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CODE FOR SEISMIC DESIGN

OF NON-STRUCTURAL BUILDING ELEMENTS

(Draft Proposal, Principles – Content)

ATHENS, DECEMBER 2016

The present proposal for Aseismic Design of Non-Structural Elements (Principles and Contents) was drafted in the period November to December 2016 by the working group consisting of Miltiades Chronopoulos, Ioannis Psycharis and Konstantinos Trezos at the National Technical University of Athens (NTUA).

TABLE OF CONTENTS

Annexes

- Annex I. Additional seismic safety measures during construction
- Annex II. Structural system material-specific requirements (steel, wood, masonry)
- Annex III. Additional requirements for existing buildings
- Annex IV. Additional requirements for escape routes in the event of fire
- Annex V. Additional requirements for the disabled
- Annex VI. Seismic design of building elements, design of fasteners, anchors, dowels etc.

1. Introduction

The present document is a preliminary draft of a code proposal for seismic design of building elements (non-structural components), without being close to being a draft code. Thus, emphasis was given to general principle issues and to the detailed content that a seismic design and arrangement code for building elements should include. The code will be drafted at a later stage by a broad committee that, due to the complex and interdisciplinary nature of the subject, should include architects, mechanical, electrical and civil engineers.

In the present code, the minimum requirements and provisions are presented in order to regulate construction of buildings as a whole as well as of their partial elements, in order to present satisfactory resistance to seismic actions.

Design and detailing of the structural system of buildings is covered by the existing seismic codes: Eurocode 8 part 1 (EN1998-1) and New Hellenic Seismic Code (NEAK). The present document refers mainly to the nonstructural elements of a building.

This code is to be followed in parallel with the Building Codes(GBC) [40] and [37] complementing them with seismic effect considerations in the design and implementation of the non-structural elements of a building.

In drafting of this document, the following were taken into account:

- Prior relative research by the Earthquake Engineering Laboratory of NTUA [1]
- Relative codes and construction practices in USA [2-15], Canada [16,17] and New Zealand [18-20]

An indicative list of building elements is shown in Table 1 [16]

Table 1. Representative List of Non- Structural Components

Building Exterior	
Appendages:	Entrance canopies, overhangs, porches, balconies, and parapets Roof-mounted mechanical units and signs Walkways
Enclosures:	Exterior non-bearing walls (precast, masonry etc.) Exterior infill walls Veneer attachments (masonry, wood, stone etc.) Glazing
Building Interior	
Partitions: (see also Building Contents)	Stairs and shafts Horizontal exits Corridors Fire separation partitions
Ceilings:	Fire rated and non-fire rated
Doors:	Room-to-hallway doors Fire doors Lobby doors and glazing Windows and curtain walls Atrium spaces and skylights Glass elevator enclosures
Lighting:	Light fixtures Emergency lighting
Emergency:	Emergency electrical system Fire and smoke detection system Fire suppression systems (sprinkler) Smoke removal systems Signage
Mechanical:	Large equipment including chillers, heat pumps, boilers, furnaces, fans Smaller equipment including room air conditioning or heating units Suspended equipment Tanks, heat exchangers, and pressure vessels Utility and service interfaces Ducts and diffusers Piping distribution pumps, sprinklers, gas piping Elevators
Electrical:	Communications systems Electrical bus ducts and primary cable systems Electrical motor control centers, transformers, and switch gear Generators, uninterrupted power supplies (UPS)
Building Contents	
	Demountable partitions Filing cabinets, bookcases and library shelving Desktop computers Decorations and artwork Photocopiers and vending machines Refrigerators, microwave ovens, coffee machines in kitchen areas

Purpose of this code is to make sure the buildings and their nonstructural components will satisfy the minimum safety, health, functionality, economic, environmental and sustainability requirements, while minimizing the impact of seismic actions both during and after a seismic event. The objective is to achieve a seismic performance so that:

- Life loss and major injuries are prevented
- Major infrastructure remains functional
- Repair cost of structural and non-structural elements is minimized

For the achievement of this objective, the code aims to:

- Avoid structural collapse under a very rare seismic event
- Control the damages of structural and non-structural elements that could cause injuries, unacceptable financial loss and loss of functionality under less rare or frequent seismic events.

This code sets the basic requirements for a safe and sound building structure or parts thereof under seismic actions, sets the principles under which the requirements are met and proposes practice rules

For this design objective to be achieved, structural and non-structural elements must have adequate strength, fixing/anchorage and displacement capacity during the seismic event.

The degree to which the design objectives are achievable depends on a number of factors, such as the structural system, its materials and the construction quality in general. Moreover the uncertainties regarding the seismic action (intensity and duration) as well as the interaction between structural and non-structural elements or with neighboring structures can prevent the achievement of the design objective. Even under the design seismic loads, as defined in (EN1998-1 and NEAK) it is almost certain to encounter damages in structural and non-structural elements.

2. Basic Principles

Basic principles that govern the seismic behavior of various building elements are:

a) Proper design (including calculations)
b) Proper detailing (in general, including construction details) and
c) Provision for proper use, inspection and maintenance (in time as well as following major seismic events).

Depending on the building and its elements, it is possible that formation of the inspection and maintenance protocol requires interdisciplinary engineering collaboration. The structural design should include references to all the building elements, while the design assumptions, calculations, general arrangement drawings and design report details should be an integral part of the building design to complement the specific discipline designs.

The present code includes rules and guidelines for the above basic principles to be fulfilled for groups of building elements, such as architectural, MEP etc., while emphasizing in escape routes in the case of fire and seismic events. The present code provisions complement the respective provisions of other codes such as seismic, building, and fire protection codes.

In Table 2 an indicative grouping of building elements according to their sensitivity against differential displacements or accelerations during a seismic event is presented [15] (that refers to HAZUS 99 taxonomy of building nonstructural components and contents)

Table 2. Seismic taxonomy of non-building elements [15].

