**EARTHQUAKE PLANNING AND PROTECTION ORGANISATION**

# SECOND LEVEL PRE-EARTHQUAKE ASSESSMENT FOR MASONRY BUILDINGS [1st Edition 2012]

**EARTHQUAKE PLANNING AND PROTECTION ORGANISATION**

# SECOND LEVEL PRE-EARTHQUAKE ASSESSMENT FORM

## MASONRY BUILDINGS [1st Edition 2012]

### A. IDENTITY OF THE BUILDING

1. REGION/PROVINCE:
2. TOWN:
3. ADDRESS:

POSTCODE: TEL :

4. BUILDING'S NAME:
5. BUILDING'S USE:
6. OWNER'S DETAILS:
7. USER'S DETAILS:

### B. TECHNICAL CHARACTERISTICS OF THE BUILDING

1. NUMBER OF LEVELS: BASEMENTS :
2. FLOOR AREA:
3. TOTAL FLOOR AREA :
4. YEAR OF CONSTRUCTION:
5. YEAR OF LAST ADDITION:
6. DETAILS OF ADDITION:
7. IS IT A LISTED BUILDING? YES ☐ NO ☐
8. HAS THE BUILDING BEEN REPAIRED/STRENGTHENED? YES ☐ NO ☐
9. IF YES, FOR WHAT REASON AND WHEN?
10. ADDITIONAL GENERAL INFORMATION:

### C. SEISMIC AND GEOTECHNICAL DATA FOR THE REGION

1. SEISMIC HAZARD ZONE (from EC 8): Z1 ☐ Z2 ☐ Z3 ☐
2. GROUND TYPE (from EC 8): A ☐ B ☐ C ☐ D ☐ E ☐ S ☐
3. POTENTIAL INCREASE IN THE RISK OF SEISMIC ACTION: YES ☐ NO ☐

### D. ASSESSMENT OF THE SEISMIC ACTION ON THE BUILDING (Hazard: H)

1. SEISMIC ACTION INDEX (H1) : ☐
2. INFLUENCE OF ADJACENT BUILDINGS INDEX (H2) : ☐

| | | |
|---|---|---|
| 3. | ESTIMATE OF THE SEISMIC ACTION (H) : *H = 0.75H1+0.25H2* | **H=** |

| | | |
|---|---|---|
| **E.** | **ASSESSMENT OF THE SEISMIC RESISTANCE OF A BUILDING (Resistance: R)** | |
| 1. | GROUND FLOOR SHEAR RESISTANCE INDEX (R1) : | |
| 2. | LOAD BEARING WALL OPENINGS INDEX (R2) : | |
| 3. | RING BEAM INDEX (R3) : | |
| 4. | DIAPHRAGM INDEX (R4) : | |
| 5. | OPENINGS NEAR CORNERS INDEX (R5) : | |
| 6. | MASONRY DAMAGE INDEX (R6) : | |
| 7. | CONNECTION BETWEEN TRANSVERSE WALLS INDEX (R7) : | |
| 8. | PERIMETER WALL OUT OF PLANE STRESS INDEX (R8): | |
| 9. | GROUND FLOOR PLAN REGULARITY INDEX (R9) : | |
| 10. | HEIGHT REGULARITY INDEX (R10) : | |
| 11. | BUILDING'S EARTHQUAKE RESISTANCE ESTIMATE (R) :<br>*R = 0.20R1+0.15(R3+R5)+0.10(R4+R7+R8)+0.05(R2+R6+R9+R10)* | **R=** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **F.** | **BUILDING'S IMPORTANCE (Value: V)** | | | | | | | | | |
| 1. | NUMBER OF USERS *(Mark the appropriate box with +)* | | | | | | | | | |
| | X≤10 | | 10<X≤50 | | 50<X≤100 | | 100<X≤200 | | >200 | |
| 2. | TOTAL FLOOR AREA ($m^2$) *(Mark the appropriate box with +)* | | | | | | | | | |
| | A≤100 | | 100<A≤500 | | 500<A≤1000 | | A>1000 | | | |
| 3. | ADMINISTRATIVE AND/OR SOCIAL IMPORTANCE *(Mark the appropriate box with +)* | | | | | | | | | |
| | LOW | | NORMAL | | IMPORTANT | | SPECIAL | | | |
| 4. | MONUMENTAL VALUE *(Mark the appropriate box with +)* | | | | | | | | | |
| | NONE | | MEDIUM | | HIGH | | | | | |
| 5. | V1 = | | V2 = | | V3 = | | V4 = | | | |
| 6. | BUILDING'S IMPORTANCE ESTIMATE *V = 0.30(V1+V2)+0.20(V3+V4)* | | | | | | | | **V=** | |

| | | |
|---|---|---|
| **G.** | **BUILDING'S SEISMIC RISK ESTIMATE (Indicator: I)** | |
| | BUILDING'S SEISMIC RISK ESTIMATE *I=V[(H/R)-1]* | **I=** |

| | | |
|---|---|---|
| **H.** | **INSPECTING ENGINEERS' DETAILS** | |
| 1. | NAME: | 2. NAME |
| | PROFESSION: | PROFESSION: |
| | SIGNATURE | SIGNATURE |

DATE OF INSPECTION:

## APPENDIX A
## INFORMATION

Table A1: Ground type (Table 3.1 of EC 8)

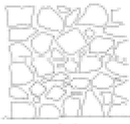
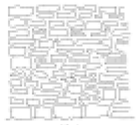
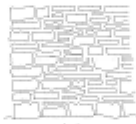
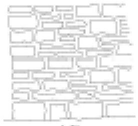
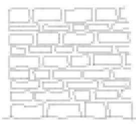
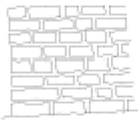
| Ground type | Description of stratigraphic profile | Parameters | | |
|---|---|---|---|---|
| | | $v_{s,30}$ (m/s) | $N_{SPT}$ (blows/30 cm) | $c_u$(kPa) |
| A | Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface. | > 800 | - | - |
| B | Deposits of very dense sand, gravel or very stiff clay, at least several tens of metres in thickness, characterised by a gradual increase of mechanical properties with depth. | 360-800 | > 50 | > 250 |
| C | Deep deposits of dense or medium dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres. | 180-360 | 15-50 | 70-250 |
| D | Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil. | < 180 | < 15 | < 70 |
| E | A soil profile consisting of a surface alluvium layer with vs values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with $v_s$ > 800 m/s. | | | |
| $S_1$ | Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content | < 100 (indicative) | - | 10-20 |
| $S_2$ | Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A to E or *S*1. | | | |

