Earthquake resistant design of buildings

Preface

The Instituto Nacional de Normalización, INN, is the organization in charge of studying and preparing national technical standards, member of the INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO) and the COMISION PANAMERICANA DE NORMAS TECNICAS (COPANT), as the representative of Chile.

The NCh433 code has been prepared by the Standardization Department of the Instituto Nacional de Normalización. The current version of this code corresponds to a revision of the document made official in 1993, its development is detailed below.

The Comité Coordinador de Normas Sismorresistentes, set up by the Instituto Nacional de Normalización, in July of 1986, was responsible for writing and developing this document, submitted to public consultation in July of 1989. The Committee had the collaboration of 30 professionals and university professors. The following people and organizations participated in developing and approving the provisions of the 1993 version.

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SERVIU Metropolitano	Ernesto Herbash A.
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Kort K., Issa	Issa Kort K.
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During the year 1994, the Asociación Chilena de Sismología e Ingeniería Antisísmica, ACHISINA, organized four working groups to collect the experience of the professional community in the application of the NCh433.Of93 code. The final conclusions of these working groups were transmitted to the INN, who analyzed and transformed these conclusions into a group of propositions to be studied in the revision process of the code. Since these did not represent important changes of the document, public consultation was omitted, and the committee, which approved the NCh433.Of93 code, was convoked directly, this invitation also included the participants of the working groups of ACHISINA. The following people and organizations participated in the committee:

ACMA S.A.	David Escárate N.
Arze, Reciné y Asociados	Elías Arze L.
Colegio de Arquitectos	Oscar Bórquez D.
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This code was studied to establish the minimum requirements for seismic design of buildings.

Annex A does not form part of the code, it has been included only as information.

Annex B forms part of the code.

The maps included, figures 4.1 a), b) y c), have been authorized by Resolution N° 136 of the Dirección Nacional de Fronteras y Límites del Estado, with the date of July 13th , 1993.

This code invalidates and substitutes NCh433.Of93, *Diseño sísmico de edificios*, declared as the Official Chilean Code by the Ministerio de Vivienda y Urbanismo, made effective under the Presidential Decree N° 90, dated August the 24th of 1993, published in the Diario Oficial N° 34.668, September the 16th of 1993.

This code has been approved by the Board of the Instituto Nacional de Normalización, in a meeting held the 26th of June of 1996.

This code has been declared Official Chilean Code by the Ministerio de Vivienda y Urbanismo, made effective under the Presidential Decree N°172, dated December the 5th of 1996, published in the Diario Oficial N°35.648, December the 23rd of 1996.

The English translation of this code was made by Ms. Rebeca Frenk under the supervision of the committee members Messrs. Tomás Guendelman and Pedro Hidalgo.

Earthquake resistant design of buildings

1 Scope

1.1 This code establishes minimal requirements for the seismic design of buildings.

1.2 This code also refers to the seismic requirements that equipment and other secondary building elements shall meet.

1.3 Recommendations on the evaluation of the seismic damage and how it should be repaired are also provided.

1.4 This code is not applicable to the seismic design of other non-building structures such as bridges, dams, tunnels, aqueducts, docks, channels nor to industrial buildings or industrial facilities. The design of such non-building structures must meet the corresponding Chilean code.

2 References

NCh427 *)	Construcción - Especificaciones para el cálculo, fabricación y construcción de estructuras de acero.
NCh430 *)	Hormigón armado - Requisitos de diseño y cálculo.
NCh431	Construcción - Sobrecargas de nieve.
NCh432	Cálculo de la acción del viento sobre las construcciones.
NCh1198	Madera - Construcciones en madera - Cálculo.
NCh1537	Diseño estructural de edificios - Cargas permanentes y sobrecargas de uso.
NCh1928	Albañilería armada - Requisitos para el diseño y cálculo.
NCh2123	Albañilería confinada - Requisitos de diseño y cálculo.

*) See annex B transitory references.

3 Terminology and symbols

3.1 Terminology

3.1.1 reinforced masonry: masonry that meets the requirements specified in the NCh1928 code.

3.1.2 confined masonry: masonry that meets the requirements specified in the NCh2123 code.

3.1.3 diaphragm: structural element at a floor level, that transmits horizontal forces to the vertical resisting elements.