Type	Item	Drift-Sensitive*	Acceleration-Sensitive*
Architectural	Nonbearing Walls/Partitions	•	◦
	Cantilever Elements and Parapets		•
	Exterior Wall Panels	•	◦
	Veneer and Finishes	•	◦
	Penthouses	•	
	Racks and Cabinets		•
	Access Floors		•
	Appendages and Ornaments		•
Mechanical and Electrical	General Mechanical (boilers, etc.)		•
	Manufacturing and Process Machinery		•
	Piping Systems	◦	•
	Storage Tanks and Spheres		•
	HVAC Systems (chillers, ductwork, etc.)	◦	•
	Elevators	◦	•
	Trussed Towers		•
	General Electrical (switchgear, ducts, etc.)	◦	•
	Lighting Fixtures		•
Contents	File Cabinets, Bookcases, etc.		•
	Office Equipment and Furnishings		•
	Computer/Communication Equipment		•
	Nonpermanent Manufacturing Equipment		•
	Manufacturing/Storage Inventory		•
	Art and other Valuable Objects		•

* Solid dots indicate primary cause of damage, open dots indicate secondary cause of damage

3. Structural and non-structural systems

Each building comprises of the structural system (that can be made out of various materials), the shell and walls system (partitions, drywall, glazing etc.), other building elements (staircases, chimneys etc.) and MEP networks. Issues related to the structural system are covered by the seismic design code, while issues related to all other building systems should be covered by the present code for seismic design of building elements complementary to the existing building codes. Inevitably, the building elements as they are directly or indirectly connected to the structural system of the building, follow its behavior, suffer its displacements and, directly or indirectly, the consequences of its damages.

For special building elements, a different performance level (degree and extent of damage) could be accepted than for the structural system (which for usual contemporary buildings is set to life safety with acceptance of extensive structural system damage). Indicatively, in a building the structural system of which is designed to life safety level:

- Non-structural elements of escape routes should be designed for immediate service (minimization of damage) after the seismic event. Similarly for tanks of flammable or toxic materials.
- On the contrary, false floors, internal partitions or certain secondary networks (security cameras, signage etc.) could be designed for severe global damage (collapse prevention).

In the present chapter of the code, there should be an explicit categorization of all non-structural building elements that shall comply to the code provisions and requirements.

4. Building categorization

For the purpose of the present code buildings can be categorized, from a seismic point of view, by structural system material, by use and by importance.

Code requirements related to seismic isolated buildings shall be included in a separate paragraph of the present code.

a. By structural system material

Although the present Code for seismic design of building elements refers to all buildings and their elements, the main document will refer to usual new reinforced concrete buildings. Therefore, annexes will be included referring to:

- New buildings of steel, wood or masonry
- Existing buildings

b. By use

Definitions and provisions of existing codes (Building Code, Building Element Code, Seismic Code, Eurocode 1) will be unified and used so that distinction between buildings and building elements is clear and detailed regarding the requirements according to the principles of the present code.

c. By importance

Requirements for design, proper use, inspection, maintenance etc. will be specified according to importance and vulnerability.

5. Joints

Joints are a fundamental parameter for reliable prediction of building behavior, either between different properties (external joints) or within the same property (internal joints).

The code must specify joint width subjects in relation to:

- The arrangement of building elements (e.g. thermal insulation) and the sealing of the joint, while, for internal joins in particular, there shall be provisions regarding their arrangement (in plan and elevation) and their interaction to building elements such as networks and installations.
- The existence or not of neighboring buildings, slab level differences and other formation subjects.

Materials and joint sealing systems must be designed and included in the building drawings.

Finally, because the Eurocode EN1998-1 is (admittedly) incomplete in regards to joint width subjects, there should be some additions based on the requirements of the Hellenic Seismic Code NEAK.

6. Building Shell

Shell elements are a fundamental group of building elements regarding the seismic response, both individually as well as in relation to the building environment (neighboring buildings, pedestrians, urban utilities, parked vehicles etc.).

Mass and stiffness properties of specific groups of shell elements such as marble or stone walls, brick coating, precast panels, rigid brick walls etc. might create force and displacement incompatibilities with the structural system and hence require specific examination of their interaction.

a. Glazing

Glazing can be categorized in embedded to the structural system and to external continuous walls (in contact or at a distance from the structural system). Their seismic design is required both in and out of plane. Special care should be given to relative displacements imposed by the structural system and the ability of supports and bearings to accommodate them.

Depending on the size and support system of the glazing, there should be provisions for strengthened or reinforced glass panels, among other measures (Figure 1, [18]).

Figure 1. Widespread damage to a glass ceiling system From [18], H. Ferner, M. Wemyss, A. Baird & A. Beer, Seismic performance of non-structural elements within buildings

b. Façade coating: marble or stone walls, bricks etc.

Those elements can be categorized in embedded to the structural system and to external panels. Provisions for their design and arrangement should be given for both cases depending on parameters such as materials, support system and coating thickness. Their dynamic response should be taken into account in analyzing their out of plane bending and their mass should be taken into account in analyzing the structural system response.

c. Façade walls, infills, prefabricated panels

Those elements are embedded to the structural system since if they are external they fall into the façade coating category.

The seismic design code for buildings has provisions regarding the façade brick walls and their interaction with the structural system (globally or locally) (and depending on the structural system material: reinforced concrete, steel, masonry or wood).

References shall be made to the provisions of the seismic design code for buildings and design and arrangement details shall be specified (see also relative provisions of code for interventions, KANEPE).

Special provisions must be included regarding single leaf (compact) walls, dual leaf (with continuous gap) walls, glass-block walls (that have extremely brittle behavior) and concrete block walls.

d. Doors/openings

Provisions shall be given for doors and openings in non-bearing walls, combined with requirements for strengthening of their perimeter.

The design of the support and function of doors and windows shall take into account the safety of persons, vehicles and goods outside and near the building during a seismic event.

Relative references must exist in Chapter 10 and in Annex IV regarding escape routes.

e. Chimneys

Chimneys will be designed and arranged in a way to minimize seismic damages, regardless if they are supported on the building facades (attached to the structural system or to non-bearing walls) or if they are located on the building roof.

Special care should be given to free heights of chimneys and measures should be taken depending on the height and the material/system.

For free heights of 3.0m and above, a structural design shall be executed, with assumptions, calculations, drawings etc.

f. MEP roof equipment

Beyond the relative provisions and requirements (see Chapter 8) the subject elements shall be designed and arranged as addenda to the building (see annex VI) individually and regarding their connections, fixings and anchorages to the structural system.

