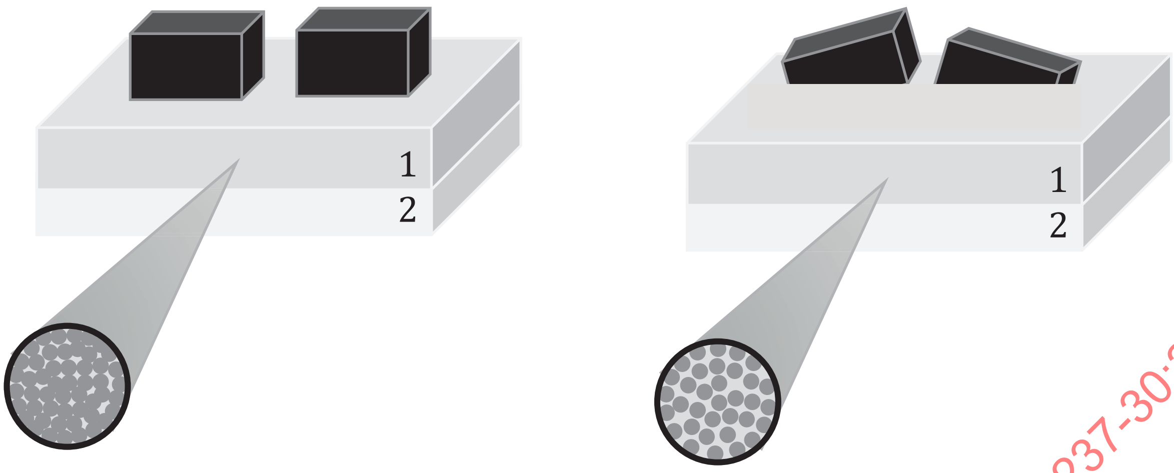
PGA range	**Impact on buildings**	**Impact on outside spaces**	**Impact on utilities**
0,25 to 0,80	Normal buildings can receive slight damage. Earthquake-resistant buildings will survive, most likely without damage.	No landslides or cracks occur.	Primary power supply can fail for a short time.
0,80 to 1,40	Cracks are formed in walls of normal buildings. Earthquake-resistant buildings suffer slight damage.	Cracks can appear in soft ground. Rockfalls and small slope failures take place.	Primary power supply can be interrupted. Safety devices can cut off the gas supply. Water pipes can be damaged and supply interrupted.
1,40 to 2,50	Medium to large cracks are formed in walls. Crossbeams and pillars of earthquake-resistant buildings can suffer cracks.	Cracks can appear in soft ground. Rockfalls and small slope failures take place.	Primary power supply can be interrupted. Gas pipes and water mains are damaged and supplies interrupted in certain areas.
NOTE 1 The term "normal buildings" in this table refers to buildings without earthquake-resistant features.			
NOTE 2 The PGA of 3,15 is the boundary commonly used to differentiate “damage” from “severe damage”.			

Table 2 *(continued)*

PGA range	Impact on buildings	Impact on outside spaces	Impact on utilities
2,50 to 3,15	Normal buildings receive heavy damage and can be destroyed. Earthquake-resistant buildings can suffer large cracks in walls and will be moderately damaged. In some buildings, wall tiles and windowpanes are damaged and fall.	Small to medium cracks appear in the ground. Larger landslides take place.	Primary power supply can be interrupted. Gas pipes and water mains are damaged and there can be widespread interruption of supply.
3,15 to 4,00	Walls collapse or are severely damaged. Normal buildings collapse. Earthquake-resistant buildings suffer severe damage.	Cracks can appear in the ground, and landslides take place.	Primary power supply is interrupted. Gas pipes and water mains are damaged and there can be widespread interruption of supply.
> 4,00	Most or all buildings suffer severe damage.	The ground is considerably distorted by large cracks and fissures, and slope failures and landslides take place, which can change topographic features.	Electrical, gas and water supplies are interrupted.
NOTE 1 The term "normal buildings" in this table refers to buildings without earthquake-resistant features. NOTE 2 The PGA of 3,15 is the boundary commonly used to differentiate “damage” from “severe damage”.			

