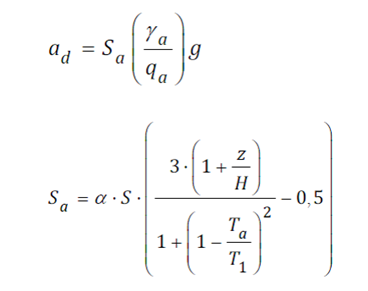
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| **GORAN SEKOVSKI**  ITI Ltd. Skopje - Institute of technical inspection and safety engineering, Skopje, North Macedonia  *Goran.Sekovski@itibi.mk* | **SEISMIC CATEGORIES FOR THE LIFTS – Possibilities for Safety Improvements**  **Abstract:** *МКС EN 81-77:2022 standard as harmonized standard under Lift Directive should be implemented in N. Macedonian legislative regarding seismic active territory. Using data placed in МКС EN 1998-1:2012 – Eurocode 8 and National Annex MKC EN 1998-1/HA:2018 and taking into account requirements and methods described in MKC EN 81-77:2022 standard* *computation of seismic category for lifts is performed for territory of North Macedonia.*  **Key words:** lifts, seismic categories, safety measures, improvements. |

**DETERMINATION OF THE DESIGN ACCELERATION**

To specify the normative requirements for new lifts in seismic conditions on a given territory, it is necessary to define seismic categories of lifts located in seismic conditions as well as mode of computation of design acceleration (ad).

The seismic category of lifts is defined according to design horizontal ground acceleration as presented in Table 1.

The design acceleration is computed according to the following formulas (МКС EN 1998-1:2012 or Eurocode 8):

*[1] Computation of ad (Annex B to МКС EN 81-77:2019)*

where (the annotations are according to those in МКС EN 1998-1:2012 Еurocode 8):

ad – design acceleration (m/s2);

g – ground acceleration (m/s2);

Sa – seismic coefficient applicable for nonstructural elements;

γa – importance factor of the element (it is taken as unity (1), while for security lifts, the value is increased in compliance with Eurocode 8. Security lifts are those installed in hospitals or those for emergency situations or evacuation – the factor presented below has been selected according to that for structural elements);

qa – factor of element behaviour (it is taken as 2);

α – ratio between design ground acceleration for soil type A (ag) according to Eurocode 8 and ground acceleration (g);

S – soil factor according to Eurocode 8;

Ta – fundamental period of vibration of a nonstructural element (Ta = 0 if the lift does not affect the fundamental period of vibration of the building. For the remaining cases, it is computed and is greater than 0) (s);

T1 – fundamental period of vibration of the building in a specified direction (s);

z – height of the nonstructural element above the level of the seismic force effect (m);

H – height of the building measured from the top of the foundation, considering the ground as level 0 (m); Table 1. Seismic categories of lifts (Annex A to МКС EN 81-77:2022.

Table 1. Seismic categories of lifts (Annex A to МКС EN 81-77:2022)

|  |  |  |
| --- | --- | --- |
| **Design acceleration (m/s2)** | **Seismic category of lifts** | **Note** |
| ad ≤ 1 | 0 | The requirements of EN 81-20 and EN 81-50 are adequate therefore no additional action is required |
| 1 < ad ≤ 2,5 | 1 | Minor correction actions required |
| 2,5 < ad ≤ 4 | 2 | Medium correction actions required |
| ad> 4 | 3 | Substantial corrective actions required |

**COMPUTATION OF SEISMIC CATEGORY AND DESIGN ACCELERATION FOR LIFTS IN THE TERRITORY OF NORTH MACEDONIA**

Taking into account the seismic zones according to the Seismic Map of North Macedonia and the classification into zones (Figure 1), the values of the soil factor that depend on the purpose of the structures and the values of the element behaviour factor (Eurocode 8 and National Annex MKC EN 1998-1/HA:2018), one can define the seismic categories of lifts in the territory of our country with a relative accuracy (assumed general soil factor for certain regions and assumed values for the data according to the National Annex), by use of equations [1].

To compute ad, the following values of coefficients can be used for different towns in North Macedonia, taking into account both lift types and type & height of buildings:

S –soil factor

S(A) = 1,0 for soil type A;

S(B) = 1,2 for soil type B;

S(C) = 1,15 for soil type C;

Importance factor

γ(II) = 1,0 for all buildings that are not in the remaining categories, including also residential buildings, with the exception of buildings requiring a greater security;

γ(III) = 1,2 for III structures – schools and institutions related to culture;

γ(V) = 1,4 за IV structures – hospitals, power plants and strategic structures;

γ(III) and γ(V) are taken equal to the importance factors corresponding to the purpose of structures where lifts are built-in according to the Eurocode 8 standard, although the МКС EN 81-77:2019 standard reads that these should be taken to be greater than 1 (unity) if an lift serves for a special safety purpose, but the value is not specified precisely.