Design and arrangement shall provide increased seismic protection for exceptionally heavy installations (including swimming-pools) or for dangerous combustible elements or toxic materials).

g. External staircases

External staircases, usually made of steel or reinforced concrete, will be treated in a different manner depending on whether they are independent structures (provided that they have adequate joint width with the building) or addenda with the required connections, fixings etc.

Provisions and requirements of this paragraph are to be examined in conjunction with those of Chapter 10 and Annex IV regarding escape routes.

All sorts of connections, fixings, anchorages etc. of structurally dependent external structures shall be designed and arranged with increased seismic protection (limitation of damage, continued serviceability, etc.)

h. Billboards

Seismic consideration and provisions for such elements shall vary depending on their size and weight and on their arrangement on the roof, on the façade or in cantilever (Figure 2 [14]).

Figure 2. If only the sign on this large hospital had been damaged in the January 17, 1994 M 6.7 Northridge Earthquake, this essential facility could have continued to function. However, the cosmetic damage is an indicator of the fact that mechanical equipment at the top level lurched loose during the earthquake. Without air conditioning, a modern hospital cannot operate, and this one had to close until repairs were made. *source: Robert Reitherman* (From [14])

Such addenda must be fixed directly on the structural system of the building and not on other building elements such as walls etc.

i. Insulation coatings

Such elements shall be secured both in and out of plane against seismic actions using suitable and durable materials for fixing and anchorage.

Relevant provisions shall cover both fixing on members of the structural system and fixing on other building elements such as walls of all kinds of the building shell.

7. Internal non-structural elements

Unlike building shell elements, internal non-structural elements as well as other internal elements (such as mezzanines not included in the original building structure) do not need to offer higher seismic protection than the rest of the building structure.

Differences between provisions for internal non-structural elements presented in Chapter 6 and external non-structural elements are presented in the below.

a. Internal brick walls

Internal brick walls (infills) are typically single leaf walls and the major factors of difference are whether they are wedged to the structural system or not and whether they are part of escape routes or not. Such brick walls shall be examined individually (in and out of plane) and regarding their interaction (locally or globally) with the structural system. In any case, provisions and measures for damage limitation should be made as they might be supporting internal networks and installations whose failure could be unacceptable for functionality reasons or of disproportional cost. For exceptionally heavy and rigid brick walls, that could be intentionally not wedged to the structural system to avoid their interaction, one could examine their complete separation designed and provisioned accordingly for out of plane behavior (Figures 3 to 5, [21]).

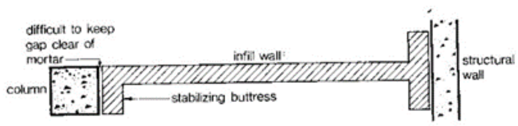

Figure 3. Separated stiff partition; plan view of stabilizing buttress systems, [21].

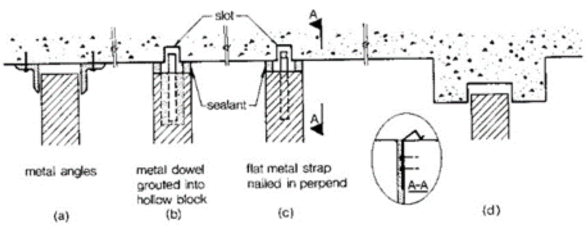

Figure 4. Separated stiff partitions; top details for lateral stability of brick or block walls,[21].

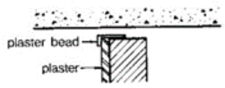

Figure 5. Plastering detail to ensure preservation of gap between partition and structure, [21].

b. Light partitions

Light partitions are divided to full height elements (that are suspended or supported on the structural system of the building) and to limited height (usually supported on the floor)

Full height light partitions are covered by the structural system damage limitation provisions of the seismic code for buildings. Limited height light partitions are exempt of additional requirements and provisions.

Relatively light full height panels that are part of escape routes (in seismic and/or fire events) shall be designed and arranged according to the provisions of Chapter 10 and Annex IV.

See in the attached Figures 6 and 7 photos of fallen partitions and details of structure separation.

Figure 6.
(above) Partition tipped over, 1994 Northridge Earthquake,
(bottom) Fallen stud/gypsum board partition, *source: Wiss, Janney, Elstner Associates, FEMA 74*
From [14]

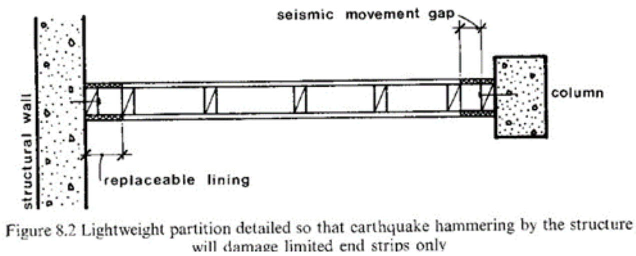

Figure 7. Lightweight partition detailed so that earthquake hammering by the structure will damage limited end strips only, [21].

c. Doors/openings

Arrangement and dimensions of openings (in non-bearing walls) shall be described in combination with requirements for strengthening of their perimeter. The design of the support and function of doors shall take into account safety under seismic event in the internal of the building. Additionally, references and requirements of Chapter 10 and Annex IV shall be considered if the doors are part of escape routes.

d. False ceilings, Lighting and Ventilation

False ceilings are elements that are usually combined with suspension of lighting and ventilation systems, beyond the decorative or functional paneling of the ceiling itself increasing thus their seismic vulnerability and risk (Figure 8 [14] and Figures 9 to 11).