6.3 Ground stability

Soil liquefaction following seismic activity represents risk to buildings and other structure as shown in the schematic of Figure 1. On stable soil, grains are held together by friction with water filling any gaps (see Figure 1a). Shaking increases the gaps between grains, such that soil loses structure and behaves like a liquid, i.e. buildings sink as soil stability reduces (see Figure 1b).



a) Stable soil b) Liquefied soil

Key

1 soil

2 bedrock

Figure 1 — The effect of soil liquefaction

Where there is an identified risk of seismic activity, a risk analysis addressing ground stability should be undertaken which includes the calculation of the liquefaction potential index (LPI). LPI is the integration of the values obtained by integrating the liquefaction index (FL) for each stratum in the ground at a certain point, so the value is larger than 1, and the more layers are liquefied, the larger the value. Table 3 indicates the outcome of such analysis.

NOTE The possibility of liquefaction is defined in Reference [11], subclause 2.1.1. It differs from the "probability of liquefaction (PL)," which can also be found in literature.

Table 3 — LPI value and risk of liquefaction

LPI value	Risk of liquefaction	Measures to be taken
LPI = 0	Very low	Detailed surveys on liquefaction are not necessary in general.
0 < LPI ≤ 5	Low	Detailed surveys are necessary when particularly important structures are designed.
5 < LPI ≤ 15	High	Detailed surveys on important structures are necessary. Measures against liquefaction are recommended.
15 < LPI	Extremely high	Detailed surveys on liquefaction and measures against liquefaction are required.

6.4 Evaluation by probable maximum loss (PML)

6.4.1 General

While information regarding PGA and LPI provides a technical basis for seismic activity risk assessment, a more commercially-based source of information is PML. The larger the PML value, the higher the earthquake risks of the building is estimated to be. In some respects it maps to the PGA of Table 2 (see Table 4).

Table 4 — Example of evaluation criteria of PML

PML (%) [a]	Risk level [a]	Predicted damage [a]	Indicative PGA
0 to 10	Extremely low	Slight damage of structures	0,25 to 0,80
10 to 20	Low	Partial damage of structures	0,80 to 1,40
20 to 30	Medium	High possibility of intermediate damage	1,40 to 3,15
30 to 60	High	High possibility of large damage	3,15 to 4,00
More than 60	Extremely high	High possibility of collapse	> 4,00

[a] This information is taken from JDCC Facility Standard Version 2.2.[11]

PML evaluation can influence the amount of reinsurance ceded on a risk.

6.4.2 Advantages and disadvantages

6.4.2.1 Advantages

The PML evaluation should consider the predicted ground motion and ground stability together with the earthquake resistance of the buildings, the facilities and infrastructures of the data centre.

The PML evaluation provides a result shown using numerical values, which makes it straightforward to understand for non-experts.

PML evaluation is the global standard for evaluation of earthquake risks in the domains of insurance and real-estate, and comparison with other countries is simple.

6.4.2.2 Disadvantages

PML evaluation should be undertaken by experienced third-party organizations. Several PML evaluation methods exist and they have not been unified. The results can differ substantially depending on the methods and the organization undertaking the evaluation.

NOTE Evaluation method PML3 takes building collapse into account and is appropriate for earthquake risk.

Future PML evaluations can change due to new knowledge and methods.

7 Seismic activity risk mitigation

7.1 Direct risk of seismic motion

7.1.1 General

The size and complexity of data centres can vary enormously. The largest and most complex will comprise many spaces and structures associated with the facilities and infrastructures necessary to maintain the function of the computer room space and the connections between the computer room space and the access networks.

The criticality of each of the spaces to the function of the computer room space should be assessed and structural mitigation appropriate to the level of seismic risk should be employed. However, all spaces should be considered in terms of personnel safety during the earthquake and the ability for those spaces to support operation after the earthquake.