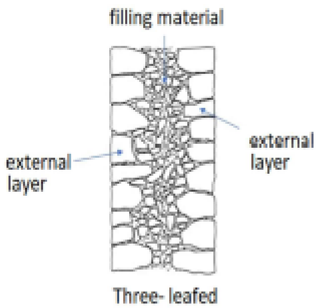
*The site should be classified according to the value of the average shear wave velocity, $v_{s,30}$, if this is available. Otherwise, the value of NSPT should be used.*

Table A2: Estimated values for the seismic action (H)

| Seismic hazard zone | Adjacent building category | Ground type | | | |
|---|---|---|---|---|---|
| | | A | B, C | D | E |
| Z1 | 1 | 1.02 | 1.20 | 1.38 | 1.50 |
| | 2 | 1.10 | 1.28 | 1.46 | 1.58 |
| | 3 | 1.15 | 1.33 | 1.51 | 1.63 |
| | 4 | 1.22 | 1.40 | 1.58 | 1.70 |
| | 5 | 1.27 | 1.45 | 1.63 | 1.75 |
| | 6 | 1.32 | 1.50 | 1.68 | 1.80 |
| Z2 | 1 | 1.53 | 1.80 | 2.07 | 2.25 |
| | 2 | 1.61 | 1.88 | 2.15 | 2.33 |
| | 3 | 1.66 | 1.93 | 2.20 | 2.38 |
| | 4 | 1.73 | 2.00 | 2.27 | 2.45 |
| | 5 | 1.78 | 2.05 | 2.32 | 2.50 |
| | 6 | 1.83 | 2.10 | 2.37 | 2.55 |
| Z3 | 1 | 2.30 | 2.70 | 3.11 | 3.38 |
| | 2 | 2.37 | 2.77 | 3.18 | 3.45 |
| | 3 | 2.42 | 2.82 | 3.23 | 3.50 |
| | 4 | 2.50 | 2.90 | 3.31 | 3.58 |
| | 5 | 2.55 | 2.95 | 3.36 | 3.63 |
| | 6 | 2.60 | 3.00 | 3.41 | 3.68 |

## Table A3: Typical types of masonry

| Rubble stone | | Flat rubble stone and semi dressed cornerstones | | Semi dressed, dressed rectangular stones | |
|---|---|---|---|---|---|
|  (a) Rubble stone of irregular shape |  (b) Flat rubble stone |  (c) Flat rubble stone Semi dressed cornerstones |  (d) Semi dressed flat stones |  (e) Semi dressed rectangular stone |  (f) Fully dressed stone |




Particular care is needed in cases (e) and (f) as most construction is three leafed masonry with an elaborate exterior and a poor interlock of masonry units

## Table A4: Characterisation of the administrative and/or the social significance of buildings

| | |
|---|---|
| Low | Buildings of minor importance to the safety of the public, such as farm buildings and barns, stables, cow sheds, pigsties, chicken farms, etc. |
| Normal | Typical buildings such as houses and offices, industrial – light industrial buildings, hotels (which do not include conference rooms), hostels, boarding houses, exhibition spaces, catering and entertainment areas (bakeries, cafes, bowling, billiards, video games, restaurants, bars, etc.), banks, clinics, markets, supermarkets, malls, shops, chemists, hairdressers, salons, fitness institutes, libraries, factories, garages and car repair/maintenance shops, paint factories, wood factories, research laboratories, synthesised food factories, cleaners, data centres, warehouses, car parks, petrol stations, wind generators, public service agencies and local government that do not fall under the category "special", etc. |
| Important | Buildings which house facilities of great economic importance, as well as public gathering buildings where many people are for all the 24 hours such as airport halls, conference rooms, buildings that house computer centres, special industries, educational buildings, classrooms, schools, nursery schools, concert halls, courtrooms, churches, sports facility complexes, theatres, cinemas, nightclubs, passenger lounges, psychiatric hospitals, disables institutions, chronically ill institutions, nursing homes, crèches, nurseries, kindergartens, playgrounds, reformatories, prisons, sewage and waste water treatment plants, etc. |
| Special | Buildings whose operation is vital during and after an earthquake such as telecommunications, energy production, hospitals, clinics, community centres, medical stations, health centres, refineries, power stations, fire and police stations, public service buildings of strategic services for earthquake emergency needs.<br>Buildings that house unique works of art such as museums, museum stores, etc. |

# APPENDIX B
# FIELD INFORMATION DATA COLLECTION FORM

### Identifying the building

| No. | Identifying the technical characteristics of the building | |
|---|---|---|
| 1 | Region/Province | |
| 2 | Town | |
| 3 | Address | |
| 4 | Telephone number | |
| 5 | Building's name | |
| 6 | Building's use | |
| 7 | Owner's details | |
| 8 | User's details | |
| 9 | Number of storeys | |
| 10 | Number of basements | |
| 11 | Year of construction | |
| 12 | Number of users | ≤10[ ], 11-50[ ], 51-100[ ], 101-200[ ], >200[ ] |
| 13 | Has another level been added at a later date? | |
| 14 | Is the building a listed building? | |
| 15 | Has the building been repaired/strengthened? | |

| **ADDITIONAL INFORMATION:** |
|---|
| |

**CLARIFICATION NOTES**

*5: Building's name*

*Enter the name of the building. If the building is part of a complex of buildings, specify which building it is (e.g. Building B Soteria Hospital or Building 1 of the 3rd City Council School, Athens).*

*6: Buildings use*

*Indicate the use of the building (e.g. hospital, education, housing, etc.). If the building has more than one use, indicate its main use for this inspection.*

*9-10: Number of storeys/basements*

*Enter the number of floors and basements. Do not count the small roof above the top of the stairs.*

*11: Year of construction*

*Note the date that the building was designed (if the plans exist) or constructed (if the plans do not exist). If it is not possible to find information concerning the date of design or construction, it is sufficient to determine the construction period (before 1959, between 1960 and 1985, between 1985 and 1995, after 1995) based on information or the buildings structural characteristics.*

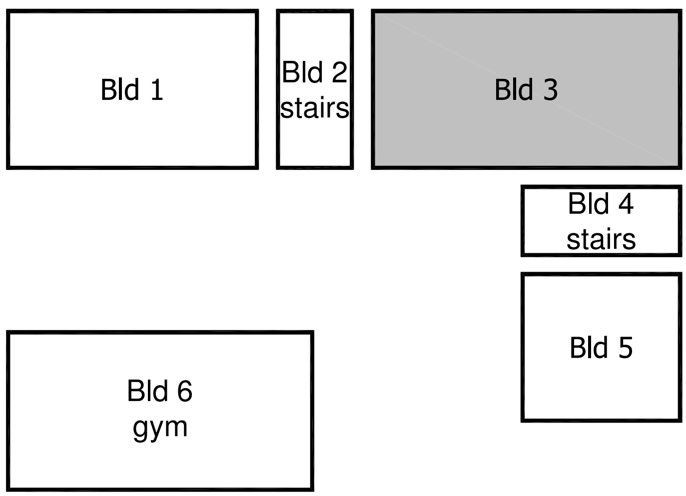
*12: Number of users*

*Mark the appropriate box with a + to indicate the maximum number of people that may congregate in the building.*

*13-15: Indicate YES or NO and consider writing a short comment.*

**SKETCH OF BUILDING COMPLEX**

When the address is the same or the property contains more than one structurally independent buildings, a sketch of the buildings' general layout is required indication Bld 1, Bld 2, etc. and hatch the building under investigation. The general layout should satisfactorily reflect the existing situation to a reasonable degree of accuracy.