3.1.4 secondary element: permanent element not being part of the resistant structure, but that it is affected by its movements and eventually interacts with it, such as dividing partitions and non-structural facade elements, large windows, false ceilings, parapets, cornices, shelves, decorative elements, lamps, mechanical and electrical equipment, etc.

3.1.5 flexible secondary element: secondary element whose fundamental period, T_p is greater than 0.06 s, including the effect of the connecting system to the resistant structure of the building.

3.1.6 rigid secondary element: secondary element that does not comply with the defined in 3.1.5.

3.1.7 mechanical or electrical equipment: any equipment that is anchored to the resistant structure of the building or that interacts with it in any form; for example, reservoirs for gases and liquids, storage systems, pipings, ducts, elevators, hoist and fixed machinery of customary use in residential or public buildings.

3.1.8 base shear: shear produced by a seismic action at the base level of the building.

3.1.9 resisting structure: the resisting structure of a building consists of all the elements, considered in the calculation, that collaborate to maintain the stability of the structure under all the possible loads that could act on it during its useful life.

3.1.10 degree of seismic damages: it is determined in the structural elements of a building after a seismic event.

3.1.11 base level: horizontal plane where the horizontal forces from the structure are assumed to be completely transferred to the foundation soil. The height and number of floors of the building are measured from this level. The provisions of paragraph 7.2 must be taken into account, for its determination.

3.2 Symbols

The symbols used in this code have the meaning indicated below:

A_o = maximum effective soil acceleration;

A_k = multiplication weight factor for level k;

C = seismic coefficient;

C_p = seismic coefficient for secondary elements;

C_R = coefficient used in the determination of σ_s;

D_w = ground water depth;

F_k = horizontal force applied at level k;

F_N = horizontal force applied at the upper level;

H = total building height above base level, height of a retaining wall in contact with the earth;

I = coefficient relative to the importance, use and failure risk of the building;

RD = relative density;

K_d = performance factor related to the seismic behavior of secondary elements;

K_p = dynamic amplification factor for designing secondary elements;

M_{nx} = equivalent mass of mode n, for the X direction;

$[M]$ = mass matrix of the structure;

N = Penetration Resistance Index resulting from the Standard Penetration Test on the soil; number of stories of a building;

P = total building weight above the base level;

P_k = weight assigned to level k;

P_N = weight assigned to the upper level;

P_p = total weight of the secondary element, including the live load and its contents, when corresponds;

Q_o = base shear of the building;

Q_p = shear at the base of the secondary element;

R = structural response modification factor (static analysis);

R_o = structural response modification factor (spectral modal analysis);

R^* = spectral acceleration reduction factor, calculated for the period of mode with the highest translational equivalent mass in the direction of the seismic analysis;

RQD = $\sum l / L$ where:

$\sum l$: sum of longitudinal fragments of sane rock with an individual length greater than 10 cm and a minimum diameter of 47.6 mm, recovered from a rock boring in a L length;

L: perforated length or reference length with $1.0\ m \leq L \leq 1.5\ m$;

S = parameter that depends on the soil type;

S_a = design spectral acceleration;

T_n = period of vibration of mode n;

T_o = parameter that depends on the soil type;

T_p = period of the fundamental mode of vibration of the secondary element;

T^* = period of mode with the highest translational equivalent mass in the direction of the seismic analysis;

T' = parameter that depends on the soil type;

X = resulting value of the spectral mode superposition;

X_i = maximum value of i th mode with its sign;

Z_k = height of level k, above base level;

b_{kx} = largest dimension of the structure, in the X direction at story level k;

f = reduction factor used to determine the maximum value of seismic coefficient C;

g = acceleration of gravity;

h = story height;

n = parameter that depends on the soil type, index assigned to the mode of vibration;

p = parameter that depends on the soil type;

q = shear coefficient of reinforced concrete walls divided by the total shear at the same level, for the same direction of seismic analysis;

q_u = compressive strength of the soil;

$\{r_x\}$ = vector having number 1.0 in each position, according to the displacement degrees of freedom in the X direction, and zero in the remaining positions;