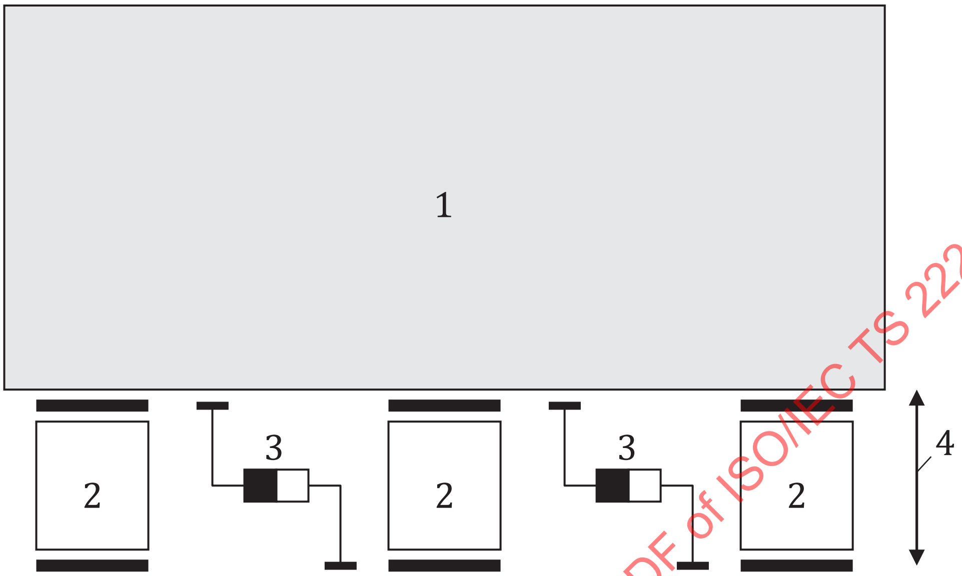
Structural mitigation is applied to complete or parts of buildings by mounting the building or relevant part on an isolation base (see 7.1.2) or, in the specific case of cabinets, frames or racks of computer room space, by mounting them on rack isolators (see 7.1.3.1).

It is highlighted that both building or local mitigation techniques should consider long-period ground motion which has been shown to be a risk for all structural mitigation solutions.

7.1.2 Structural mitigation using isolation base techniques

7.1.2.1 General

Figure 2 shows a structure supported on an isolation base using a combination of damper (see 7.1.2.2) and isolation techniques (see 7.1.2.3).



Key

1 data centre structure

2 isolator

3 damper

4 seismic isolation layer

Figure 2 — Structure with an isolation base

The pathways providing connection between the spaces of the data centres (including power, gas, fuel, water, sewerage, environmental control and telecommunications) should be designed to survive the predicted seismic risk. This can include extra lengths of cables, piping, etc. with an appropriate flexibility to survive the predicted differential ground motion between the spaces.

7.1.2.2 Passive damper technologies

Figure 3, Figure 4 and Figure 5 show examples of passive dampers.

