EN 81-77:2022 – Safety Rules for Lifts in Seismic Conditions

Current status and future developments of this European harmonized standard"

EN 81-77: Lifts in Seismic Conditions – Overview and Requirements

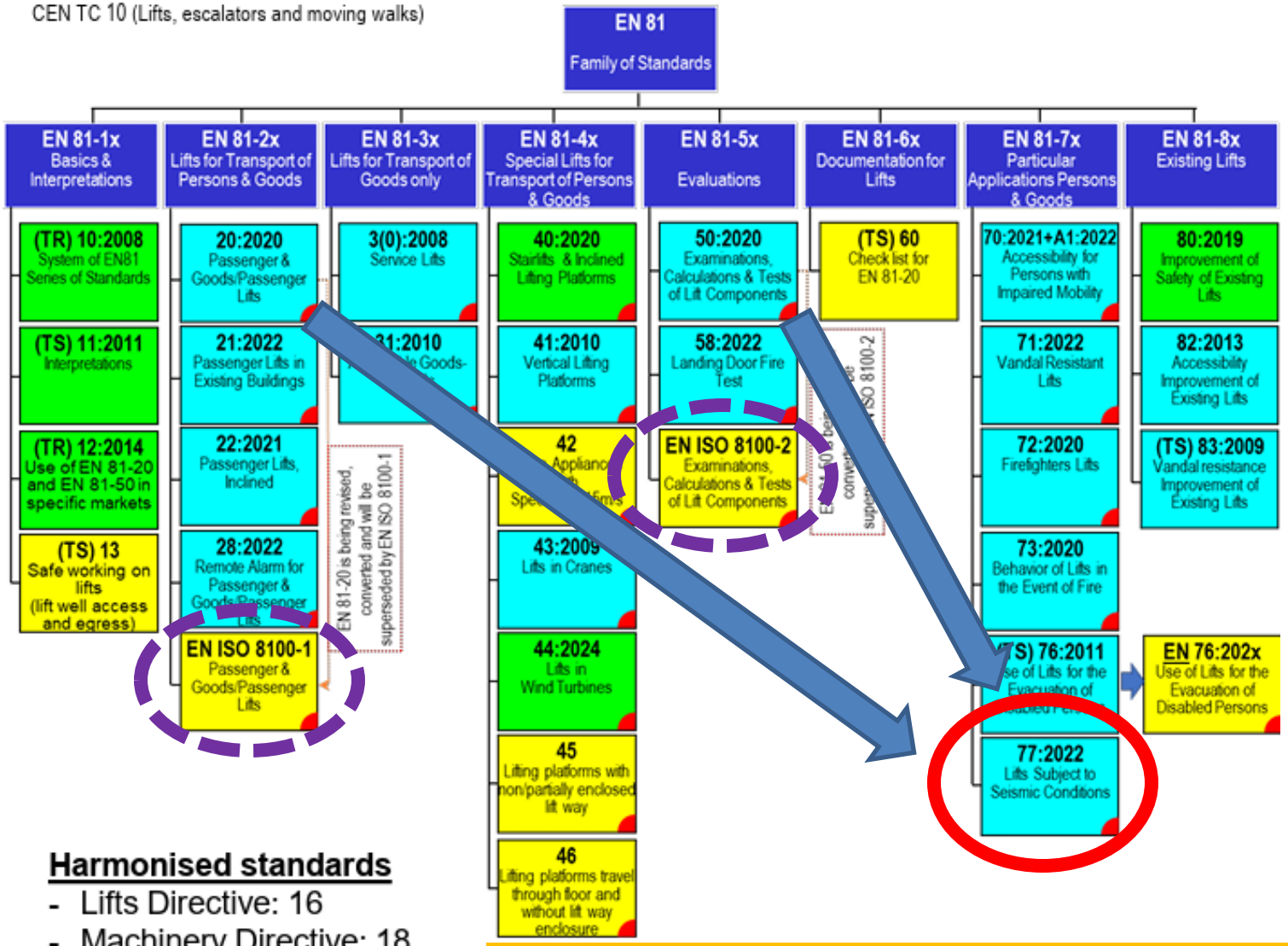
- **EN 81-77:2022** is part of the EN 81 series and addresses **additional safety requirements for lifts in seismic zones**
- Developed to ensure **passenger safety** and **lift functionality** during and after seismic events
- Applies to:
  - Passenger and goods-passenger Electric traction lifts
  - Passenger and goods-passenger Hydraulic lifts
- Works **in conjunction** with EN 81-20 and EN 81-50
- Based on **Eurocode 8 (EN 1998-1)** for seismic actions