$\{r_\theta\}$ = vector having number 1.0 in each position, according to the rotational degrees of freedom, and zero in the remaining positions;

s_u = undrained shear strength of the soil;

v_s = in-situ shear wave propagation velocity;

α = amplification factor of the maximum effective acceleration;

β = coefficient used in the determination of K_p;

γ = total (wet) unit weight of the soil;

γ_d = dry unit weight of the soil;

$\{\phi_n\}$ = mode shape associated to the n^{th} mode of vibration;

λ = coefficient assigned to the automatic shut-down of conduit systems such as gas, steam, high temperature water, etc.;

ρ_{ij} = cross-modal coefficient between modes i and j;

σ_s = seismic earth pressure;

ξ = damping ratio.

4 General provisions

4.1 Seismic zoning

Three seismic zones in the national territory can be distinguished, as it is shown in the figures 4.1 a), 4.1 b) and 4.1 c). For the seismic zoning of regions IV, V, VI, VII, VIII, IX and Metropolitan, the zoning based on the political division by communes, indicated in table 4.1, must prevail.

4.2 Effect of the foundation soil and topography on the characteristics of the seismic movement

4.2.1 For the soil profiles that are defined in table 6.2, the parameters representing the characteristics of the foundation soil that influence the value of the base shear, are determined according to the values established in table 6.3, for the types of soil profiles that are defined in table 4.2. It is assumed, that those profiles have a horizontal topography and stratification, and the affected structures are found far from geomorphological and topographical singularities.

4.2.2 The following types of soils, which require a special study, have been excluded from table 4.2:

a) potentially liquefiable soils, that is to say sands, silty sands or silts, saturated, with a penetration resistance from the Standard Penetration Test, N, less than 20, (standardized at the effective overburden pressure of 0,10 Mpa);

b) soils prone to densification due to vibration.

4.2.3 The characterization of the soil must be substantiated by a report based on a subsoil exploration program proportionate to the characteristics of the project.

4.2.4 When the information on the foundation soil is not sufficient to classify it according to table 4.2, the soil profile that results in the highest value of the base shear shall be assumed.

4.3 Classification of buildings and structures according to their importance, occupancy and failure risk

4.3.1 For the purpose of the application of this code, the buildings are classified as follows:

- **Category A:** governmental, municipal, public service or of public use (such as police stations, power plants and telephone exchanges, post offices and telegraphs, broadcasting stations, television channels, waterworks and pumping stations, etc.), and those whose use is of special importance in the event of a catastrophe (such as hospitals, first aid units, fire stations, garages for emergency vehicles, terminal stations, etc.).

- **Category B:** buildings whose content is of great value (such as libraries, museums, etc.) and those which frequently receive a great number of people:

  - assembly rooms for 100 people or more;

  - stadiums and bleachers for 2 000 people or more;

  - schools, nursery schools and university buildings;

  - prisons and detention precincts;

  - commercial stores with an area equal to or greater than 500 m^2 per floor, or more than 12 m in height;

  - shopping malls, with a total area greater than 3 000 m^2 ,not including the parking lot.

- **Category C:** buildings intended for private or public use that do not belong to category A or B, and constructions of any type, whose failure may jeopardize other constructions classified as A, B or C.

- **Category D:** isolated or provisional structures not intended for living and which cannot be classified in any of the aforementioned categories.

4.4 Seismic instruments

When planning a building, the competent authority may demand the incorporation of at least two adequate areas for the installation of strong motion accelerographs.

Table 4.1 - Seismic zonation by communes for the Fourth to the Ninth Region

Region	Zone 3	Zone 2	Zone 1
4th.	Andacollo Combarbalá Coquimbo Illapel La Higuera La Serena Los Vilos Mincha Monte Patria Ovalle Paiguano Punitaqui Río Hurtado Salamanca Vicuña		
5th.	Algarrobo Cabildo Calera Cartagena Casablanca Catemu El Quisco El Tabo Hijuelas La Cruz La Ligua Limache Llayllay Nogales Olmué Panquehue Papudo Petorca Puchuncaví Putaendo Quillota Quilpué Quintero Rinconada San Antonio San Felipe Santa María Santo Domingo Valparaíso Villa Alemana Viña del Mar Zapallar	Calle Larga Los Andes San Esteban	