Figure 8. Complete collapse of a suspended ceiling over a swimming facility. *source: Shojiro Motoyui, Tokyo Institute of Technology* (From [14])

Figure 9. After severe shaking in the January 17, 1994 M 6.7 Northridge Earthquake, light fixtures at Olive View Medical Center were dislodged from their ceiling support, but properly installed back-up safety support wires kept them from falling. source: Robert Reitherman [14]

Figure 10. Widespread damage to a ceiling system From [18], H. Ferner, M. Wemyss, A. Baird & A. Beer, Seismic performance of non-structural elements within buildings

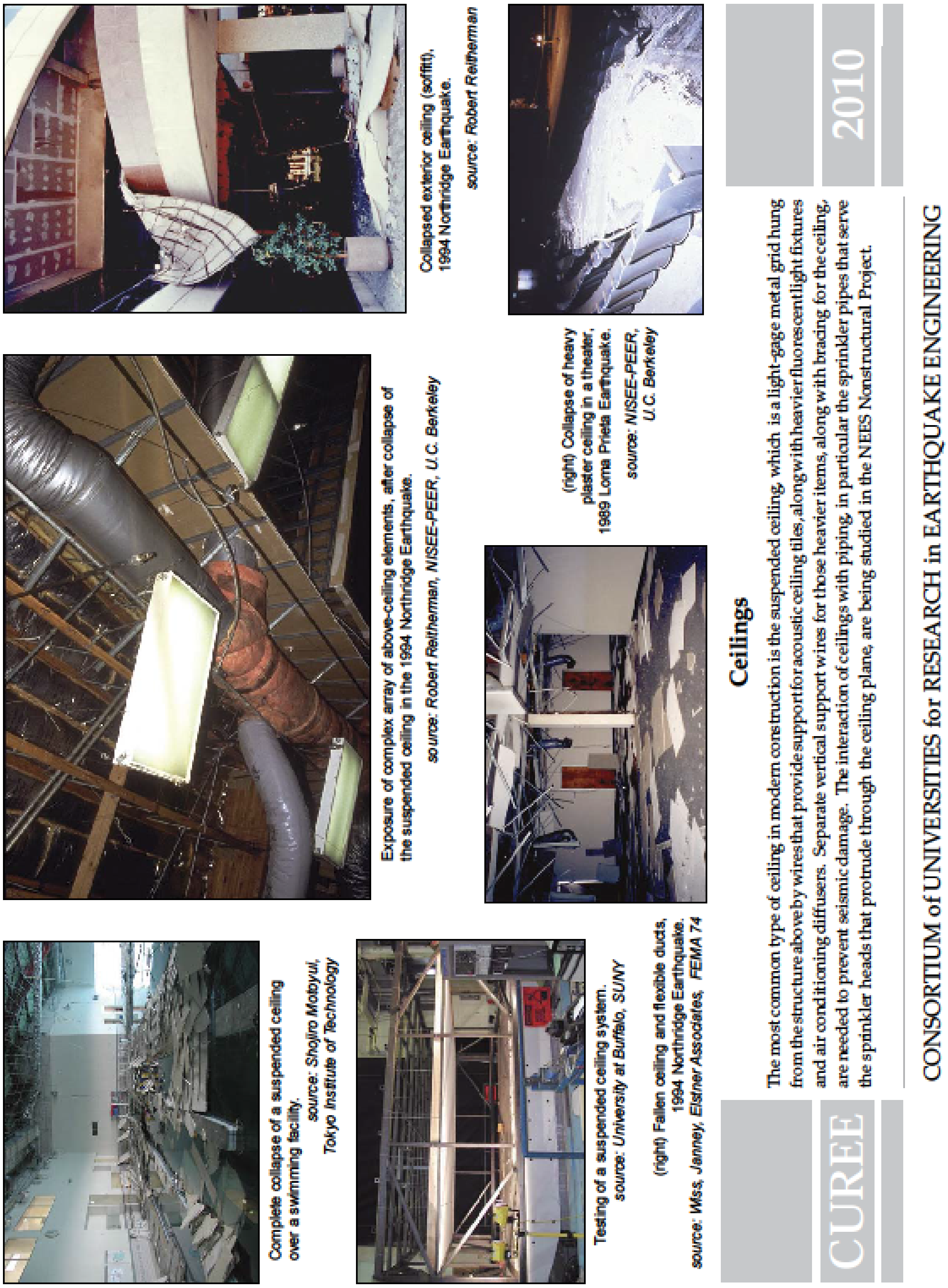

Figure 11. Ceilings (characteristic damages) [14]

A differentiating factor for false ceilings is their support system: either simply suspended from the structural elements (slabs and beams) or both suspended and fixed to the vertical structural elements. Design of the simply suspended ceilings is governed mainly by gravity loads and joint width to the surrounding structure, while for the second group interaction with the structural system in terms of strength and displacements must also be considered.

Further to the design and arrangement of the false ceiling, provisions shall be made to secure elements supported on it against falling (seating widths and joints, construction tolerances etc.). In Fig 12, [12], an indicative detail is given concerning proper arrangement of the ceiling.

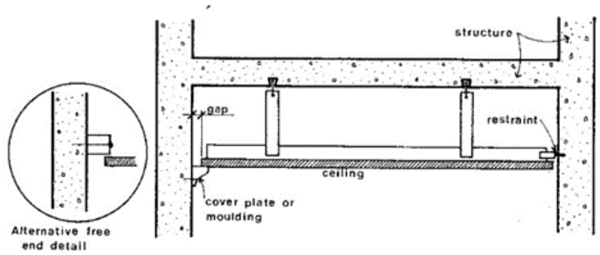

Figure 12. Details at periphery of suspended ceilings to prevent hammering and excessive movement, [21]

e. Other elements: mezzanines etc.

For the purpose of this code mezzanines are considered horizontal bearing elements that have been constructed after the completion of the structural system of the building that are supported on, or suspended from, under- or overlaying structural elements. Mezzanines are obviously designed against gravity and seismic loads, in the present code however, their structural and construction requirements related to their interaction with the structural system and other building elements (such as walls, false ceilings, networks and installations) are specified.

8. MEP elements

MEP elements have increased complexity and uncertainty due to:

- the nature and the extent of the MEP equipment, the pipes and cables network, the distribution system
- the seismic response of the structure that is related to the networks and installations as well as the amount of crossings, connections and fixings
- the necessary connections of the internal building networks to the external urban networks

The seismic design of MEP elements is presented in the Annex VI, while in the present chapter of the code provisions and requirements are given regarding their construction and arrangement so that the seismic damages are controlled.

Compatibility of displacements of the structural system to the crossing of supported MEP elements must be secured. There is a plethora of industrialized elements for isolation, absorption or damping of vibrations or other displacements, suitable for various cases of networks, installations and pipes. Those industrialized parts should however be decoded and filed in regards to their specifications, level of protection provided, strength, durability, replaceability etc.

a. Networks/installations / piping

Those elements must be categorized in regards to their risk level (gas, electricity vs. heating or cooling) and in regards to their importance for the specific use and size of the building (e.g. oxygen supply to a hospital, fire detection/fighting in a multistory building).