**SKETCH OF THE BASEMENT PLAN**

(Separate page)

**SKETCH OF THE GROUND FLOOR PLAN**

(Separate page)

**SKETCH OF THE 1ST STOREY PLAN**

(Separate page)

**SKETCH OF THE 2ND STOREY PLAN**

(Separate page)

etc.

**Assessment of the seismic action on the building (Hazard: H)**

**Data to classify the seismic action (H1)**

| No. | Factors that may locally increase the seismic action | |
|---|---|---|
| 1 | Building on or near an unstable natural slope | |
| 2 | Shallow foundation on loose fill | |

**Data to classify the effect of adjacent buildings (H2)**

| No. | Features of adjacent buildings | |
|---|---|---|
| 1 | Free building or adequate seismic gap between buildings | |
| 2 | Same floor height and significant stiffness difference | |
| 3 | Difference of one floor in height without a pounding risk | |
| 4 | Same number of floors but difference in floor heights (pounding risk) | |
| 5 | Height difference in two or more floors without pounding risk | |
| 6 | Height difference in one or more floors with pounding risk | |
| 7 | In contact with several adjacent buildings | |

*The width of the seismic separation joint should be considered at the highest point of contact between two adjacent buildings and is considered sufficient if more than 2 cm is provided for the first 3.0 m of height with an additional 1.0 cm provided for further any 2.0 m of height.*

**Assessment of the seismic resistance of a building (Resistance: R)**

**Data to classify the shear resistance (R1)**

| No. | Type of masonry unit and construction | Type of mortar | | |
|---|---|---|---|---|
| | | Cement-lime mortar | Lime mortar | Clay mortar |
| 1 | Semi dressed or fully dressed stone | | | |
| 2 | Flat stone masonry | | | |
| 3 | Rubble stone | | | |
| 4 | Cobble stone | | | |
| 5 | Whole brick masonry | | | |
| 6 | Hollow brick masonry | | | |
| 7 | Concrete block | | | |
| 8 | Mud bricks (adobe) | | | |

| | |
|---|---|
| In the case of three-leafed masonry, mark a **+** | |

Description of how the three-leafed masonry is constructed[1]:

| | |
|---|---|
| In the case that the masonry is strengthened, mark a **+** | |

Description of how the masonry is strengthened[2]:

In the case that there is a change of type of masonry from floor to floor[3]:

1. *e.g. The construction of walls includes two single lines of brickwork linked together with reinforced concrete. The total thickness of the walls is 28 cm and incorporates 8 cm hollow bricks and 12 cm intermediate concrete*
2. *e.g. Deep mortar, grout and internally reinforced jacket of shotcrete on one or both sides of the wall*
3. *e.g. The ground floor is type 3 masonry with a lime mortar while the first floor is type 6 masonry with a cement-lime mortar*

**Data to classify the ring beam (R3)**

| Position of the ring beam | |
|---|---|
| Absence of ring beam or ring beam discontinuous | |
| Ring beams at the level of the lintels | |
| Ring beams at the level of the floors but not below the roof | |
| Ring beams at the level of the floors and below the roof | |
| Ring beams at the level of the floors, lintels and below the roof | |
| Single storey building with ring beam at the top | |
| Multi-storey building with a single ring beam under the roof | |

| Type of ring beam | |
|---|---|
| Wood | |
| Metal | |
| Concrete | |

| In the case of a wooden or metallic ring beam | YES | NO |
|---|---|---|
| The wooden or metallic beam supporting the floor or the roof is only seated on the inside part of the wall? | | |
| The ring beam covers the perimeter walls and all major internal load bearing walls? | | |
| The longitudinal elements of wood or metal have ensured continuity (splices) and connect the corners and intersections of walls? | | |
| There are loose or corroded connections or severe damage? | | |

| **DESCRIPTION – COMMENTS ON THE RING BEAMS:** |
|---|
| |

**Data to classify the diaphragms (R4)**

**The characterization of the layout of the walls in plan refers to their worst, in terms of layout, building arrangement.*

| No. | Arrangement of bearing walls in plan | |
|---|---|---|
| 1 | Symmetric | |
| 2 | Partially symmetric | |
| 3 | Asymmetric | |

| No. | Type of floor and roof | |
|---|---|---|
| 1 | Wooden floor with single floorboards | |
| 2 | Wooden floor with double floorboards | |
| 3 | Metal beams with flat brick filling | |
| 4 | Metal beams with vaulted masonry filling | |
| 5 | Reinforced concrete slab | |
| 6 | Vaulted floors of single or double curvature | |
| 7 | Roof without bracing without roofing boards | |
| 8 | Roof without clear bracing but with roofing boards | |
| 9 | Roof with a clear bracing without roofing boards | |
| 10 | Roof with a clear bracing and roofing boards | |
| 11 | Other type | |

| **DESCRIPTION-COMMENTS:** |
|---|
| |

| No. | Connection type of floors or roof to the underlying walls | |
|---|---|---|
| 1 | Wooden rafters or metal beams directly on the walls | |
| 2 | Wooden rafters or metal beams on continuous wall mounted beam | |
| 3 | Wooden rafters or metal beams on ring beams | |
| 4 | Reinforced concrete slab only seated at certain points | |
| 5 | Reinforced concrete slab continuously seated partially in the thickness of the wall | |
| 6 | Reinforced concrete slab continuously seated on the whole thickness of the wall | |
| 7 | Vaulted floors | |

| **DESCRIPTION-COMMENTS:** |
|---|
| |

**Data to classify the damage to the masonry (R6).**

| No. | Type of masonry damage | |
|---|---|---|
| 1 | No damage | |
| 2 | Light scattered damage | |
| 3 | Light extensive damage or medium scattered damage | |
| 4 | Severe damage | |

**DESCRIPTION-COMMENTS:**

*Light damage is cracks up to 1.0 mm wide. Moderate damage is cracks up to 2.0 mm wide without material crushing under compression and without significant residual deformation.*

**Data to classify the connection between transverse walls (R7)**

| No. | Characterisation of the connection between transverse walls | |
|---|---|---|
| 1 | Sufficient connection at all intersections | |
| 2 | The external walls are sufficiently connected but are not connected to the internal walls | |
| 3 | Poor connection at all intersections | |