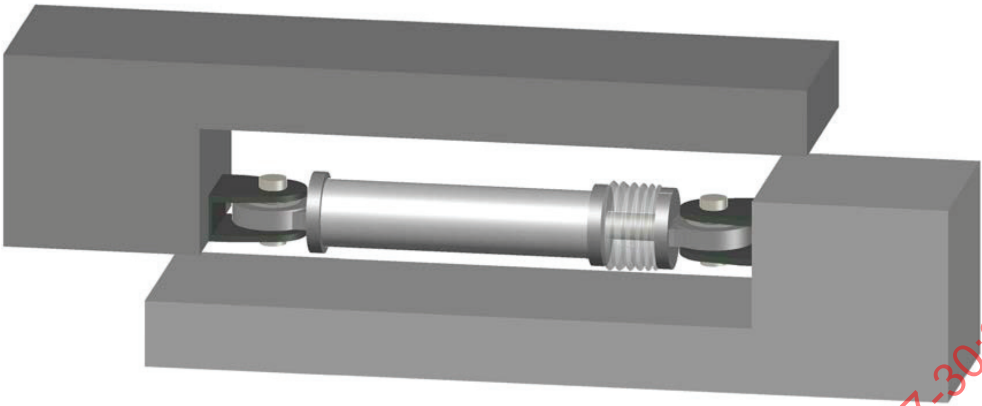


Figure 3 — Oil damper

Figure 4 — Lead damper

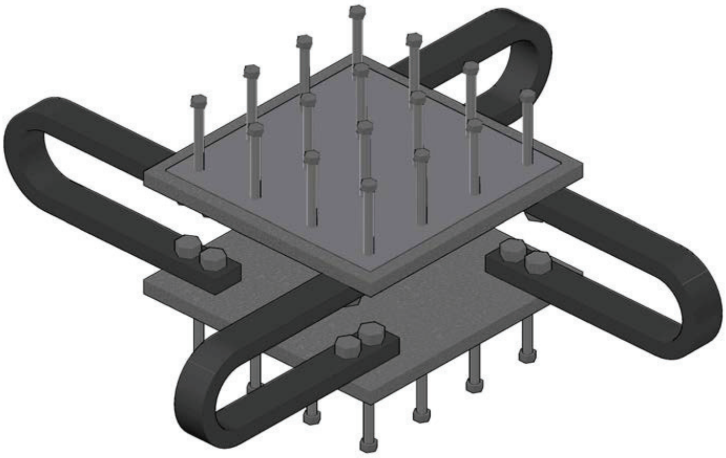


Figure 5 — Steel damper

7.1.2.3 Base isolation technologies

Figure 6, Figure 7 and Figure 8 show examples of base isolation.

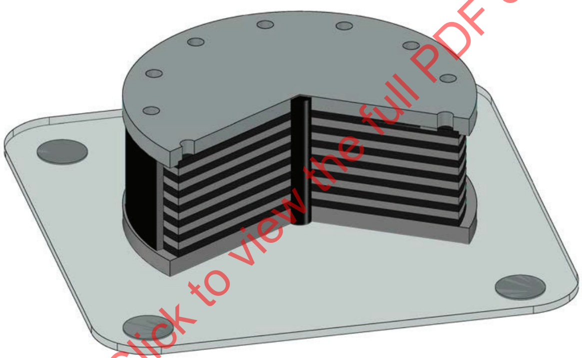


Figure 6 — Laminated rubber isolator

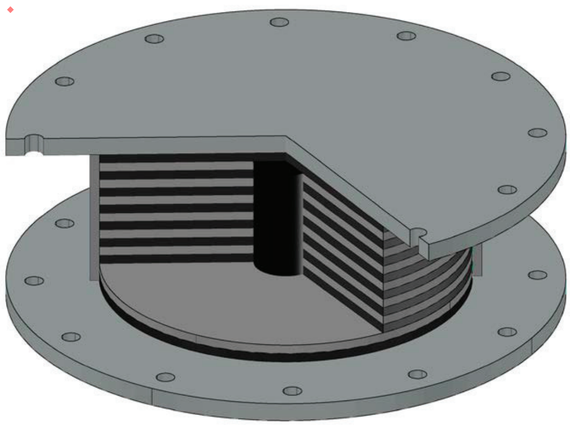
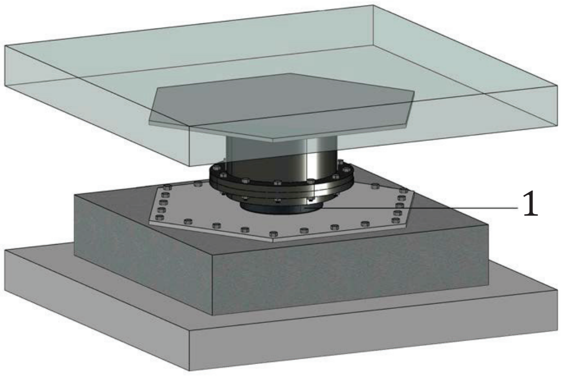


Figure 7 — Laminated rubber isolator with lead plug



Key:

1 Polytetrafluoroethylene (PTFE)

Figure 8 — Sliding bearing

7.1.3 Localized mitigation

7.1.3.1 Rack isolation

Data centre spaces accommodating information technology (IT) equipment critical to the service provided by the data centre can have base isolation structures or more localized mitigation.