EN 81-77: 2013
EN 81-77: 2018
EN 81-77: 2022

- *Applies in EU countries where lifts are installed in seismically active areas*

CEN/TC 10 Work program
Overview

CEN TC 10 (Lifts, escalators and moving walks)



Harmonised standards

- Lifts Directive: 16
- Machinery Directive: 18
- EMC Directive: 2

In lifts and elevators sector total of
31 work items (excluding escalators and MW, EMC, Risk Assessment, buolders hoiists, etc…)

How EN 81-77 Fits into the European Regulatory Framework

- **EN 81-20 / EN 81-50** → baseline safety requirements
- **EN 81-77** → additional rules when seismic action is relevant
- Is based on **EN 1998-1 (Eurocode 8)** to define:
  - Seismic design acceleration (**ad**)
  - Importance class of the building and other parameters

- **Harmonised under the Lift Directive 2014/33/EU**

- *National Annexes to Eurocode 8 determine local seismic design parameters*

Design acceleration a_d

- For the purpose of the standard lifts have been divided into categories, taking into account the design acceleration ($\mathbf{a_d}$)
- $\mathbf{a_d}$ is the acceleration to be used for calculation of forces – moments acting on lift systems and arisen from seismic events

Subdivision of the lifts in categories considering the

design acceleration

- a_d is function of peak ground acceleration and other factors (type of soil, importance building factor, the natural vibration period of the building, and all the other parameters stated in EN 1998 – Eurocode8)
- This value has to be provided by the **owner of the building**
- The next table shows the seismic lift categories

Lifts categories

Design Acceleration (m/s^2)	Effect on buildings	Lift Cat.	Comment
$a_d < 1$	No building damage	//	The requirements of EN81-20 and EN81-50 are adequate **no additional action is required**
$1 \leq a_d < 2,5$	Minor building damage	1	**Minor corrective action required** (as required in Clause 5 for Category 1 lifts)
$2,5 \leq a_d < 4$	Substantial building damage	2	**Substantial corrective action required** (as required in Clause 5 for Category 2 lifts)
$a_d \geq 4$	High building damage	3	**More substantial corrective action required** (as required in Clause 5 for Category 3 lifts)

Key Design & Safety Requirements under EN 81-77

Component	**Seismic Requirement**
Guide Rails & Fixings	Must resist lateral seismic forces; fixings spaced per SLC level
Counterweight System	Must prevent derailment using safety devices or guide shoe systems
Suspension System	Strength verified against dynamic effects; protect from loss of traction
Buffers & Pit Equipment	Must withstand seismic displacements without critical damage
Clearances	Increased horizontal clearances between car and shaft walls
Control System	Optional seismic detector to stop lift at nearest floor during tremor

- *Seismic Lift Categories (SLC 1–3) determine design stringency*

Loads and forces

- The car structure and retaining devices shall be sufficient to withstand the loads and forces imposed on them including forces generated by the design acceleration ($\mathbf{a_d}$)
- *For passenger lifts shall be taken into account the mass of the car plus 40% of the rated load*
- *For goods passenger lifts shall be taken into account the mass of the car plus 80% of the rated load*