**DESCRIPTION-COMMENTS:**

*Investigating a connection requires the localised removal of the wall coating for the full height in the corner where walls connect. An adequate connection is where the masonry units are interlocked together. The existence of sufficient steel brackets anchored in the corners of intersecting walls ensures an adequate connection. In the case where extensions have been added or local rebuilding has occurred, it is unlikely that there is any connection with the rest of the building's walls.*

# APPENDIX C

# SECOND LEVEL DATA COLLECTION FORM FOR THE

# PRE-EARTHQUAKE ASSESSMENT OF MASONRY BUILDINGS

# SECOND LEVEL PRE-EARTHQUAKE ASSESSMENT FOR MASONRY BUILDINGS

## CONTENTS

# INTRODUCTION

## 1.1 Preface

Masonry is one of the oldest building materials. However, knowledge about the mechanical behaviour and the response of masonry buildings is relatively limited. This contradiction may be attributed to the following reasons:

a. The development of the science of engineering almost coincided with the emergence of new strong and ductile construction materials (steel, reinforced concrete) that reduced costs and increased the safety of the supporting structure while masonry gradually reduced its role from a load bearing system to an infill system.
b. Masonry walls have relatively low strength and exhibit brittle behaviour, which leads to the need of increased wall thickness and cost of the supporting structure and limits the number of floor levels, especially in areas of high seismicity.
c. Masonry is multiphase, multifaceted and "unruly". The basic ingredients are masonry units and mortar. Masonry units are very diverse materials, processes, shapes and sizes. The mortar has a large variety of formulations and strengths but may be absent altogether (dry stone walls). Another factor is the diversity and construction type (bonding) of the masonry.

In every medium or large earthquake in Greece and worldwide, masonry buildings are highly vulnerable. This weakness can be attributed to a number of reasons, such as:

- The brittleness of unreinforced masonry.
- Insufficient diaphragm action of the floors and roof.
- Inadequate connection of the horizontal and vertical elements of the supporting structure.
- All kinds of imperfections.
- Interventions, modifications and additions from time to time.
- Poor maintenance and aging of materials.
- The complete absence or failure of design, if any.

Consequently, masonry needs fundamental research of its individual phases (masonry units – mortar) and engineering "cooperation" to understand its behaviour. A hindrance to the development of international cooperation for the promotion of research into the physical and mechanical behaviour of masonry is its diversity and the multiple types of the material itself, resulting in the great difficulty of standardizing materials and methods. Therefore, until the beginning of the 20$^{th}$ century, designing buildings of load bearing masonry was almost empirical.

Since the end of the 1970s, there has been a strong international awareness concerning the preservation and enhancement of the built heritage. This situation has rekindled research into the mechanical behaviour of masonry as the vast majority of monuments and listed buildings and complexes consist of buildings from masonry. At the same time, the rediscovery of the forgotten virtues of masonry began, such as insulation, fire resistance, durability and aesthetic superiority.

The treatment of existing masonry buildings differs from that of newly constructed for the following reasons:

- The materials and types of older masonry structures generally do not meet the requirements of EC 6 [1].

- The design corresponds to the level of knowledge at the time of construction, while the vast majority have been constructed without any structural design.
- The structure usually contains design flaws, many of which may be difficult to detect.
- There is a serious possibility that previous earthquakes or other accidental loading has affected the structure with unknown consequences.
- The consequences of the aging of materials are difficult to assess, particularly for embedded structural components.
- Finally and perhaps without exception, existing buildings have been subjected to human interventions (modifications, additions and demolition) that are not easy to identify and take into account.

Consequently, for the evaluation and redesign of existing masonry buildings, a special suitably adapted regulatory framework is required. EPPO has already set up a special scientific committee for this purpose.

The range of buildings of masonry construction as found throughout Greece is enormous. Many buildings are public gathering places while a significant number have been declared as listed buildings. The vast majority of existing buildings of masonry, for reasons mentioned above, require pre-earthquake strengthening.

It is therefore evident that the Country is facing a particularly difficult and economically unbearable problem with public buildings of masonry. Addressing the problem requires an initial inventory and hierarchical evaluation of the building stock in order that limited financial resources are optimally mobilised for the seismic strengthening of the buildings.

### 1.2 Scope and purpose of second level pre-earthquake assessment

In agreement with international practice, the inventory and hierarchical evaluation of the existing building stock is performed in three stages known as:

a. Rapid visual screening or first level pre-earthquake inspection
b. Second level pre-earthquake inspection
c. Third level pre-earthquake inspection

EPPO has already developed and standardised the method and the corresponding data collection form for the first level pre-earthquake assessment of masonry buildings, on which many public entities have made significant progress towards ranking existing buildings' potential vulnerability.

Rapid visual screening is a simplified methodology that can be quickly applied to a large set of buildings and, therefore, its reliability is inherently limited.

The second level pre-earthquake assessment is directed at masonry buildings that have received a score from the first level pre-earthquake assessment that is below a certain threshold value.

The aim of the second level pre-earthquake assessment is to re-evaluate the ranking of identified vulnerable buildings based on the detailing and evaluation of structural parameters and social criteria. This evaluation goes into more detail and requires access to all parts of the building, sketches detailing geometry and damage, visual assessment and spot checks of construction materials and basic calculations to quantify the characteristics of indexes without performing an analysis of the structure.

This guide presents the process of the second level pre-earthquake assessment. The end result of such an assessment is a "score" called the "seismic risk index" of the building. This index does not have an ultimate objective significance but indicates the priority order for the third part of the process (third level pre-earthquake assessment), that is the preparation of assessment studies and redesigns (strengthening) of a limited number of buildings depending on the economic capabilities of each public body.

## 1.3 Data requirements for the second level assessment

1.3.1 General

Before visiting a particular building, the team performing the second level inspection must have studied the first level data collection form in order to identify any gaps or ambiguities in the information. During the site visit, certain types of data must be collected that fall into the following categories:

- Data to identify the building
- Data to classify the seismic action on the building
- Data to classify the seismic resistance on the building
- Data to classify the importance of the building

Appendix B contains a data collection form for gathering the required field data.

The detailing of each data collection category and the individual characteristics needed to estimate the final assessment and relative classification of buildings must be as reliable as possible.

1.3.2 Data to identify the building

This necessary information is usually included in the first level pre-earthquake inspection form and can be simply copied to the "identifying the building" table of the second level pre-earthquake inspection form.

If the first level pre-earthquake inspection form is not available, the inspection team must collect the relevant information and complete the "identifying the building" table (see Appendix B).

