Lifts and earthquake, EN 81-77:

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Abstract:

Two major earthquake happened in Turkey on 6 February 2023. Level of earthquakes were 7,8 M_w and 7,5 M_w and were very destructive. More than 40.000 people died and cities, towns and viliages destroyed completely.

I visited earthquake zone just after the earthquake and saw that most of the buildings were completely collapsed. But what happened to the lifts in the buildings which are standing: Mostly the situation were that counterweight frames left from guide rails, suspension ropes left from sheaves, damaged travelling cables.

Contents of this paper is the protective measures of EN 81-77 requires in the lifts. What is design acceleration (a_d)and how it is calculated. We will review the required information from EN 1998-1 that required for calculation of design acceleration. How seismic zones are defined based on a_d will be seen. Protective measures on the elevators in each seismic zone will be reviewed.

1.0 Introduction:

Earthquake is a serious natural disaster for many countries and cities around the World. Like whole west coast of US and Canada, Italy, Iceland, Balkans, Turkiye, east coast of Mediterrenian Sea, Iran, Pakistan, Central Asia, South East Asia, whole Central America and West coast of South America. Around 1,6 billion of people on the World lives under the high risk of earthquake.

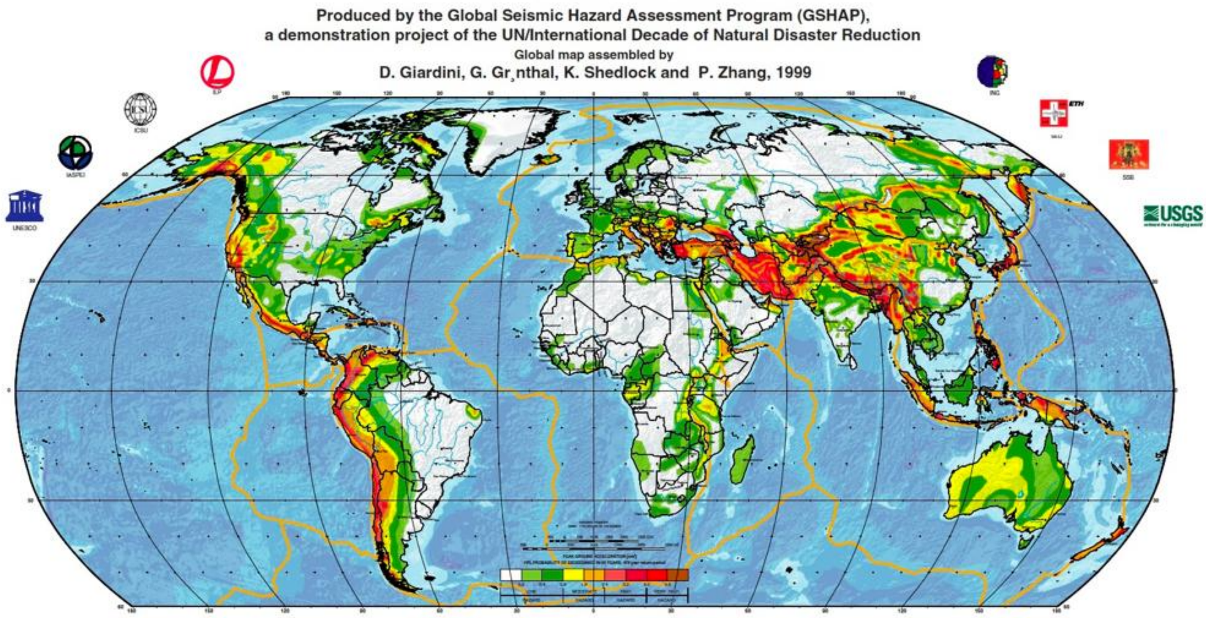

Figure – 1: Earthquake risk map of the world

Through hundred of years, humanity developed measures in building structures against earthquake. Vertical transporation industry developed as well measures to keep elevators and escalators safey in case of an earthquake happens. Mainly European, North American and Japanese Codes are leading to improve the safety of elevators in case of an earthquake.

EN 81-77 is the European Code and describes safety rules and requirements for passenger and goods lifts should withstand in seismic conditions in compliance with EN 1998-1. EN 81-77 aims to avoid loos of life, reduce injuries, prevent trapping in the car, prevent damage and environmental problems and reduce number of lifts that not working after an earthquake.

2.0 Design Acceleration:

Design acceleration (a_d) is the horizontal acceleration arising from seismic events and used for calculation of forces acting on lifts systems. It is function of ground acceleration, soil behaviour, importance of non structural elements and some other parameters. Elevators are non-structural elements according to EN 1998-1. EN 1998-1 is Eurocode8 and is regarding .esign of structures for earthquake resistance. Formula of design acceleration (a_d) is as below:

$$a_d = S_a \left(\frac{\gamma_a}{q_a} \right) g$$

Sa in the formula is the seismic coefficient that applicable for non-structural elements and is a number and is non-dimensional.