Equipment mounted in cabinets, racks and frames can potentially fall over during an earthquake thereby damaging the equipment and connections to it.

Cabinets, racks and frames can be installed directly on the floor slab, on floor panels or on an access floor.

If installed on the floor slab within an isolated base structure, the following mitigation should be applied:

— fixing to the floor slab using anchor bolts, etc.;

— fixing to a steel base (which is fixed on a floor slab using anchor bolts) using bolts;

— fixing to a rack isolator plate (see Figure 9).

When subject to long-period ground motion, the cabinets, frames or racks can fall over when the isolation rack base reaches the end of its movable range. This can also apply to isolation base structures. This needs to be considered in any design solution implemented and effective fixing is necessary.

NOTE This figure shows an ISO-Base™ seismic isolation platform from WorkSafe Technologies[1)].

SOURCE WorkSafe Technologies, reproduced with the permission of the authors.

Figure 9 — Rack isolator

If installed on a floor panel, the floor panels should be fixed using bolts, fixing clips or fixing claws.

Mitigation actions for the access floor include the use of seismic columns or stringers (with seismic columns being preferred to maximize underfloor space).

If installed on an access floor, the following mitigation should be applied:

— fixing using bolts on anti-seismic reinforcement such as angles installed in the access floor (without obstructing any airflow required for the environmental control system);

— fixing to a floor panel (which is fixed on a supporting column using bolts) of an access floor with anti-seismic reinforcement, such as bolted stringers.

Independent of the approach taken, the clearance surrounding the cabinets, frames and racks should take into account the predicted range of movement.

7.1.3.2 Pathways, pathway systems and cabling

The pathways providing a connection to the cabinets, frames and racks and other equipment and closures should be designed to survive the predicted seismic risk. This can include pathway systems incorporating extra lengths of cables with an appropriate flexibility to survive the predicted differential ground motion.

Power distribution and telecommunications cables should be located or design to be protected against damage from falling equipment.

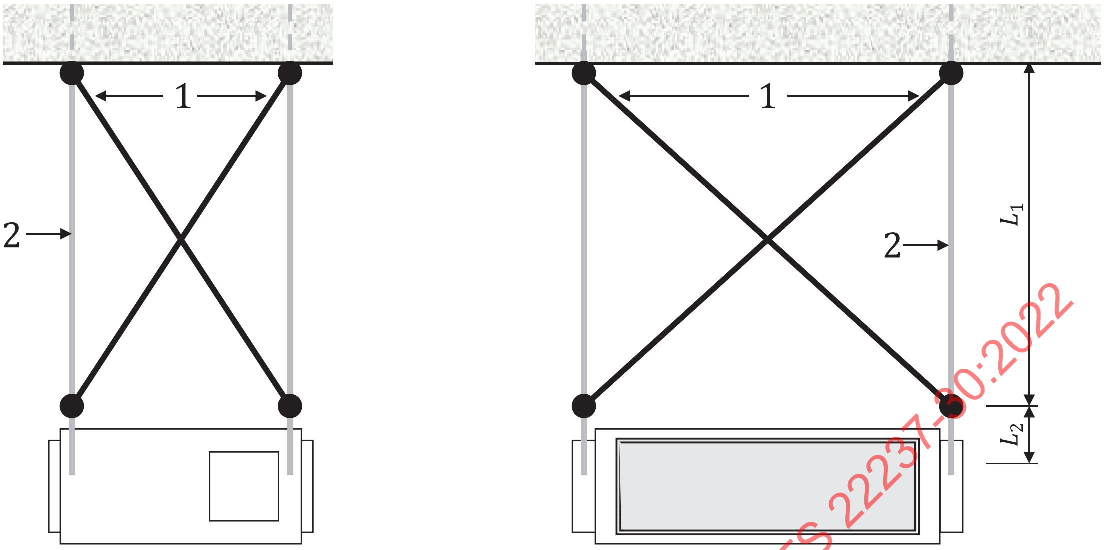
7.1.4 Roofs and ceiling supports

7.1.4.1 Suspended equipment of mass 16 kg to 100 kg

When lighting equipment is suspension-supported from an upper slab or steel-frame using steel bars, diagonal aseismic anti-vibration bars (two steel bars) should be installed on each vertical plane formed by the two steel bars for suspension (see Figure 10).