An initial network categorization could be:

- Water supply - sewage
- Cooling - heating
- Gas
- High Voltage
- Low voltage
- Fire detection - fighting
- Oxygen and other medical networks in hospitals

Design and arrangement requirements shall be provided for the above network categories, taking into account the structural system and the rest of the building elements in combination with the available special parts for absorption and damping of vibrations and displacements.

In the next Figures 13 and 14 bracings details are presented, while in Figure 15 mountings and vibration isolation details are given.

Figure 13. Common prescriptive approach to bracing a typical lightweight suspended ceiling, with four-way bracing wires and a vertical compression strut, [14].

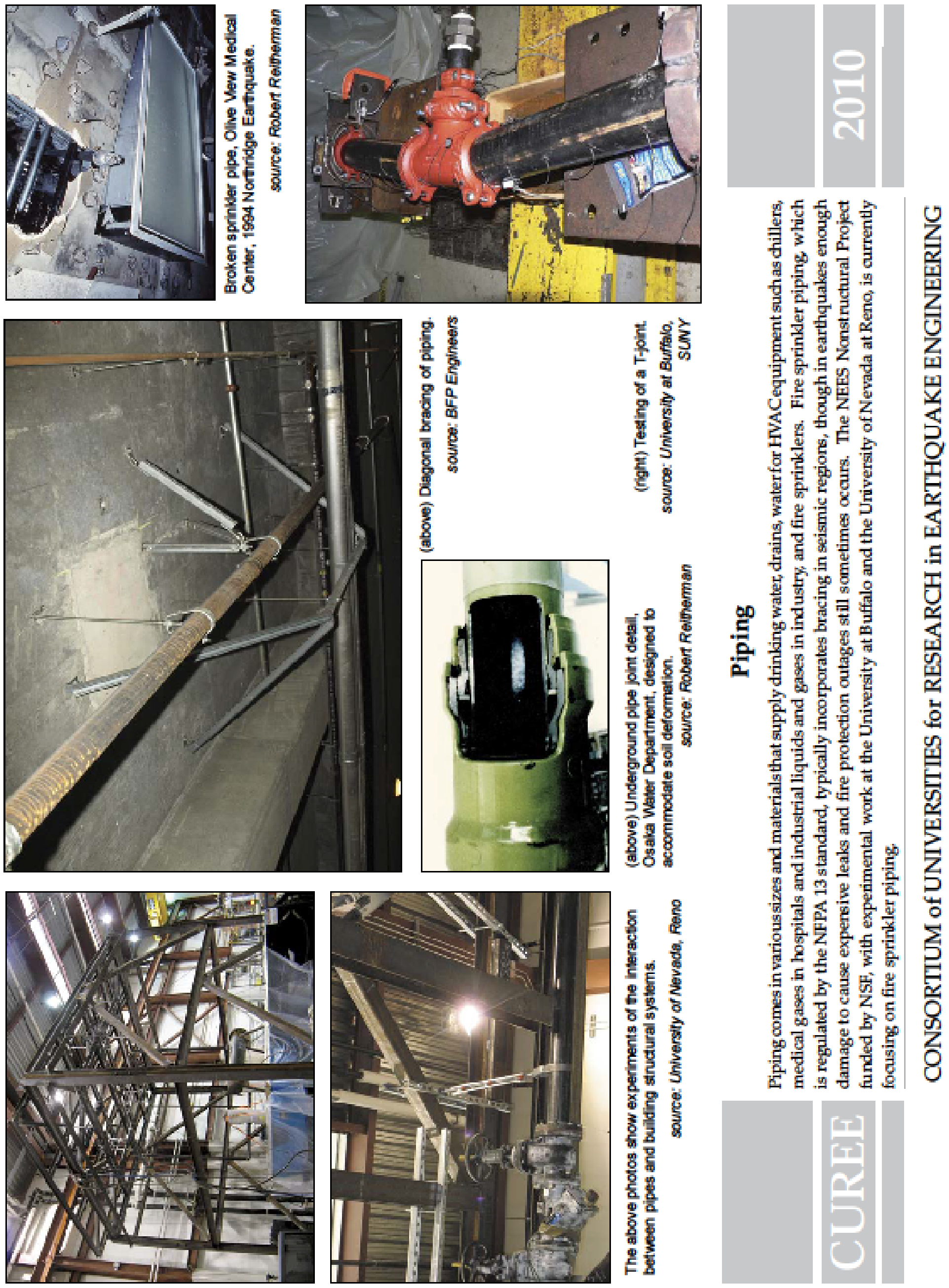

Figure 14: Piping (From [14])

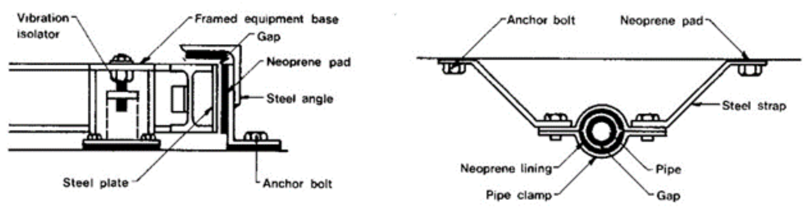

Figure 15. Combined earthquake mountings and vibration isolation for machine bases and pipework [21](after Berry, O.R.: “Architectural seismic detailing”, State of the art report No. 3, IABSE-ASCE International Conference on Planning and Design of Tall Buildings, Lehigh University, August 1972))

b. Elevators

The two main elevator categories are mechanic and hydraulic, while there is a differentiation according to the construction materials of the elevator shaft structure (concrete shear walls, masonry, steel, etc.). For both main systems, additional damage limitation provisions shall be given.

c. Travellators, escalators

Those elements, due to their mass and the potential (intentional or not) connection between subsequent floors, might create interaction problems against which special measures should be taken either to absorb the relative displacements, or to accommodate them in the design of both the building structure and the element itself.

9. Equipment – content

Depending on the function, use and importance of each building, there should be recommendations or provisions for the protection of the equipment and content of the building during a seismic event.

Indicatively, reference shall be made for cases of special or valuable equipment/content (e.g. art, sensitive electronics, etc.), heavy files, heavy storage facilities etc. (See Figures 16 to 18).