Table 4.1 - Seismic zonation by communes for the Fourth to the Ninth Region (continuation)

Region	Zone 3	Zone 2	Zone 1
Metropolitan	Alhué	Buin	
	Curacaví	Calera de Tango	
	El Monte	Cerrillos	
	Lampa	Cerro Navia	
	María Pinto	Colina	
	Melipilla	Conchalí	
	San Pedro	El Bosque	
	Tiltil	Estación Central	
		Huechuraba	
		Independencia	
		Isla de Maipo	
		La Cisterna	
		La Florida	
		La Granja	
		La Pintana	
		La Reina	
		Las Condes	
		Lo Barnechea	
		Lo Espejo	
		Lo Prado	
		Macul	
		Maipú	
		Ñuñoa	
		Paine	
		Pedro Aguirre Cerda	
		Peñaflor	
		Peñalolén	
		Pirque	
		Providencia	
		Pudahuel	
		Puente Alto	
		Quilicura	
		Quinta Normal	
		Recoleta	
		Renca	
		San Bernardo	
		San Joaquín	
		San José de Maipo	
		San Miguel	
		San Ramón	
		Santiago	
		Talagante	
		Vitacura	

Table 4.1 - Seismic zonation by communes for the Fourth to the Ninth Region (continuation)

Region	Zone 3	Zone 2	Zone 1
6th.	La Estrella Las Cabras Litueche Lolol Marchigüe Navidad Palmilla Peralillo Paredones Peumo Pichidegua Pichilemu Pumanque Santa Cruz	Chépica Chimbarongo Codegua Coinco Coltauco Doñihue Graneros Machalí Malloa Mostazal Nancagua Olivar Placilla Quinta de Tilcoco Rancagua Rengo Requínoa San Fernando San Vicente de Tagua Tagua	
7th.	Cauquenes Chanco Constitución Curepto Empedrado Hualañé Licantén Maule Pelluhue Pencahue San Javier Talca Vichuquén	Colbún Curicó Linares Longaví Molina Parral Pelarco Rauco Retiro Río Claro Romeral Sagrada Familia San Clemente Teno Villa Alegre Yerbas Buenas	

Table 4.1 - Seismic zoning by communes for the Fourth to the Ninth Region (end)

Region	Zone 3	Zone 2	Zone 1
8th.	Arauco Bulnes Cabrero Cañete Chillán Cobquecura Coelemu Concepción Contulmo Coronel Curanilahue Florida Hualqui Laja Lebu Los Alamos Lota Nacimiento Negrete Ninhue Penco Portezuelo Quillón Quirihue Ranquil San Carlos San Nicolás San Rosendo Santa Juana Talcahuano Tirúa Tomé Treguaco Yumbel	Antuco Coihueco El Carmen Los Angeles Mulchén Ñiquén Pemuco Pinto Quilaco Quilleco San Fabián San Ignacio Santa Bárbara Tucapel Yungay	
9th.	Angol Carahue Galvarino Los Sauces Lumaco Nueva Imperial Purén Renaico Saavedra Teodoro Schmidt Toltén Traiguén	Collipulli Cunco Curacautín Ercilla Freire Gorbea Lautaro Loncoche Perquenco Pitrufquén Temuco Victoria Vilcún Villarrica	Curarrehue Lonquimay Melipeuco Pucón

Table 4.2 - Types of foundation soils. (Only to be used with table 6.3)