NOTE Equipment suspended using four suspension bars will be fitted with eight seismic anti-vibration bars.

1) ISO-Base™ is the trademark of a product supplied by WorkSafe Technologies. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.



a) Side face of equipment

b) Front face of the equipment

Key

1 aseismic anti-vibration bars

2 suspension bar(s)

L_x suspension length

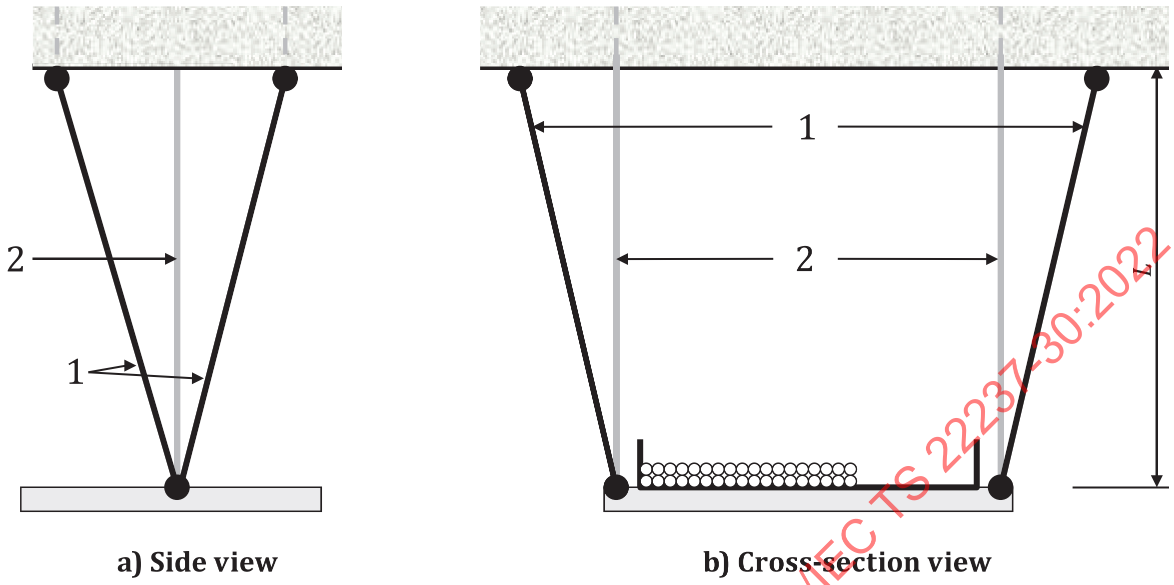
Figure 10 — Equipment suspended from roof/ceiling slab

Steel rods should be used where the suspension length (L_1+L_2) ≤ 1,5 m (with L_2 < 0,2 m).

Steel bars should be used where the suspension length (L_1+L_2) > 1,5 m (with L_2 < 0,2 m).

7.1.4.2 Suspended ducts and cable management systems of mass 16 kg to 100 kg

Where environmental control ducting or cable management systems are suspended from an upper slab or steel-frame using pairs of steel bars (full thread bolts), seismic anti-vibration bars (six steel bars in total) shall be installed in the direction of the axis of the duct or cable management system and the direction perpendicular to it (see Figure 11).



Key

1 aseismic anti-vibration bars

2 suspension bar(s)

L suspension length

Figure 11 — Example of duct or cable management systems suspended from roof/ceiling slab

7.1.4.3 Lighting systems in suspended ceilings

Seismic measures of lighting equipment for suspended ceiling systems should:

— connect lighting equipment to a suspension member of the ceiling using two or more anti-drop wires; or

— fix lighting equipment on a T-bar using a fitting, and fix it using a dedicated uplift prevention fitting that is inserted into a lug of the T-bar (see Figure 12).

Uplift prevention fittings should be mounted at intervals of 600 mm or less along the edge of lighting equipment.