Figure 16. Longitudinal failure of library shelving. The tremendous mass of the books, accelerated along the axis of the shelving, can overwhelm sometimes deficient bracing that is seen only when the books are removed. Bracing rows of shelving transversely, as here with an overhead strut, does not prevent this kind of dangerous damage. *source: NISEE-PEER, U.C. Berkeley* From [14]

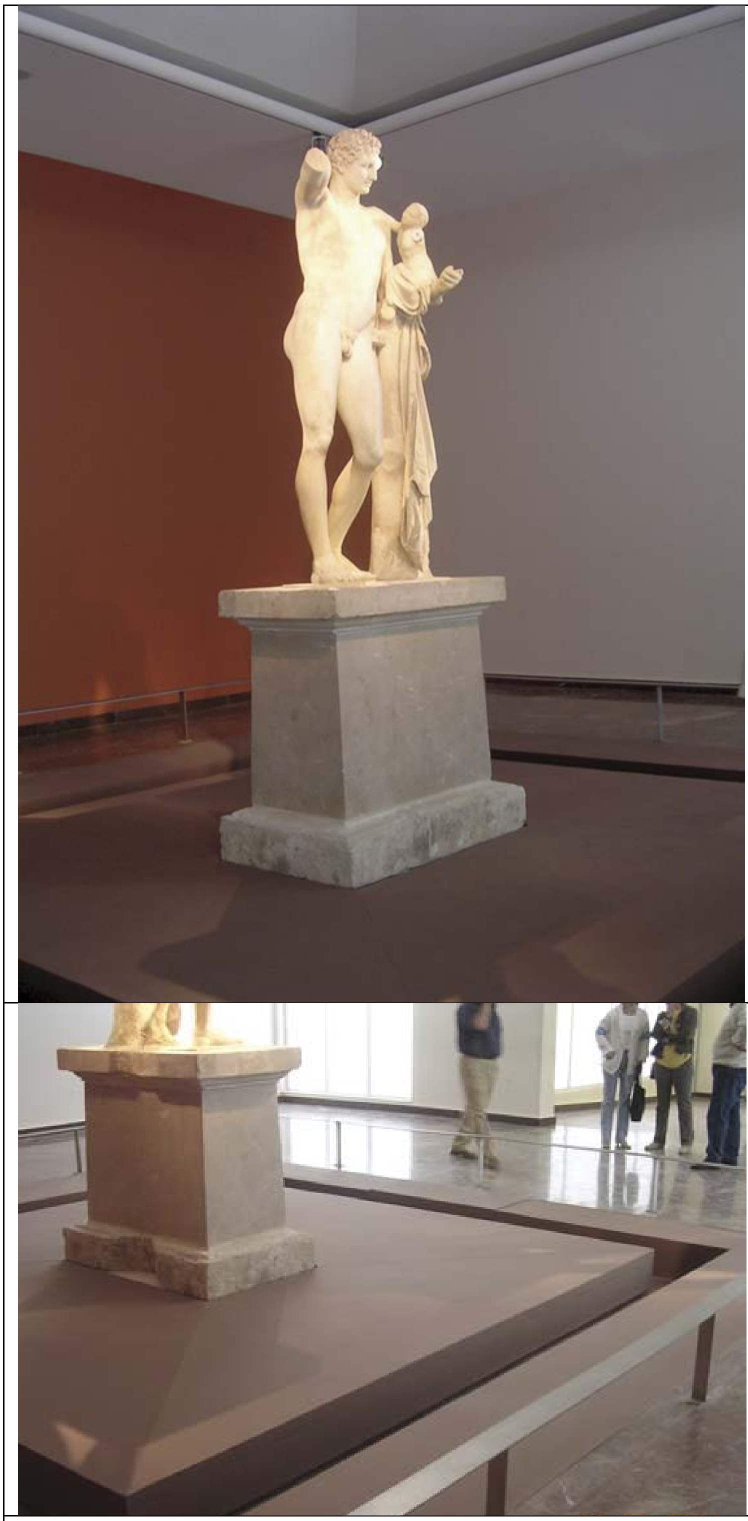

Figure 17. Statue of Hermes by Praxiteles, Archaelogical Museum of Olympia. The statue has been mounted on a seismically isolated base. *source: Michael Constantinou From* [14]

Figure 18. Seismic restraint of an object of artistic and historical value with nylon filament (fishing line) in the Tokyo National Museum in Ueno Park. (From [14])

Depending on the case, the provisions shall include simple fixing with elastic strands or strips, metal or plastic elements etc. or design of suitable fixing and anchorage onto the structural system, both at the foot of the fixed element and along its height, to avoid falling overturning and breaking. Additionally, the elements of the equipment and the content of the building that are to be considered and designed as addenda to the building shall be specified.

10. Escape routes (and exits)

The requirements of the Fire Protection Code for Buildings (ING 32/A/17-2-88) cover for the most part the requirements regarding the escape routes during a seismic event.

This chapter presents additional requirements for escape routes, created by the particularity of the seismic danger and by the need to address a potential fire following a seismic event.

The damage categories that affect the post-seismic performance against fire of a building concern three groups: fire compartments, escape routes and structural integrity.

Further to the requirements of the Fire Protection Code for Buildings (ING 32/A/17-2-88), escape routes must fulfill the below requirements.

- Importance factor of fire detection and fire-fighting elements and for elements that could block the escape routes.
- Forces and displacements
- Potential failure of non-structural elements shall not impede the escape routes function (fixed panels, false ceilings, roofs, partitions, false floors, glass panels)
- Failure of an element may trigger failure of other members (chain failure)
- Measures of increased protection shall be provided for non-structural elements (marble slab coatings, parapets, shelters, decorative items) that are located in the escape routes, such as fixing with anchors and dowels, reinforced masonry etc.
- Escape route exits might require protection by special shelters
- Moving or falling due to seismic actions of non-stabilized furniture (bookcases, desks)
- Potential failure of shelters or fall of glass panels at escape route exits
- Attention to stoves, boilers, risk of fire
- Lower user escaping speed depending on the degree of damage (from 1m/s in the case of no damage to 0.3m/s in the case of extensive damage)

Due to the severity of the subject, two annexes are provided: additional requirements for the event of fire and additional requirements for the disabled.

The below are from the research: “Seismic Design Code for Building Elements” [1] and from the Fire Protection Code for Buildings [22]

a. General

Requirements of this chapter intend to provide safe and timely escape of persons inside the building during the seismic event as well as during fire (that could also happen after an earthquake). This is achieved by providing suitable escape routes.