- Let’s have a look to examples of seismic damages on lifts

Example of damage

- Car, counterweight, balancing weight move out from guide rails

- The guide rail stiffness must be increased; guide rails, joints and attachments shall comply with requirements of EN 81-20 and EN 81-50 and they shall withstand the loads and forces generated by the design acceleration (**ad**)

P. 1 e 2 from: *Terremoto in Umbria, gli effetti sugli ascensori*; Elevatori, March-April 1998

Example of damage

- Machinery and main equipment in the machinery space overturns and/or is displaced as a result of seismic forces

- Machinery, pulleys, and other devices i.e. overhead beams and supports, rope attachments, overspeed governor, tension pulley, compensation ropes tension devices, shall be anchored to prevent overturning and displacement as a result of the forces imposed on them including forces generated by the design acceleration (**ad**)

P.1, 2: electric lift installed in L'Aquila

Example of damage

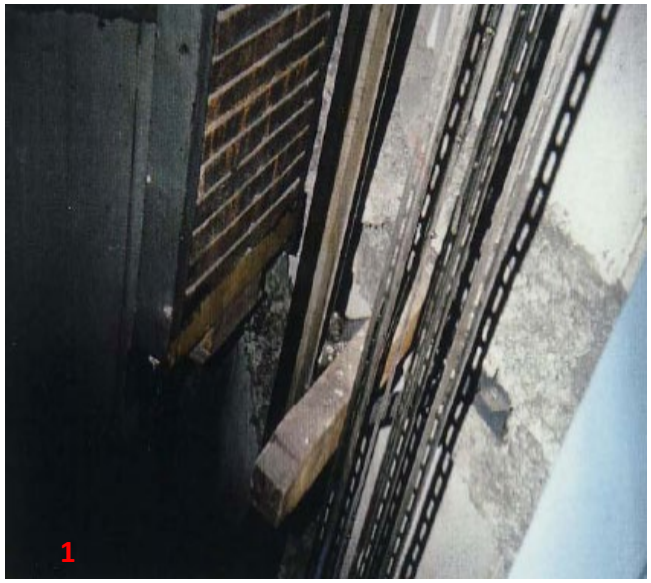
- Machinery and main equipments in the machine room overturns and/or is displaced as a result of seismic forces

P. 1 from: *Terremoto in Umbria, gli effetti sugli ascensori*; Elevatori, Marzo-Aprile 1998

P. 2: : electric lift installed in L'Aquila

Example of damage

- Weight blocks of the counterweight or balancing weight coming out from the frame



If the counterweight or the balancing weight incorporates filler weights, necessary measures shall be taken to prevent their movement outside the frame

P. 1 from: *Aesismic Design Guideline For Elevators in Japan*; Japan Elevator Assosiacion, 25 Apr. 2008

P. 2 from: *From the Wenchuan Seism: Statistics & Analysis of Elevator Dameges in Xi'an*; Elevator World, November 2008

Example of damage

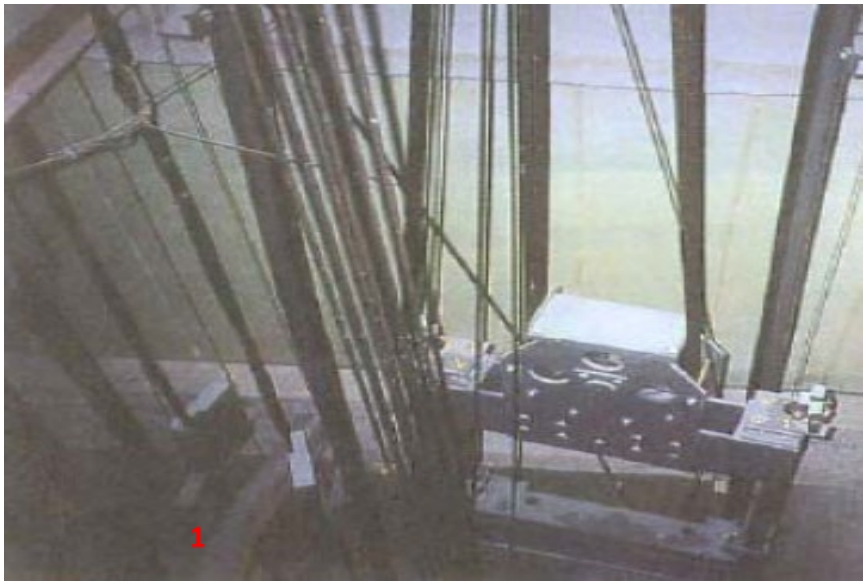
- Car, counterweight, balancing weight goes out from guide rails