Behaviour factor

qa = 2

The z/H ratio for structures in the Republic of N. Macedonia most frequently has the value of 1(z/H = 1), due to the usual practice of constructing lifts with approximately the same height as that of the buildings themselves.

The fundamental periods of vibration are taken as fixed values: Ta = 0 и T1 = 2.

Based on these values of the stated characteristics and the values of the design ground acceleration taken from the Seismic Map of North Macedonia, the seismic categories of lifts have been defined per regions, i.e., seismic zones in which they are located.

As shown in Table 2, in the territory of N. Macedonia, there are no lifts categorized into seismic category 0, which means that negligible to considerable corrective measures are necessary to be anticipated for all new lifts, which is, first of all, done in the very order for lifts, in accordance with the MKC EN 81-77:2019 standard.

It is evident that, in Skopje region, lifts should be considered to belong to seismic category 2 (the soil of the Skopje region is usually considered to be of type B), provided that the maximum ground acceleration is equal over the entire region. If the microseismic map of the Skopje region shows local accelerations greater than 0,27g or, use of another importance coefficient for residential buildings (II category structures) different from and greater than 1 (in the Skopje case, it is sufficient that it is 1,1), some of the lifts, or all lifts will be categorized into seismic category 3. The lifts in schools, hospitals, strategic facilities as are power plants and governmental buildings are classified into the highest seismic category in all variants due to their high importance factor in the Skopje region.

Still, the importance of these structures quantified through the importance factor that is used in definition of seismic categories of lifts has been defined based on the proposal for use of a corresponding value of the importance factor (equal to the importance factor of the structural elements of buildings according to their purpose) since the standard itself does not specify any value and also allows higher values to be defined.

Irrespective of the importance of structures, for all new lifts (except lifts in residential buildings constructed on soil type A, i.e., rock) in Ohrid-Struga-Debar region, as well as in Pehchevo-Berovo and Valandovo region, it is necessary to apply measures referring to lifts belonging to seismic category 3.

Table 2 Definition of seismic categories of lifts according to МКС EN 81-77:2019 standard.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Seismic zone Z-5 (ad = 0,30 g)** | | | | | | |
| **α =** | **0,30** | S | Sa | ad | | |
|  | Type of soil | γ (II) | γ (III) | γ (IV) |
| 1,0 | 1,2 | 1,4 |
| A | 1,00 | 0,7500 | 3,6788 | 4,4145 | 5,1503 |
| B | 1,20 | 0,9000 | 4,4145 | 5,2974 | 6,1803 |
| C | 1,15 | 0,8625 | 4,2306 | 5,0767 | 5,9228 |
|  |  |  |  |  |  |  |
| **Seismic zone Z-4 (ad = 0,25 g)** | | | | | | |
| **α =** | **0,25** | S | Sa | ad | | |
|  | Type of soil | γ (II) | γ (III) | γ (IV) |
| 1,0 | 1,2 | 1,4 |
| A | 1,00 | 0,6250 | 3,0656 | 3,6788 | 4,2919 |
| B | 1,20 | 0,7500 | 3,6788 | 4,4145 | 5,1503 |
| C | 1,15 | 0,7188 | 3,5255 | 4,2306 | 4,9357 |
|  |  |  |  |  |  |  |
| **Seismic zone Z-3 (ad = 0,20 g)** | | | | | | |
| **α =** | **0,20** | S | Sa | ad | | |
|  | Type of soil | γ (II) | γ (III) | γ (IV) |
| 1,0 | 1,2 | 1,4 |
| A | 1,00 | 0,5000 | 2,4525 | 2,943 | 3,4335 |
| B | 1,20 | 0,6000 | 2,9430 | 3,5316 | 4,1202 |
| C | 1,15 | 0,5750 | 2,8204 | 3,3845 | 3,9485 |
|  |  |  |  |  |  |  |
| **Seismic zone Z-2 (ad = 0,15 g)** | | | | | | |
| **α =** | **0,15** | S | Sa | ad | | |
|  | Type of soil | γ (II) | γ (III) | γ (IV) |
| 1,0 | 1,2 | 1,4 |
| A | 1 | 0,3750 | 1,8394 | 2,2073 | 2,5751 |
| B | 1,20 | 0,4500 | 2,2073 | 2,6487 | 3,0902 |
| C | 1,15 | 0,4313 | 2,1153 | 2,5383 | 2,9614 |
|  |  |  |  |  |  |  |
| **Seismic zone Z-1 (ad = 0,10 g)** | | | | | | |
| **α =** | **0,10** | S | Sa | ad | | |
|  | Type of soil | γ (II) | γ (III) | γ (IV) |
| 1,0 | 1,2 | 1,4 |
| A | 1 | 0,2500 | 1,2263 | 1,4715 | 1,7168 |
| B | 1,20 | 0,3000 | 1,4715 | 1,7658 | 2,0601 |
| C | 1,15 | 0,2875 | 1,4102 | 1,6922 | 1,9743 |