The exceptional conditions that are created by the seismic event require the existence of escape plans for the public that will be operational during the emergency situation.

Additionally, correct planning of the building elements and seismic-safe arrangement and function of the building, require the existence of escape routes that will evacuate the public in a safe manner from the damaged areas to refuges that can provide protection to the public.

In the Fire Protection Code for Buildings, escape route is defined as a continuous and unobstructed safe exit course from any point of any building or structure to a public street, and subsequently to a refuge.

Escape of the building users in the case of emergency happens in three discrete stages:

- Stage one: Emergency access. The stage of the escape route from any building point towards an exit.
- Stage two: Protected escape path. The stage of the escape route through built or external areas that are separated by the rest by suitable structural elements, materials and arrangements in order to secure a protected walkway towards an exit or to a public street.
- Stage three: Emergency exit. The stage of the escape route between the end of the escape path and the public street or the refuge.

The risk of an escape route (possibility of failure) must be decreasing towards the exit. Therefore, suitable shelters might be required at the exits.

Geometrical and functional properties of the escape routes are:

- Flow capacity
- Width

- Free height and
- Relative position of exits

Those properties must be defined depending on the use and function of each building, while provisions shall be made for the route design, arrangement, materials, elements, networks, installations etc.

The escape route must be a specially protected part of the building due to the importance of its part in the secure and safe evacuation and must follow the below safety requirements:

- Along its length there should not be any objects, or if they are necessary they must be fixed to avoid dangerous displacements during a seismic event.
- Its layout must be as simple and short as possible and at the same time accessible from all the building areas that it covers.
- Proper signage is required along the escape route that will point the escape direction and all intermediate doors will open towards that direction.
- The escape route will not include any part whose function is dangerous or prohibited in a seismic or fire event, such as elevators, escalators, travellators, cantilevers etc.

For the present code, all requirements and provisions regarding escape routes and emergency exits are included in this chapter, while references are included in other chapters or annexes such as Annexes III and IV (regarding fire in existing buildings) and Annex V (additional provisions for the disabled).

In certain cases, various building elements of those escape routes must exhibit higher seismic protection level compared to the structural system of the building as will be specified in the code.

b. Properties

Flow Capacity

The required capacity of an escape route is determined by the population and the use of the building and it is determined by its properties.

Width

Width of an escape route is considered as the free width at its narrowest point with a minimum height of 2,00m. Handrails that protrude up to 0,09m and beams that protrude up to 0,04m are exempt from the above. As escape route width through a door is considered the free width of the open door. Door handles and hinges are not considered to limit the measured width

Relative position of exits

When the code requires more than one emergency exits, at least two of them should be positioned far from each other. For buildings with nine or more levels above ground, if emergency accesses that lead to different exits for the same floor use the same corridor, that corridor must follow the strictest standards.

Free height

Free height of escape routes shall under no circumstances be less than 2,20m in general and 2,00m in staircases and individual locations such as under the hang of beams, doors or signs.

Floor level changes

Floor level changes along an escape route shall be by steps or ramps. When the height does not exceed 0,40m changes shall be exclusively by ramps. Exceptions are possible for outdoor areas of exits and if so specified by specific requirements depending on the building use.

Internal finishes

Internal finishes of structural elements around an escape route shall follow the requirements specified per the building use.

Escape access, Length measurement

Lengths of an escape access are measured on the floor, steps or ramp along the central line of the natural route. Measurement begins at 0,30m from the furthest point of the floor, follows the shortest path a person can take avoiding corners and obstacles by 0,30m and finishes at the middle of the exit.

As an exception, in cases of rooms that are not used by more than six persons and the natural route from any floor point to the door does not exceed 15,00m, measurement starts from the middle of the room door.

For parts of the escape route that include steps, the length is calculated as 1,2 times the horizontal length.

For parts of the escape route that include ramp, the length is measured on plan view. In case any part of the escape route, with one side open to outdoors, is in horizontal distance of less than 3,00m from an unprotected building opening, this part of the escape route until the ground level is included in the emergency access length.

Emergency accesses, Length limit

The maximum length of emergency accesses shall be determined according to the building use.

Emergency accesses, Outdoor parts

Emergency accesses can pass through external balconies, verandas or roofs under the condition that all of the below are fulfilled:

- Those outdoor parts have solid smooth floor, adequately flat and are equipped with balustrades wherever they are not limited by a wall
- Each outdoor part has such arrangement that there are no dead ends longer than 6,00m.
- For a path to qualify as part of an escape route, it must not be inhibited by barriers, movable or not obstacles of any kind, nor include doors that can be locked.

c. Emergency accesses, Exits arrangement

Emergency exits arrangement must be such that they are always easily accessible.

From every building location, access to two emergency exits through different escape routes will always be available, unless allowed otherwise by other codes.

Every door leading from a room towards an exit or an escape route must rotate around a vertical axis at its edge and comply to the requirements of the present chapter. The rotation direction of the door must be towards the escape direction when the room may be occupied by 50 persons or more or when the room has a high degree of danger due to its contents.

Escape routes are not allowed to pass through bedrooms, bathrooms or other areas that can be locked. This prohibition is void if the escape route concerns only the area that can be locked.

Escape routes and emergency exits must be arranged such as to be easily recognized. Doors of escape routes are not allowed to be covered by curtains or else that would hide or obstruct the escape. Placement of mirrors near or along escape routes in a way that can create confusion as to the direction of the escape route are not allowed.

Minimum width of escape routes will be determined according to the building use, but under no circumstances will it be less than 0,70m. In case where one single escape route ends in one exit, its width is not allowed to be smaller than the required exit width. In case where more than one escape routes end in one exit, their width will be at least according to the amount of people it will serve.

d. Protected escape route

When a protected escape route is required by the code, this must be separated by other building parts, by building elements that are considered the protected escape route shell and must comply with certain standards.

No part of a protected escape route may be used for purposes that would decrease its value as a protected escape route. Pipes containing combustible gases or liquids are not allowed. Other pipes may be allowed according to the standards.

11. Inspection - Maintenance – Proper use

The present code must include recommendations (at least) for the proper use in time of all the elements that compose the building, with additional guidelines for the most vulnerable (under seismic or fire events) building elements, such as thin walls, combustible or toxic materials area, expensive or special equipment areas.