γ_a is importance factor. This factor is 1 for lifts in residential, office buildings. If lifts are in hospitals or will be used for special reasons like emergency services, in this case value shall be increased according to EN 1998-1. γ_a is non-dimensional. Importance factor can be defined by National Authorities as well based on seismic behaviours in the country.

q_a is behaviour factor of the element. İt is non-dimensional and should be equal 2 for lifts.

Sa need to be calculated like we will explain at the below:

$$S_a = \alpha \cdot S \cdot \left(\frac{3 \cdot \left(1 + \frac{z}{H}\right)}{1 + \left(1 - \frac{T_a}{T_1}\right)^2} - 0,5 \right)$$

α is non-dimensional and is ratio of design ground acceleration (a_g) on Type A ground to the gravity (g).

$\alpha = a_g/g$.

$a_g = \gamma_I . a_{gR}$.

ag : Design ground acceleration.

γ_I : Importance factor.

a_{gR} : Reference peak ground acceleration on type A ground.

γ_I, importance factor is defined based on importance classes of buildings and it is between 0,8 – 1,4. Importance classes of buildings are related to the building types like defined below:
Class – I (γ_I=0,8): Buildings have minor importance for public safety like agricultural buildings etc.
Class – II (γ_I=1,0): Ordinary buildings, not belonging in the other categories.
Class – III (γ_I=1,2): Buildings whose seismic resistance is of importance in view of the consequences associated with a collapse, e.g. schools, assembly halls, cultural institutions etc.
Class – IV (γ_I=1,4): Buildings whose integrity during earthquakes is of vital importance for civil protection, e.g. hospitals, fire stations, power plants, etc.

a_{gR}, is the reference peak ground acceleration on type A ground, a_{gR}, for use in a country or parts of the country, may be derived from zonation maps that can be found in related National Annexes.

S in the formula is soil factor according to EN 1998-1 and it is non-dimensional. S is 1,0 for type A ground, 1,2 for type B, 1,15 for type C, 1,35 for type D and 1,4 for type E. We recommend you always to get ground type of project from static designer of the project.

T_a is fundamental vibration period of non-structural element and it is in seconds. If lift does not effect fundamental vibration of building, T_a is 0.

T_1 is is fundamental vibration period and it is in seconds.

z is height of the highest part of the lift above foundation or rigid basement. It is in meters.

H is height of building above ground level and it is in meters.

3.0 Seismic Lift Categories

Seismic category of a lift is determined according to a_d.
If , $1 < a_d \leq 2,5$, lift's seismic category is 1,
$2,5 < a_d \leq 4$, lift's seismic category is 2,
a_d 4, lift's seismic category is 3>.

4.0 Requirements for Category 1

Suspension ropes, overspeed governor ropes, travelling cables, compansation ropes and chains may sway during an earthquake in the lift shaft and will get entangled with fixed equipments and snag points. These snag points will be created by brackets, sills and devices fixed in lift shaft. Snag points need to be protected if shaft height is above 20 meters.

The following protection measures need to be taken when travelling height is between 20 – 60 meter:

- If any snag point in the shaft like brackets, sills etc. is closer than 900 mm from loop of travelling cable, it is required to make protection with a wire, between snag points.

- Wire protection between brackets and similar snags is required during whole travel height for compensation ropes, chains and CWT overspeed governor ropes if snag points are closer than 750 mm to the related equipments. This is required during whole travel height if overspeed governor rope is closer than 500 mm and suspension rope is closer than to any snag point in the shaft.

If travel height of lift is more than 60 meters, above meintoned snag protection measures need to be taken whole travel height.

If building is divided to independent units by expansion joints, machinery space of lift should be in the same independent unit of the building.

Counterweight should have retaining device as shown in Figure – 2 at the top and bottom of the frame and as much as near to the guide shoes. d_1, d_2 and d_3 dimensions in the figure should be max. 5 mm. Retaining device should not cause accidental activation of safety gear in there is at counterweight side. Retaining device should be designed and fixed in such a way that z_3 in the Figure-2 should be minimum 5 mm.