Debar, Struga, Ohrid, Pehchevo, Berovo and Valandovo

Skopje, Strumica, Mavrovo and Delchevo

Gevgelija, Kochani, Radovish, Kumanovo, Tetovo, Gostivar, Kichevo and Resen

Kriva Palanka, Shtip, Veles, Negotino, Kavadarci and Bitola

|  |  |
| --- | --- |
| **Seismic category of lifts** | |
|
| 0 |  |
| 1 |  |
| 2 |  |
| 3 |  |

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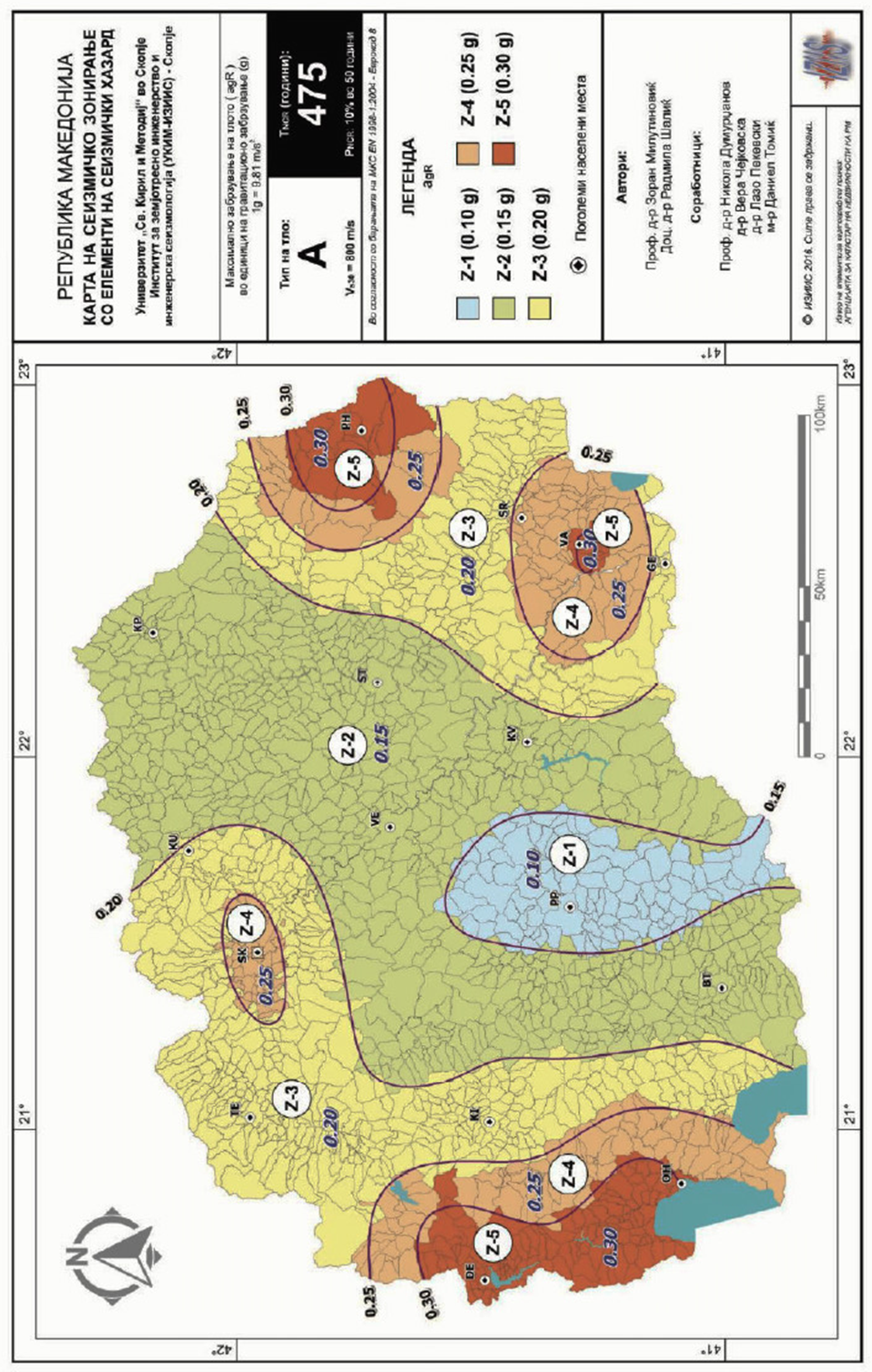
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Figure 1. Seismic Zoning Map of N. Macedonia (IZIIS 2018).