1.3.3 Data to classify the seismic action on the building

Knowledge of the following data is required:

- Seismic hazard zone
- Ground type
- Possible local factors that may increase the seismic action
- Risk of pounding from adjacent buildings

1.3.4 Data to classify the seismic resistance of the building

For the collection of these parameters, it is supposed that the two-person inspection team is composed of civil engineers with relevant knowledge and experience:

- Geometry and damage to the masonry. Design sketches of the floor plans with full dimensions are required detailing the location and width of all openings and the thickness of all load bearing walls. A qualitative assessment of the general cause of damage is also required, paying particular attention to detailing and providing sketches of any serious damage.

- Type of masonry. Normally, masonry walls of various material types coexist in the same building. Therefore, it is necessary to label drawings of the floor plans detailing the different types of masonry units, mortars and construction type of masonry walls.
- Determining the load bearing structure. This requires the investigation and recording of the following:
  - Ring beams: The heights and types of ring beams must be detailed together with the adequacy of connections between ring beams at intersections.
  - Horizontal load bearing structure: Record the type of floor and roof supporting structure. Assess the degree of diaphragm action and the axial rigidity of the connection with load bearing walls.
  - Connection at wall junctions: Investigate the degree of connection at corners and record the existence of any metal brackets.

1.3.5 Data concerning the importance of the building

It is necessary to assess the following elements and features of the building:

- Number of users and frequency estimation of gatherings of people within the building
- The economic value of the building
- The administrative or social importance of the building
- The monumental value of the building

## 2. BRIEF DESCRIPTION OF THE METHOD

### 2.1 Introduction

The method follows, with appropriate modifications and additions, the procedure described in "Measuring of the relative seismic risk of historic masonry buildings" by Tassios and Vintzilaiou [2].

The classification of the building is based on a comparison between the seismic action on the building (H) and the seismic resistance of the building (R) in accordance with the following basic inequality of safety:

$$H \ngtr R \quad \text{or} \quad H/R - 1 \ngtr 0$$

The basic quantity assessment of the building is to consider the "extent of insufficiency" H/R – 1 that, however, in most existing masonry buildings is expected to have positive values due to high vulnerability, especially in the light of current concepts of seismic action.

At this point, it should be remembered that the empirical nature of the method (that is, the relative arbitrariness in the definition of the calibration factors of the recorded parameters) does not guarantee a theoretically "exact" value for the ratio H/R. Neither does the possibility of $H/R < 1$ provide necessary evidence of the seismic adequacy of the structure since H and R are conventional, that is, they are only useful when prioritising the relative risk comparison between buildings.

### 2.2 Building's seismic hazard index

The seismic action on the building (Hazard) "H" will not be expressed in terms of accelerations or forces (since there will be no calculations) but the probable seismic action will be taken into account through the seismic hazard zone, local geomorphological factors and the soil type. Finally, an additional parameter is introduced that assesses the risk of and possible effects of pounding with adjacent buildings.

Obviously, because the probable seismic action is much more important than the influence of adjacent buildings, both parameters are introduced with various weighting factors "$h_i$" when determining the final estimate of the seismic action on the building.

### 2.3 Building's earthquake resistance index

The seismic resistance (Resistance) "R" of the building is based on various "resistance parameters" that are classified into two categories. The first category contains parameters relating to the strength of the walls such as materials, thicknesses, percent and position of openings, existing ring beams and damage. The second category includes features that contribute to the overall cooperation of the structure, that is the connection between transverse walls and the existence of diaphragms as well as an evaluation of the regularity of the the building in plan and height.

The associated formula for calculating the value of "R" for the building includes for each parameter weighting factors "$r_i$". These weighting factors attempt to express the interaction between resistance parameters instead of simply summing the values of each parameter.

### 2.4 Building's importance index

The overall seismic risk of the building in question must include its importance for the safety of human life, potential financial losses, the administrative or social function of the building and also its historic value. For this reason another factor, called the Building

Importance Index (Value) "V", is introduced. This index takes into account value parameters, for each of which is proposed indicative values and weighting factors "$v_i$" based on the importance of the participation of each parameter.

Obviously, these parameters reflect ethical value perceptions and, therefore, cannot be determined in an absolute way.

### 2.5 Assessment of the building's seismic risk

After calculating the above indices, the relative seismic risk index (indicator) "I" follows from the expression:

$$I = V(H/R - 1)$$

It should be repeated that this index does not have an ultimate objective importance as it only offers the possibility of a comparative ranking of a set of buildings and enables priority ordering for the State before the third stage of the process, which includes studies concerning pre-earthquake strengthening.

Appendix C contains the second level pre-earthquake assessment data collection form.

## 3. ASSESSMENT OF THE SEISMIC ACTION ON A BUILDING (Hazard: H)

### 3.1 Seismic action index (H1)

The seismic action is mainly affected by the seismicity of the region and the soil under the foundation. The seismicity factor coefficient (a) is given by referring to the design ground acceleration for the seismic hazard zone. The ground type coefficient (s), referring to the corresponding design acceleration multiplier (S) is according to EC 8 [3]. Table A1 in appendix A includes a stratigraphy description for the classification of soils into categories (Table 3.1 of EC 8 [3]).

Based on the above index, the probable seismic action (H1) is determined through the equation H1 = a*s. Appropriate values for H1 can be found in table 1. Index values H1 give approximate estimates of EC 8 [3] and the respective National Annex for the case of seismic action.

Table 1: Values to determine the seismic action (H1)

| Seismic hazard zone | Coefficient values for a | Ground type/Coefficient values for s | | | | |
|---|---|---|---|---|---|---|
| | | A | B, C | D | E | S1, S2* |
| | | 0.85 | 1.00 | 1.15 | 1.25 | - |
| Z1 | 1.6 | 1.36 | 1.60 | 1.84 | 2.00 | - |
| Z2 | 2.4 | 2.04 | 2.40 | 2.76 | 3.00 | - |
| Z3 | 3.6 | 3.06 | 3.60 | 4.14 | 4.50 | - |

* Buildings on soils $S_1$ or $S_2$ are automatically forwarded to the third level pre-earthquake assessment

- In masonry buildings with ring beams (existence of horizontal and vertical elements of reinforced concrete or metal at intervals specified by EC 6 [1]) or reinforced masonry, the seismic action index H1 is multiplied by 0.75 or 0.60 respectively. This depreciative multiplier recognises the increased ductility of reinforced masonry or, by analogy, corresponding values of behaviour factor q, as defined in chapter 9 of EC 8 [3].
- If there is sufficient evidence for a local magnification of the potential risk from the seismic action due to the building's in place geomorphology, it is possible to increase the building's H1 index value by up to 50%. Some examples are the following cases:
  – Buildings near or on an unsafe natural slope.
  – Surface foundation on loose backfill.

### 3.2 Influence of adjacent buildings index (H2)

This index reflects the effect on a building from adjacent buildings where there is not a sufficient seismic gap. In cases of unequal floor heights where strong diaphragm actions exist, there is the possibility of pounding.