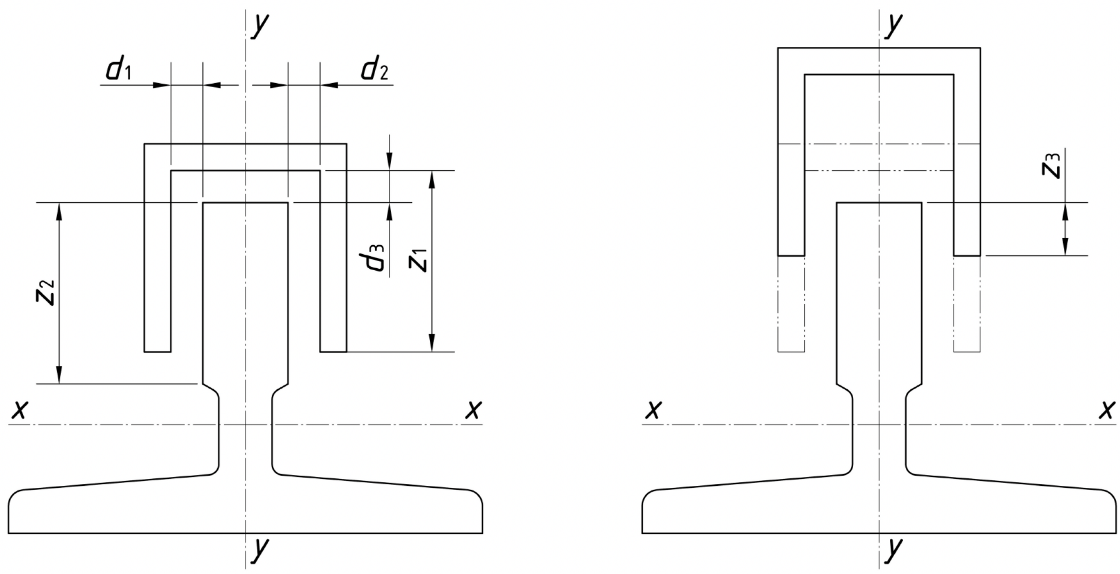

Figure – 2: retaining device

It is required to have retainers for traction and diverting pulleys for traction and compensation ropes. Retainers should be at 15^0 from entrance and exit of ropes and also in every 90^0 of wrapping of ropes. Retainers should be enough effective in comparison with rope diameters. Retainers are required for chain and sprockets as well.

Compensation means need to be guided in the pit to prevent swaying and engaging with any snag points.

In case of hydraulic lifts, lift should have rupture valve to prevent oil spillage when earthquake happens.

Guide rails, rail joints and brackets need to withstand the forces that will be created by calculated design acceleration (a_d). If there is retaining device, the device can be used as support for frame. The deflection occured by design accelaration cannot cause unsafe working of lifts. Door locking devices should remain active, safety gears should work properly and moving parts should not encounter with each other. In case of having retaining device, in maximum deflection should not cause less than 5 mm overlapping of retaining device and blade of guide rail.

Machine, suspensions means, overspeed governor, compesation means and their attachments should be designed and fixed in such a way that forces created by design acceleration (a_d) should not cause overturning and displacement. In case of having rigid pipes for hydraulic lifts, each rigid pipe should end with flexible pipe.

All electrical equipments and switches in the lift shaft should withstand with forces created by design acceleration (a_d).

5.0 Requirements for Category 2

Requirements for Category 2 lifts are combination of Category 1 requirements and the following protective measures.

It is required to have retaining device at the top and bottom side of car frame. Clearances defined for Category 1 should be maintained for car retaining device as well.

Lifts in Category 2 and 3 should have car door locking device. Door locking device is a safety component and need to be tested and certified according to EN 81-50.

In case of power failure, lift should be able to move next landing floor in up or down direction and trapping of persons in the cabin should be prevented. Lift should open its door and keep open, when it arrives to the landing. If lift is with semi-automatic door, door should be unlocked when lift stops at the landing. If power failure happens when lift is at the landing, doors should be open to rescue possible trapped passengers.

6.0 Requirements for Category 3

Requirements for Category 3 lifts are combination of Category 1 and 2 requirements and the following protective measures.

If the lift has counterweight or balancing weight, than lift should be equipped with seismic detection system. Detection system should be in the lowest pit level of lifts in the building or lower places than lift shafts. It should be possible detect three-axial acceleration. Any acceleration equal or lower than 1 m/s^2 should active seismic ssytem. Response time should be maximum 3 seconds. Seismic detection system should be checked at least every 24 hours and if it does not work, lift should be taken out from service. Seismic detection system should have a power supply back up for at least 24 hours. And it should be possible only manually reset the detection system.

When seismic detection system becomes active, lift should cancel all hall and car calls and should move to the nearest landing with maximum 0,3 m/s speed. Car should not pass counterweight or balancing weight while moving to the nearest landing level. If seismic detection system is active when lift is at the landing, closed doors should be open and lift should leave from service. If doors are semi-automatic, door should be unlocked. The seismic mode shall not override any safety device, inspection operation, emergency electrical operation and phase-2 of fire fighter mode according to EN 81-72.

7.0 Conclusion

We tried to explain the calculation of design acceleration and requirements in the lifts in case of according to design acceleration lift is in seismic categories. Our main guide fort his paper was EN 81-77 and EN 1998-1 standards. We strongly recommend in any Project to calculate design acceleration and take needed measures on lift based on calculated seismic category.

Biography:

Suleyman Ozcan is electronic engineer and working in vertical transportation industry since January 2001. He started his career as field engineer in 2001 and worked in technical, sales and management positions in vertical transportation industry. He is leading Solutions Engineering since January 2023. Solutions Engineering provides vertical transportation consultancy in Turkiye, Middle East, Balkans, Africa and Caucasus. Suleyman is member of board of the Elevator World Inc. and he is member of steering and technical committees of International Elevator & Escalator Symposium (IEES).