Soil type	Description
I	**Rock**: Natural material, with in-situ shear wave propagation velocity equal to or greater than 900 m/s, or uniaxial compressive strength of intact specimens (without fissures) equal to or greater than 10 MPa and RQD equal to or greater than 50%.
II	a) Soil with v_s equal to or greater than 400 m/s in the upper 10 m, and increasing depth, or, b) Dense gravel with a dry unit weight γ_d equal to or greater than 20 kN/m^3, or greater than 95% of the maximum determined in the Modified Proctor Compaction Test, or a relative density (RD) equal to or greater than 75%, or, c) Dense sand with a (RD) greater than 75%, or a Penetration Resistance Index N greater than 40 (standardized at the effective overburden pressure of 0.10 MPa), or a compaction degree greater than 95% of the maximum Modified Proctor value; or, d) Stiff cohesive soil, with an undrained shear strength s_u equal to or greater than 0.10 MPa (compressive strength q_u equal to or greater than 0.20 MPa) in specimens without fissures. In all cases, the requirements specified must be met, regardless of the position of the ground water level, and the minimum stratum thickness must be 20 m. If the thickness above the rock is lower than 20 m, the soil may be classified as type I.
III	a) Permanently unsaturated sand with (RD) in the range of 55 and 75%, or N greater than 20 (without standardizing at the effective overburden pressure of 0.10 MPa); or, b) Unsaturated gravel or sand, with a compaction degree less than 95% of the maximum Modified Proctor value or, c) Cohesive soil with s_u in the range of 0.025 y 0.10 MPa (q_u between 0.05 and 0.20 MPa) , regardless of the ground water level; or, d) Saturated sand with N in the range of 20 and 40 (standardized at the effective overburden pressure of 0.10 MPa). Minimum stratum thickness: 10 m. If the stratum thickness above the rock or soil type II is less than 10 m, the soil may be classified as type II.
IV	Saturated cohesive soil with s_u equal to or greater than 0.025 MPa (q_u equal to or less than 0.050 MPa). Minimum stratum thickness: 10 m. If the stratum thickness above soil types I, II or III is less than 10 m, the soil may be classified as type III.