Additionally, provisions and requirements regarding the periodical inspection and maintenance of the building elements shall also be included, depending on the size, use and importance of the building, combined with a related protocol and archive. Building elements can be divided into large groups that will require inspection every one, five, fifteen or twenty-five years.

The inspections will include checking not only of the building elements themselves, but also all sorts of anchorages, connections, fixings etc. to the structural elements of the building and they will be compulsory after every major seismic and fire event. In case any damage is identified after any such event, all subsequent repairs and interventions shall be recorded in the "building identity log".

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Annex I.

Additional seismic safety measures during construction

Provisions and requirements shall be given for additional safety measures i.e. regarding temporary scaffolding, shoring, retaining or supporting etc. during construction works of:

- Construction of new buildings
- Excavation or retaining
- Maintenance or repair internally or externally
- Modification or addition
- Retrofitting or strengthening after seismic damages

Relative provisions for prefabrication should also be included.

Temporary design situation according to EN1990 will be considered.

Annex II.

Structural system material-specific requirements (steel, wood, masonry)

Beyond the basic requirements for each building type, detailed reference shall be made to special building elements with structural system made of steel, wood or masonry.

Indicatively, such elements include panels, light wall partitions and secondary structural elements made of steel, wood, masonry etc.

Annex III.

Additional requirements for existing buildings

Based on the total of requirements for elements of new buildings, the provisions for existing buildings should be modified according to the use, the size, the importance etc. while special requirements should be set for historic or traditional buildings.

For existing buildings, a lower seismic protection could be accepted for elements other than their structural system.

Annex IV.

Additional requirements for escape routes in the event of fire

According to the codes, building elements that are part of escape routes for seismic events shall be designed so as to provide a safe escape route and exit for the event of a fire following the seismic event.

Additional provisions will be set, wherever required, for the structural integrity of the building elements in the event of fire.

Annex V.

Additional requirements for the disabled

Wherever necessary, i.e. in escape routes, or in vertical communication routes between building stories, additional requirements for the disabled should be set.

A provision could be made for the existence of safe rooms within the building with increased fire and seismic resistance regarding the building elements.

Besides other provisions, building elements outside the building shell, such as elevators, escalators and corridors, should be provided for the disabled. Relative provisions (with references) should be included in annex III for existing buildings.

Annex VI.

Seismic design of building elements, design of fasteners, anchors, dowels etc..

Seismic design provisions and requirements regarding forces, displacements or deformations shall be given for each group of building elements (such as non-structural elements (appendages), architectural, MEP networks, installations etc.).

Relevant requirements will refer not only to the building elements themselves (under seismic loads) but also to their connections, fixings, foundations, anchorages etc. according to structural material of the system.

In the below, the provisions for non-structural elements (appendages) of buildings are indicatively presented, while it is noted that additional provisions for other element groups (i.e. glazing, chimneys, billboards, etc.) are required.

[The next text is from Eurocode 1998.1]

(1)P Non-structural elements (appendages) of buildings (e.g. parapets, gables, antennae, mechanical appendages and equipment, curtain walls, partitions, railings) that might, in case of failure, cause risks to persons or affect the main structure of the prEN 1998-1:2003 (E) 53 building or services of critical facilities, shall, together with their supports, be verified to resist the design seismic action.

(2)P For non-structural elements of great importance or of a particularly dangerous nature, the seismic analysis shall be based on a realistic model of the relevant structures and on the use of appropriate response spectra derived from the response of the supporting structural elements of the main seismic resisting system.

(3) In all other cases properly justified simplifications of this procedure (e.g. as given in **4.3.5.2(2)**) are allowed.

Verification

(1)P The non-structural elements, as well as their connections and attachments or anchorages, shall be verified for the seismic design situation (see **3.2.4**).

> NOTE The local transmission of actions to the structure by the fastening of non-structural elements and their influence on the structural behaviour should be taken into account. The requirements for fastenings to concrete are given in EN1992-1-1:2004, 2.7.

(2) The effects of the seismic action may be determined by applying to the non-structural element a horizontal force F_a which is defined as follows:

$$F_a = (S_a \cdot W_a \cdot \gamma_a)/q_a \tag{4.24}$$

where

F_a is the horizontal seismic force, acting at the centre of mass of the non-structural element in the most unfavourable direction

W_a is the weight of the element

S_a is the seismic coefficient applicable to non-structural elements, (see **(3)** of this subclause);

γ_a is the importance factor of the element, see **4.3.5.3**

q_a is the behaviour factor of the element, see Table 4.4.

(3) The seismic coefficient S_a may be calculated using the following expression:

$$S_a = \alpha \cdot S \cdot [3(1 + z/H) / (1 + (1 - T_a/T_1)^2) - 0,5] \quad (4.25)$$

where

α is the ratio of the design ground acceleration on type A ground, ag, to the acceleration of gravity g;

S is the soil factor;

T_a is the fundamental vibration period of the non-structural element;

T_1 is the fundamental vibration period of the building in the relevant direction;

z is the height of the non-structural element above the level of application of the seismic action; and

H is the building height measured from the foundation or from the top of a rigid basement.

The value of the seismic coefficient S_a may not be taken less than $\alpha \cdot S$.

Importance factors

(1)P For the following non-structural elements the importance factor γa shall not be less than 1,5::

- anchorage elements of machinery and equipment required for life safety systems
- tanks and vessels containing toxic or explosive substances considered to be hazardous to the safety of the general public.

(2) In all other cases the importance factor γa of non-structural elements may be assumed to be γa = 1,0.

Behaviour factors

(1) Upper limit values of the behaviour factor q_a for non-structural elements are given in Table 4.4.

Table 4.4: Values of qa for non-structural elements

Type of non-structural element	q_a
Cantilevering parapets or ornamentations Signs and billboards Chimneys, masts and tanks on legs acting as unbraced cantilevers along more than one half of their total height	1,0
Exterior and interior walls Partitions and facades Chimneys, masts and tanks on legs acting as unbraced cantilevers along less than one half of their total height, or braced or guyed to the structure at or above their centre of mass Anchorage elements for permanent cabinets and book stacks supported by the floor Anchorage elements for false (suspended) ceilings and light fixtures	2,0