**ADDITIONAL SAFETY MEASURES FOR NEW LIFTS IN SEISMIC CONDITIONS**

In addition to the computation for the guide rails proposed in Annex D to the MKS EN 81-77:2022 standard for lifts in seismic conditions, the standard also anticipates a series of other measures for improvement of safety of lifts in seismic zones for categories 1, 2 and 3 prescribed by the same standard. For lifts of seismic category 0, it is not necessary to take any additional corrective measures whereat it is considered that the essential safety requirements pertaining to MKC EN 81-20:2014 and MKC EN 81-50:2014 are sufficient enough.

**ADDITIONAL MEASURES FOR LIFTS BELONGING TO SEISMIC CATEGORIES 1, 2 AND 3**

Additional requirements for lifts of seismic categories 1, 2 and 3 are anticipated for: the lift well (protection of snag points), the machine room, the counterweight guide rails or the balance guide rails (specific calculation), the bearing and compensation devices, the guide rails (car and counterweight retaining device), the traction pulley (retainer) the lift machine and the remaining lift equipment and electrical equipment in the lift well (see standard МКС EN 81-77:2019.

**ADDITIONAL MEASURES FOR LIFTS BELONGING TO SEISMIC CATEGORIES 2 AND 3**

In addition to the measures taken for categories 1, 2 and 3 (general requirement for lifts subject of seismic conditions) to be satisfied the following measures should be taken for lifts categorized into seismic categories 2 and 3:

* The car, i.e., the frame of the car should be provided with a retaining device that will prevent displacement of the car from the guide rails and uncontrolled motion beyond the defined direction.
* The lending doors should be prevented from opening as described in provisions 5.3.9. for the general case and in special cases in item 5.3.9.1. of the standard Locking and unlocking of the lending doors and car doors in emergency cases should be compliant with the MKC EN 81-20:2014 standard.
* For the purpose of avoiding the possibility for people to be stuck in a car between two storeys, there should be a device that will move the car to the first upper or lower level.

**ADDITIONAL MEASURES ONLY FOR LIFTS BELONGING TO SEISMIC CATEGORY 3**

In addition to the previously stated devices for seismic category 1 and those for seismic categories 2 and 3, electrical lifts with a counterweight or a balance weight categorized into seismic zone 3 should be equipped with a seismic detection device and additionally, by way of negotiations and consent given by the owner, but not obligatorily, a system for detection of primary waves as described in Annex C of the MKS EN 81-77:2022. Considering that primary seismic waves are the fastest in their propagation, this system is very efficient and has been increasingly applied since it safely brings the lift car to a stop prior to the arrival of the secondary and the most destructive surface waves.

**References**

1. МКС EN 1998-1:2012 Eurocode 8 – Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings;
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3. МКС EN 81-77:2022 – Safety rules for the construction and installations of lifts - Particular applications for passenger and goods passenger lifts - Part 77: Lifts subject to seismic conditions;
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**BIOGRAPHY**

**Goran Sekovski** was born in Skopje, SR Macedonia, in 1966.

He received the diploma in mechanical engineering from the University Ss. Cyril and Methodius in Skopje, Faculty of Mechanical Engineering and the M.Sc. degree in Earthquake Engineering from the University Ss. Cyril and Methodius in Skopje, Institute of Earthquake Engineering and Engineering Seismology IZIIS, University Ss. Cyril and Methodius in Skopje.

He is founder and general manager of ITI Ltd. Skopje, company dealing as Inspection Body for conformity assessment and technical inspection of lifts, cranes and other technical equipment and installations and offer services in the fields of occupational safety and environmental protection.

Currently, besides his primary occupations, he is Chairmen of TK6 – Technical committee for lifts under ISRSM (Institute of standardisation of R. of N. Macedonia) and President of Macedonian Lift Association.