The width of the seismic gap is considered at the highest level of contact between buildings and is considered sufficient if there is a 2 cm gap for the first 3 m height with the addition of 1.0 cm for every 2.0 m additional height.

Based on the above, table 2 proposes index values (H2) to take into account the effects of adjacent buildings.

Table 2: Index values for the effects of adjacent buildings (H2)

| No | Features of adjacent buildings | H2 |
|---|---|---|
| 1 | Free building or adequate seismic gap between buildings | 0.00 |
| 2 | Same floor height and significant stiffness difference | 0.30 |
| 3 | Difference of one floor in height without a pounding risk | 0.50 |
| 4 | Same number of floors but difference in floor heights (pounding risk) | 0.80 |
| 5 | Height difference in two or more floors without pounding risk | 1.00 |
| 6 | Height difference in one or more floors with pounding risk | 1.20 |

- In the case where contact with several adjacent buildings is possible, based on the judgement of the inspecting engineer, intermediate or higher values up to or more than 1.50 can be adopted.

### 3.3 Estimate of the seismic action (H)

Obviously, the probable seismic action is more influenced by the seismic action index rather than the adjacent building index. Therefore, the following weighting factors ($h_i$) for the two indices are proposed (where: $\Sigma h_i = 1.00$):

– Seismic action index (H1): $h_1 = 0.75$.

– Adjacent building index (H2): $h_2 = 0.25$.

- With the above values, the estimate of the seismic action is determined as follows: $H = \Sigma h_1 * H_i = 0.75H1+0.25H2$. Table A2 in appendix A presents calculated values for the index H for all possible combinations of seismic hazard zone, soil type and degree of influence of adjacent buildings. Values range from between 1.02 and 3.68 for favourable to unfavourable combinations of data respectively.

# 4. ASSESSMENT OF THE SEISMIC RESISTANCE OF A BUILDING (Resistance: R)

## 4.1 Ground floor shear resistance index (R1)

This is the only index of the ten indices that are used to determine the seismic resistance that indirectly evaluates the shear strength of the ground floor and is also the only one that includes indirectly the type of masonry structure.

The proposed equation for this index is as follows:

$$R1 = 12 * (m * \lambda_m) * \frac{\Sigma A_w}{n * A} < 1.00 \quad (1a)$$

where:

m: Coefficient for the type of masonry structure (see table 3 below). Table A3 in appendix A provides sketches and comments in order to facilitate the characterisation of the various types of masonry structures.

$\lambda_m$: Reduction factor for obviously poor interlock of masonry units and/or a severe disintegration of the mortar ($0.70 \leq \lambda \leq 1.00$).

$\Sigma A_w$: Sum of the cross sectional areas of the load bearing walls (walls between openings) of the ground floor in the most unfavourable direction (direction with mimimum $\Sigma A_w$). Ignore walls between openings where $\ell_w < 1.00$ m.

n: Number of floors including the ground floor. Discount any stairwell above the roof.

A: Plan area of the ground floor.

12: Numerical coefficient that under normal circumstances results in $R1 \leq 1.00$.

- When, during the assessment by the inspecting engineer, it is found that there is a probable reduction in R1 in the upper floor level (e.g. a sharp reduction in wall thickness), the above calculation is also performed at this floor level and the number of floors (n) includes this level and all those above. Ultimately, the building is characterised by the lowest value of R1.
- It should be noted that the determination of the R1 index is not required in basement levels, closed or not, as it is assumed that a higher R1 index value would be expected.
- Three leafed masonry (as is usually the case when wall thickness > 0.50 m) is considered to be poor interlock of masonry units.
- If the level being checked consists of different types of masonry walls, the above equation is amended as follows:

$$R1 = 12 * \frac{\Sigma(m * \lambda_m * \Sigma A_w)}{n * A} < 1.00 \quad (1b)$$

- In the case that the building has been strengthened with reinforced jackets or sheets, coefficients m and $\lambda_m$ are assigned the value of 1.00.

Table 3: Coefficient values for different types of masonry wall (m)

| Type of masonry unit and construction | Type of mortar | | |
|---|---|---|---|
| | Cement-lime mortar | Lime mortar | Clay mortar |
| Semi dressed or fully dressed stone | 1.00 | 0.80 | - |
| Flat stone masonry | 0.80 | 0.70 | 0.50 |
| Rubble stone | 0.60 | 0.50 | 0.40 |
| Cobble stone | 0.50 | 0.40 | 0.30 |
| Whole brick masonry | 1.00 | 0.80 | 0.60 |
| Hollow brick masonry | 0.80 | 0.70 | 0.50 |
| Concrete block | 0.70 | 0.60 | 0.50 |
| Mud bricks (adobe) | - | 0.40 | 0.25 |

### 4.2 Load bearing wall openings index (R2)

The load bearing wall openings index (R2) is determined at the ground floor level and in the direction that gives the lowest value.

The R2 index is determined from equation (2), where "α" is the total length of openings in the load bearing walls divided by the length of the bearing walls including the openings.

$$R2 = \frac{1}{\alpha + 0.4} - 0.7 < 1.00 \quad (2)$$

- The formulation of equation (2) ensures that this index value is positive and does not exceed +1.0.

### 4.3 Ring beam index (R3)

The proposed values for the ring beam index R3 are presented in table 4.

Table 4: Values for the ring beam index (R3)

| Position of the ring beam | R3 |
|---|---|
| Absence of ring beam or ring beam discontinuous | 0.50 |
| Ring beams at the level of the lintels | 0.60 |
| Ring beams at the level of the floors but not below the roof | 0.75 |
| Ring beams at the level of the floors and below the roof | 0.90 |
| Ring beams at the level of the floors, lintels and below the roof | 1.00 |

- The ring beams can be from wood (wooden frames with transverse crossbeams, steel or reinforced concrete. Wooden or metal wall mounted beams seating floors or roofs, only on the inside of the wall are not considered as ring beams.
- This consideration implies that the ring beam is continuous for the whole length of the perimeter walls and the main load bearing walls of the floor level.
- The longitudinal elements of the wooden or steel ring beam must be guaranteed continuous (spliced) and must be well connected at corners and wall intersections.
- In the case of loose or corroded connections or seriously damaged material, the value of index R3 can be reduced based on the judgment of the inspecting engineer.
- In the case of extensions or local reconstruction, the continuity of the ring beam should be carefully checked.
- For single storey buildings with ring beam at the top: R3 = 0.90.

- For multi-storey buildings with a single ring beam under the roof:

  R3 = 0.90 – 0.15n ≮ 0.50 where (n) is the number of floor levels without a ring beam.

### 4.4 Diaphragm index (R4)

The proposed values for the diaphragm index (R4) are presented in table 5.