P. 1, 2, 3: electric lifts installed in L'Aquila

- For some defined lift categories as protection measure for car and counterweight (or balancing weight) shall be provided **retaining devices** able to hold the frame on its guide rails
- The retaining devices shall be placed in such a way to distribute loads in a similar way as the guide shoes
- The retaining devices shall either be integrated or mounted close to the guide shoes

Example of damage

- Ropes/chains swaying in the shaft and becoming snagged on fixed devices in the shaft as for example the guide fixing or ramps



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P.2 from: *From the Wenchuan Seism: Statistics & Analysis of Elevator Dameges in Xi'an*; Elevator World, November 2008

After a long discussione WG1 agreed to introduce a mixed approach for this argument:
-Jea guide approach for the height of the well
-- ASME A17 approach for the horizontal distances between snag points

In order to prevent that suspension ropes, governor ropes, travelling cables, compensation ropes and chains, swaying in the well, get entangled with fixed equipment, snag points created by brackets, sills, devices and other equipment mounted in the well shall be protected according to the following Table and Figure

Height of the well	Horizontal distance of snag points	Item No.1	Protected Equipment	Protection Measures	Construction Scope
Below 20 m				Not necessary due to very small shake (displacement) of buildings	
Below 60 m over 20 m	915 mm (Intermediate point of the travelling cables located 915 mm or less horizontally from a snag point)	(1)	Travelling cables	Stretch a protection wire in the corner of the rail bracket near the travelling cables.	Area lower than the intermediate point of the travel.
		(2)	Travelling cables	Install a protection mesh cover or protector in the middle beam of the travelling cables. But, the use of the protector is permitted only for the elevators below 1,75 m/s at speed.	In case of placing the tail code along the middle beam, lower than the middle of the travel.
	760 mm	(3)	Compensating Chain(s), Compensating rope(s), Counterweight governor rope	Stretch a protection wire in the corner of the rail bracket of the counterweight.	Full travel in case of installing either of the compensating chain or compensating rope or counterweight governor.
	500 mm	(4)	Governor rope	Install a rope guide and protector. Otherwise use protection wire.	Keep pitch below 20 m to the return rope. But, in case of installing the governor rope on the inductor plate, below 15 m pitch, install around the surroundings so that the rope will not touch the well switch.
	300 mm	(5)	Suspension ropes	Install a tape guide and protector. Otherwise use protection wire.	Keep pitch below 20 m to the return rope. But, in case of installing the suspension ropes on the inductor plate below 15 m pitch, install around the surroundings so that the ropes will not touch the well switch.
Over 60 m	Protect all snag points independently from horizontal distance	(1) - (5)	Ditto	Ditto	
		(6)	Travelling cables	Install a protector or a protection wire.	Install in the sill and the header edge in the travelling cables. (Below the intermediate area of the travel distance).