Table 5: Values for the diaphragm index (R4)

| Arrangement of load bearing walls in plan | Stiffness of diaphragm and connection to the underlying walls | | |
|---|---|---|---|
| | Weak | Medium | Strong |
| Symmetric | 0.80 | 0.90 | 1.00 |
| Partially symmetric | 0.60 | 0.75 | 0.90 |
| Asymmetric | 0.40 | 0.55 | 0.70 |

- The characterisation of the walls in plan refers to the worst direction of the building in terms of the wall arrangement.
- Table 6 presents qualitative characterisations of the diaphragm stiffness of various types of floors.
- Table 7 presents qualitative characterisations of the degree of connectivity of the floors to the underlying level.
- In the case that the qualitative stiffness of the floor differs from the degree of connection to the underlying level, a suitable intermediate R4 index value based on the judgement of the inspecting engineer should be adopted.
- The R4 index characterises the horizontal stiffness of the load bearing structure and the degree of connectivity of load bearing walls at all levels of the building. Consequently, the adoption of intermediate values based on the judgement of the inspecting engineer is permitted.

Table 6: Diaphragm stiffness of the floors and roof

| Type of floor and roof | Diaphragm stiffness |
|---|---|
| Wooden floor with single floorboards | Weak |
| Wooden floor with double floorboards | Medium |
| Metal beams with flat brick filling | Medium |
| Metal beams with vaulted masonry filling | Strong |
| Reinforced concrete slab | Strong |
| Vaulted floors of single or double curvature | Strong |
| Roof without bracing without roofing boards | Weak |
| Roof without clear bracing but with roofing boards | Medium |
| Roof with clear bracing without roofing boards | Medium |
| Roof with clear bracing and roofing boards | Strong |

Table 7: Connection type of floors or roof to the underlying walls

| Type of connection of the floors or roof to the walls | Connection |
|---|---|
| Wooden rafters or metal beams directly on the walls | Weak |
| Wooden rafters or metal beams on continuous wall mounted beam | Medium |
| Wooden rafters or metal beams on ring beams | Strong |
| Reinforced concrete slab only seated at certain points | Weak |
| Reinforced concrete slab continuously seated partially in the thickness of the wall | Medium |
| Reinforced concrete slab continuously seated on the whole thickness of the wall | Strong |
| Vaulted floors | Strong |

## 4.5 Openings near corners index (R5)

If there are no openings less than 1.00 m from an outstanding corner of the building, R5 = 0.00. Otherwise, the R5 index is calculated from equation (3):

$$R5 = -(\lambda + \frac{\alpha}{2\gamma} * \frac{\alpha}{\Sigma L_w}) \geq -1.00 \qquad (3)$$

where:

$\lambda$: Record $\lambda$ = 0.25 or 0.50 if there is one wall between openings with length < 1.00 m on one or both sides of the corner respectively

$\alpha$: The number of walls between openings of length < 1.00 m at outstanding corners on all floors

$\gamma$: The number of outstanding corners on all floors.

$\Sigma L_w$: The sum of the length of all walls between openings < 1.00 m at outstanding corners.

- It is considered that there is a high risk of out of plane earthquake failure of thin walls between openings near outstanding corners. In this case, re-entrant corners are considered to be in much less danger than outstanding corners.
- The high value of R5 for every corner wall between openings of width < 1.00 m is attributed to the increased risk of local collapse of all above levels at the corner if a thin wall between openings fails.
- In levels with diaphragms or continuous ring beams at the lintel level above openings in all perimeter and main interior walls, the number ($\alpha$) of walls between openings of width < 1.00 m at outstanding corners of the level in question is multiplied by 0.50.

## 4.6 Masonry damage index (R6)

The proposed values for the masonry damage index (R6) are presented in table 8.

Table 8: Values for the masonry damage index (R6)

| Type of masonry damage | R6 |
|---|---|
| No damage | 1.00 |
| Light scattered damage | 0.75 |
| Light extensive damage or medium scattered damage | 0.50 |
| Severe damage | - |

- Light damage is cracks up to 1.0 mm wide. Moderate damage is cracks up to 2.0 mm wide without material crushing under compression and without significant residual deformation.
- In the case of severe damage to the load bearing walls, the building is automatically forwarded to the third level pre-earthquake assessment.
- The R6 index can be assigned intermediate values based on the judgement of the inspecting engineer.

### 4.7 Connection between transverse walls index (R7)

The proposed values for the connection between transverse walls index (R7) are presented in table 9.

Table 9: Values for the connection between transverse walls index (R7)

| Characterisation of the connection between transverse walls | R7 |
|---|---|
| Sufficient connection at all intersections | 1.00 |
| The external walls are sufficiently connected but are not connected to the internal walls | 0.80 |
| Poor connection at all intersections | 0.40 |

- Investigating a connection requires the localised removal of the wall coating for the full height in the corner where walls connect. An adequate connection is where the masonry units are interlocked together.
- The existence of sufficient metal brackets anchored in the corners of intersecting walls ensures an adequate connection.
- In the case where extensions have been added or local rebuilding has occurred, it is unlikely that there is any connection with the rest of the building's walls.
- The R7 index can be assigned intermediate values based on the judgement of the inspecting engineer.

### 4.8 Perimeter wall out of plane stress index (R8)

This index only refers to the perimeter walls as internal walls usually have a much better connection with the horizontal load bearing structure.

The R8 index is determined from equation (4):

$$R8 = 6 * \sqrt{t} / L < 1.00 \qquad \text{(t and L in metres)} \qquad (4)$$

where

t: The thickness of the perimeter walls

L: The distance between transverse internal walls that support the perimeter

6: A numerical factor used to reduce R8 values to below unity for adequate distances between transverse walls.

- For every group of perimeter wall thicknesses, the calculated R8 index corresponds to the wall with the largest (L). The building is characterized by the minimum value of this index.
- Note that the factor $\sqrt{t}/L$ characterises the out of plane vulnerability by considering the wall behaviour as a vertical plate modelled with three vertical straight lined pinned

joints. Two of these joints are side joints in contact with the transverse walls while the third joint is in the middle region of the plate.

### 4.9 Ground floor plan regularity index (R9)

This index refers to the shape of the floor plan of the ground floor.

The building is characterised by the following geometric criteria:

- Oblong in plan. This criterion is the ratio of the lengths $\lambda = L_{max}/L_{min}$, where dimensions are measured in the main orthogonal directions.

  i. $\lambda < 4.0$: Normal building.
  ii. $4.0 \leq \lambda < 8.0$: Partially normal building.
  iii. $\lambda \geq 8.0$: Abnormal building.