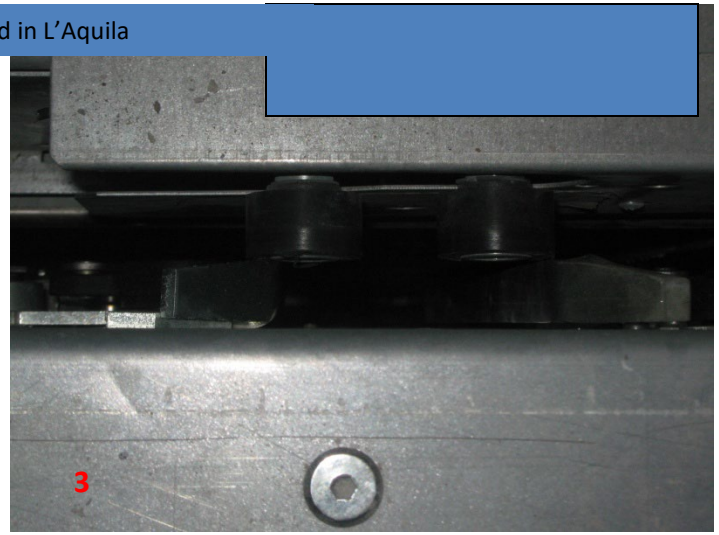
Note 1 Items in ( ) correspond to numbers in circles in Figure 1

Example of damage: Machinery and pulley spaces

- The different parts of the building move apart and the devices of the lift are subject to displacement

Where buildings are designed with expansion joints subdividing the structure into dynamically independent units, the machinery and the well of electric lifts shall be located on the same side of an expansion joint

P. 1, 2, 3: electric lifts installed in L'Aquila



Example of damage

- Ropes/chains (including governor rope and compensation ropes) come out from traction sheave or diverting pulley

P. 1-2 from: *From the Wenchuan Seism: Statistics & Analysis of Elevator Dameges in Xi'an*; Elevator World, November 2008

Suspension, compensation and overspeed protection

- The devices for preventing the ropes from leaving the grooves of pulley shall include one retainer at the points where the ropes enter and leave the pulleys
- Continuous guards are allowed and shall protect the full arc of contact between rope and its pulley
- The strength and stiffness of the continuos guards or the retainers and their distance to the pulleys compared to the diameter of the ropes shall be such that they are effective
- In case of retainers, WT5 has also defined a minimum acceptable angle of wrap

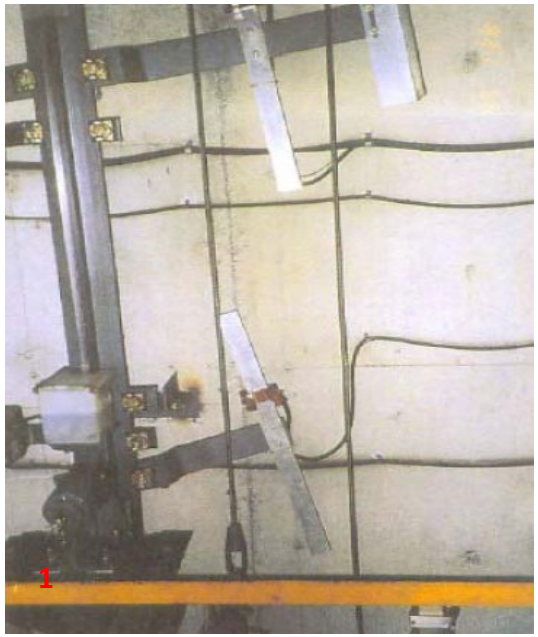
Suspension, compensation and overspeed protection

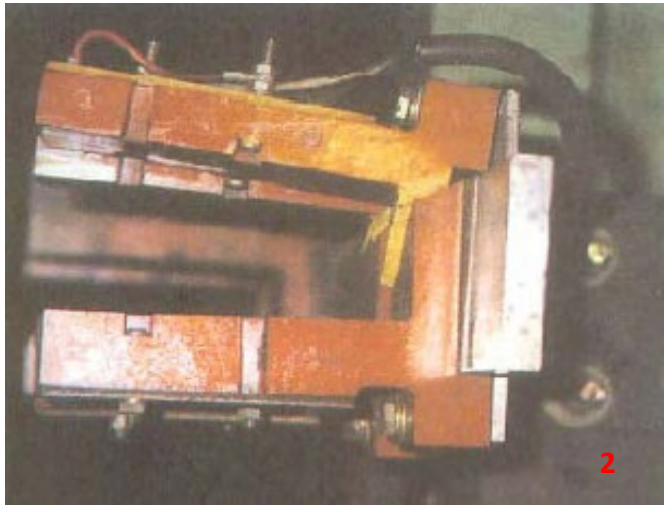
- Compensation chains shall be guided in the pit in order to limit them from swaying and being caught on snag points
- Hydraulic lifts shall be provided with a rupture valve (to avoid overspread governor, but especially for the rope of the over speed governor