- Complex plan forms, such as L, T, Π, E, etc. This criterion takes into account the total area of the recesses $\Sigma A_E$ and the area of the largest recess $A_{E,max}$ in relation to the area of the floor plan $A_{tot}$. The area of each recess is considered by drawing a convex polygon along the outer sides of the building and directly connecting the outstanding corners where there is a recess.
  i. $\Sigma A_E < 0.25A_{tot}$ or $A_{E,max} < 0.15A_{tot}$: Building normal in plan.
  ii. $0.25A_{tot} \leq \Sigma A_E < 0.40A_{tot}$ or $0.15A_{tot} \leq A_{E,max} < 0.25A_{tot}$: Building partially normal in plan.
  iii. $\Sigma A_E \geq 0.40A_{tot}$ or $A_{E,max} \geq 0.25A_{tot}$: Building abnormal in plan.

The proposed values for index R9 are presented in table 10.

Table 10: Values for ground floor plan regularity index (R9)

| Characterisation of the shape of the building in plan | R9 |
|---|---|
| Normal in plan | 1.00 |
| Partially normal in plan | 0.75 |
| Abnormal in plan | 0.50 |

- The adoption of intermediate values based on the judgement of the inspecting engineer is permitted.
- Buildings with a normal in plan ground floor but partially normal or abnormal upper levels are dealt with by the height regularity index (section 4.10).

### 4.10 Height regularity index (R10)

The building is characterised by the following geometric criteria:

- Buildings with variable floor areas by virtue of recesses or galleries (ignoring the roof overhangs if their area is less than 0.25A, where A is the area of the last floor level):
  i. A floor area greater than 75% of the overlying or underlying floor or a total recess area of all floors less than 40% of the area of the ground floor level: Normal building.
  ii. A floor area of between 60 and 75% of the overlying or underlying floor or a total recess area of all floors of between 40 and 60% of the ground floor level: Partially normal building.

iii. A floor area of less than 60% of the overlying or underlying floor or a total recess area of all floors more than 60% of the area of the ground floor level: Abnormal building.

– Buildings with significant stiffness differences between adjacent floor levels. The stiffness is approximately expressed through the cumulative cross sectional area of the wall ($\Sigma A_w$) for each direction minus openings:

i. Difference in $\Sigma A_w$ between adjacent floor levels < 30%: Normal building.

ii. Difference in $\Sigma A_w$ between adjacent floor levels from 30 to 50%: Partially normal building.

iii. Difference in $\Sigma A_w$ between adjacent floor levels > 50%: Abnormal building.

– Buildings on sloping ground with a height difference of less than one, between one and two or greater than two floors between the lowest and highest level are designated as normal, partially normal or abnormal.

The proposed values for the R10 index are presented in table 11.

Table 11: Values for the height regularity index (R10)

| Characterisation of the form of the building | R10 |
|---|---|
| Normal in height | 1.00 |
| Partially normal in height | 0.75 |
| Abnormal in height | 0.50 |

- The R10 index can be assigned intermediate values based on the judgement of the inspecting engineer.

## 4.11 Earthquake resistance estimate (R)

By considering sections 4.1 to 4.10, it is obvious that the ten seismic resistance indices ($R_i$) should not be weighted equally when determining the value of the seismic resistance (R).

The following classification of the indices into groups is proposed with the corresponding weighting factors ($r_i$), Where $\Sigma r_i = 1.00$.

– Index R1…………………………………… : $r_i = 0.20$
– Indices R3 and R5……………………… : $r_i = 0.15$
– Indices R4, R7 and R8………………… : $r_i = 0.10$
– Indices R2, R6, R9 and R10………… : $r_i = 0.05$

- Based on the above values, the estimate of the seismic resistance of the building (R) is as follows:

$$R = \Sigma r_i \cdot R_i = 0.20R1+0.15(R3+R5)+0.10(R4+R7+R8)+0.05(R2+R6+R9+R10)$$

- Note that all the individual indices take on positive values not exceeding +1.0 with the exception of the R5 index, which is either zero or a negative value not less than -1.0. Consequently, the value of the earthquake resistance estimate in every case is a positive numbers with an upper limit of +1.0.

# 5. BUILDING IMPORTANCE ASSESSMENT (Value: V)

## 5.1 Number of users index (V1)

The following index values are proposed and they depend on the estimated residents or visitors staying in or visiting the building per day:

| Number of people | $X \leq 10$ | $10 < X \leq 50$ | $50 < X \leq 100$ | $100 < X \leq 200$ | >200 |
|---|---|---|---|---|---|
| Values for index V1 | 1.00 | 1.50 | 2.00 | 2.25 | 2.50 |

## 5.2 Building cost index (V2)

The following index values are proposed and they depend on the sum of the floor areas:

| Total floor area ($m^2$) | $A \leq 100$ | $100 < A \leq 500$ | $500 < A \leq 1000$ | $A > 1000$ |
|---|---|---|---|---|
| Values for index V2 | 1.00 | 1.50 | 2.00 | 2.50 |

## 5.3 Administrative and/or social importance index (V3)

The following index values are proposed and they depend on the estimated administrative and/or social importance of the building (see table A4 of appendix A):

| Administrative-social importance | Low | Medium | Important | Special |
|---|---|---|---|---|
| Values for index V3 | 0.80 | 1.00 | 1.50 | 2.00 |

## 5.4 Monumental importance index (V4)

The following index values are proposed and they depend on national, historical, aesthetic, etc. values and contribute to the "monumental" value:

| Monumental value | None | Medium | High |
|---|---|---|---|
| Values for index V4 | 1.00 | 1.50 | 2.50 |

## 5.5. Importance of the building estimate (V)

The following weighting factors ($v_i$) are recommended for the four building importance indices, where $\Sigma v_i = 1.00$:

| Importance indices | V1 | V2 | V3 | V4 |
|---|---|---|---|---|
| Weighting factors ($v_i$) | 0.30 | 0.30 | 0.20 | 0.20 |

- From the above values, the importance of the building estimate (V) is as follows:

$$V = \Sigma v_i * V_i = 0.30(V1+V2)+0.20(V3+V4)$$

- It is noted that, based on the values of the individual indices and their corresponding weighting factors, the importance of the building estimate will be within the range of 0.96 to 2.40.

## 6. BUILDING'S SEISMIC RISK INDEX (Indicator: I)

Based on all of the above, equation 5 determines the seismic risk index (I) of the building.

$$I = V(H/R - 1) \qquad (5)$$

Taking into consideration the values of the individual indices, the seismic risk index of the vast majority of buildings is a positive decimal number that allows the relative ranking of a group of masonry buildings ordered in terms of their need for strengthening before an earthquake occurs.

## 7. REFERENCES

1. EC 6 [2005] European Standard EN, *Design of Masonry Structures, Part 1-1, General Rules for Reinforced and Unreinforced Masonry Structures*, EN 1996-1-1: 1996, CEN Technical Committee CEN/TC250, Brussels.
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