Electric installations and appliances

Example of damage

- Landing switch devices or final limit switches are broken due to the fact the car moves and devices fixed on the car enter in contact with vane and ramps fixed in the shaft





The fixing of landing switch devices or final limit switches, vanes or similar devices fixed in the shaft shall be designed to withstand the loads and forces imposed on them including forces generated by the design acceleration (**ad**)
In addition the devices mentioned above shall be protected by guards from swaying ropes and cables in the shaft

P. 1-2 from: Presentazione *Aesismic Design Guideline For Elevators in Japan*; Japan Elevator Assosiacion, 25 Apr. 2008

Example of damage

- The behavior of the lifts in case of earthquake has to reduce the risk for passengers being trapped in a car in the event of earthquake in a building

P. 1: hydraulic lift installed in L'Aquila

2 different operations:
- in case of failure of the normal power supply
- in seismic mode (special mode in which the lift performs after detection of seismic trigger level)

Behaviour of the lift in case of failure of the normal power supply

- In case of seismic events, for seismic lift category 3, in order to avoid people to be trapped in the car **in case of failure of the normal power supply**, the lift has to be able to move automatically the car to the next landing in up or down direction
- At landing the lift shall operate as described below:
  - a lift with automatic power operated doors, when parked at a landing, shall open the doors, remove the lift from service and keep the door open
  - for a lift with manually operated doors, when the car arrives at the designated landing, its door(s) shall be unlocked and the lift removed from normal service

Seismic mode = Seismic Detection System

- A seismic detection system shall be provided for **lifts with counterweight or balancing weight** **in seismic lift category 3**
- The Seismic detection system is part of the building, provided from the owner of the building
- Where the seismic detection system is used exclusively to control the lift, the seismic detection system shall be placed in the pit of the lowest lift in the building adjacent to load bearing building structural members

Seismic Detection System

- The seismic detection system shall comply some technical specification (in progress, taking in account codes, standards and products available)

Seismic Detection System

- **The seismic detection system shall comply to the following specifications:**
- detection of tri-axial acceleration
- seismic trigger level ≤ 1.00 m/s^2 in any direction including vectors
- frequency response between 0,5 – 10 Hz
- system reaction time ≤ 3 sec (≤ 1 sec after China comment)
- automatic system test ≤ 24 hours
- emergency power supply back-up system for ≥ 24 hours
- manual reset of alarm trigger

Seismic mode

- After activation of the seismic detection system, the lift shall perform as described below:
  1) all registered car and landing calls shall be cancelled; new calls shall be ignored
  2) a lift with automatic power operated doors, when parked at a landing, shall open the doors, remove the lift from service and keep the door open
  3) a lift with manually operated or non-automatic power operated doors, if parked at a landing, shall remain in this condition and be removed from service with the doors unlocked
  4) a lift in motion shall reduce the speed or stop and proceed to the next landing in up or down direction with maximum 0.3 m/s car speed. At landing operate as described above in (2) or (3)

About Notices, markings and operating instructions

- Maintenance instruction provided by the installer shall take into account the information for maintenance personnel to properly check the lift (also after an earthquake)

Primary wave detection system

(Annex B – Informative)

- **Subject to negotiation, provided from the owner of the building (part of the building),** in addition to the seismic detection system, **in seismic lift category 3, a primary wave detection system** may be provided complying with the following specifications:
  - primary wave trigger level ≤ 0,10 m/s^2
  - sensing direction: vertical
  - frequency response: 1 – 10 Hz

Technical specifications

P-wave and S-wave

primary wave

- types of elastic waves produced by earthquakes. Earthquake advance warning is possible by detecting **the non-destructive primary waves that travel more quickly** through the Earth's crust than do the destructive secondary waves. The amount of advance warning depends on the delay between the arrival of the primary wave and other destructive waves, generally in the order of seconds for distant, large quakes

secondary wave

- waves produced by earthquakes; they are also named shear waves because they move through the body of an object, unlike surface waves. The secondary wave moves as a shear or transverse wave, so motion is perpendicular to the direction of wave propagation. **The secondary waves are destructive and arrive later than primary waves**

Primary wave detection system

(Annex B – Informative)

- In case a primary wave detection system is provided, **after activation of the primary wave detection system, but no activation of the seismic detection system**, the lift shall operate as described below:
  - a lift parked at a landing shall remain in this condition for the next 60 seconds. If, during this time, the seismic detection system is activated by a seismic signal, the lift shall go into the seismic mode, otherwise the lift shall be automatically switched back into normal operation

Primary wave detection system

(Annex B – Informative)

- a lift in motion shall reduce the speed or stop and proceed to the nearest floor in up or down direction with maximum 0,3 m/s car speed.
- At landing: a lift with automatic power operated doors shall open the doors and remain in this condition for 60 seconds after initiating stand-by mode; a lift with manually operated or non-automatic power operated doors shall unlock the doors and remain in this condition for 60 seconds after initiating stand-by mode.
- If, during this time, the seismic detection system is activated by a seismic signal, the lift shall operate as described in 5.9.5, otherwise the lift shall be automatically switched back into normal operation

To summarize:

P-wave Seismic Detection System

- Detection of seismic waves will activate control management of the car movement in order to:
  - put the car in safety status attending the expected seismic event
  - restart the car in the case of no seismic event in order to optimize safety of users and units and minimize loss of time in job activities in the building

…from 2018 to 2022 version…

- The version EN 81-77:2022 supersedes EN 81-77:2018
- In comparison with the previous edition, the 2022 version introduce the following changes :
  - normative references have been updated;
  - editorial corrections to assist in understanding;
  - visual indication of seismic mode;
  - replacement of mass P with PEC in proof of guide rails (Annex D);
  - removal of Table 4 and reference to ISO7465:2007;
  - modification of Annex ZA

…from 2022 to 202X version…

- During the last WT5 meeting (two days ago) was approved the NWI form to be sent to the ballot to open officially the revision of the EN 81-77:2022 standard
- The time available to complete the review is very short
- The EU Standardization request M599 is listing the EN 81-77 as harmonized and cited standard
- EN 81-77 shall be fully lined up with the request M599 and made available latest April 2028

…from 2022 to 202X version…

- CEN/TC10/WG1/WT5 decided to create 3 TF as below:
- TF1 - General (everything related to introduction, scope, references to Eurocode 8, design acceleration, Chapter 7)
- TF2 - Guide rails calculation (everything related to the calculation of guides, retainers, etc.) + mechanical components + Hydraulic (part related to hydraulic elevators)
- TF3 - Electric (part related to electric elevators) + operations (everything related to the part of the various electric maneuvers)

…from 2022 to 202X version…

- Concerning the revision of EN 81-77, will be introduced a Chapter 7 concerning Building Interfaces (in line with prEN ISO 8100-1)
- A check will be done to the relationship between construction (zone) categories and lift categories (under design acceleration)
- The revision will be based on alignement:
  - to EN ISO 8100-1 and EN ISO 8100-2
  - with the last comment received
- **At the moment seems there are no requests for new technical requirements**

Conclusion

- **EN 81-77 plays a vital role**
  in ensuring seismic safety of lifts in Europe
- **Future revisions aim to enhance**
  clarity, safety, and technological integration
- **Ongoing collaboration**
  between standards bodies, industry (including installers) and regulators is key to maintaining relevance and effectiveness

- Thanks you for your attention
- Any questions?

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