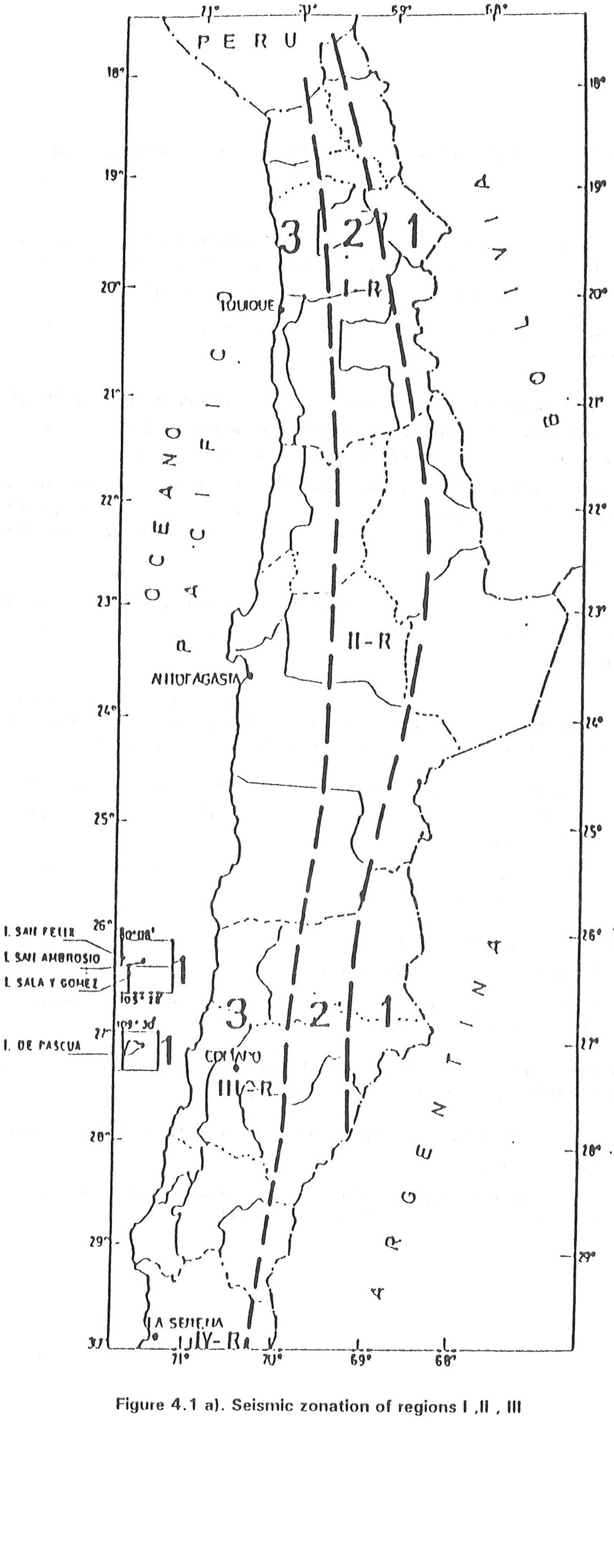

Figure 4.1 a). Seismic zonation of regions I ,II , III

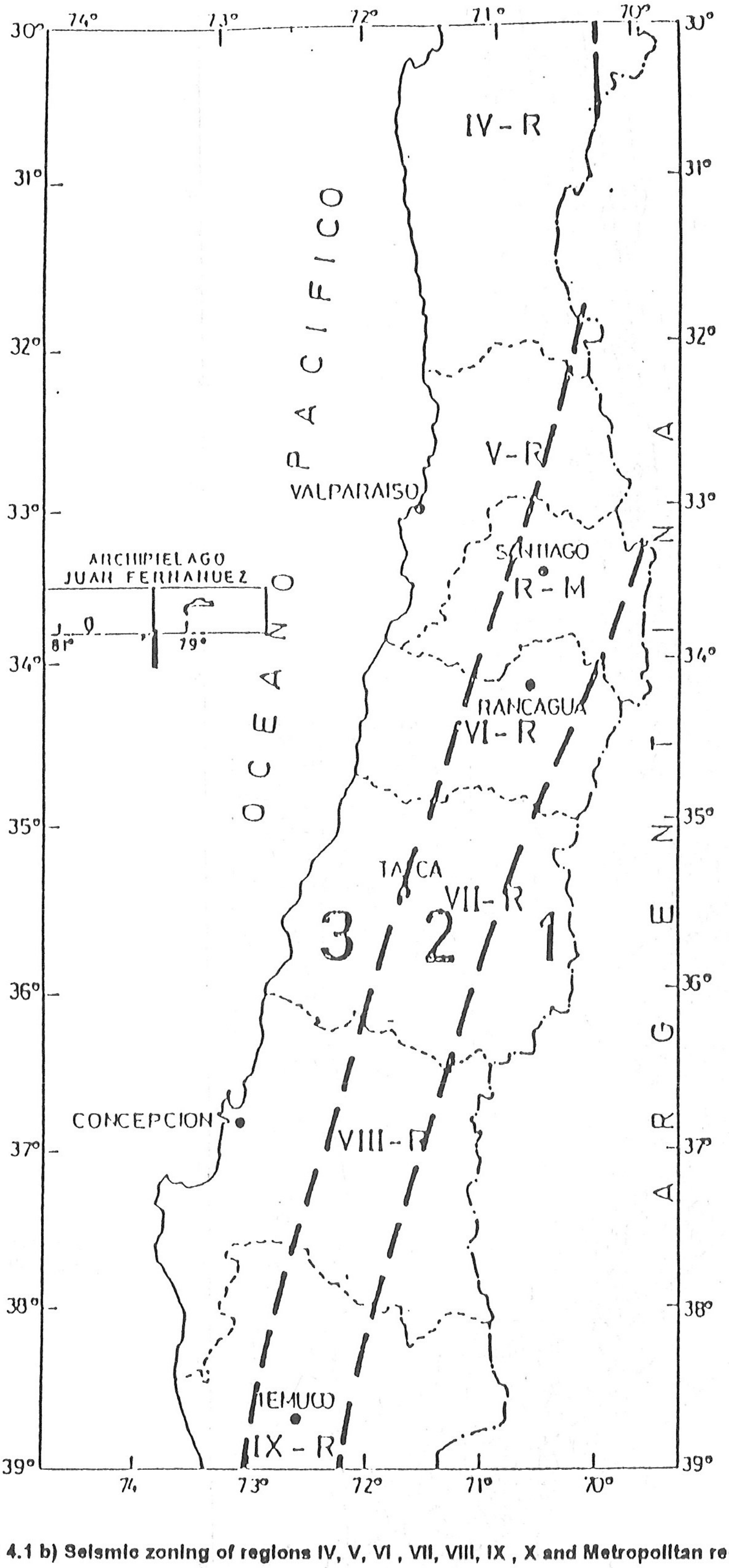

Figure 4.1 b) Seismic zoning of regions IV, V, VI , VII, VIII, IX , X and Metropolitan region

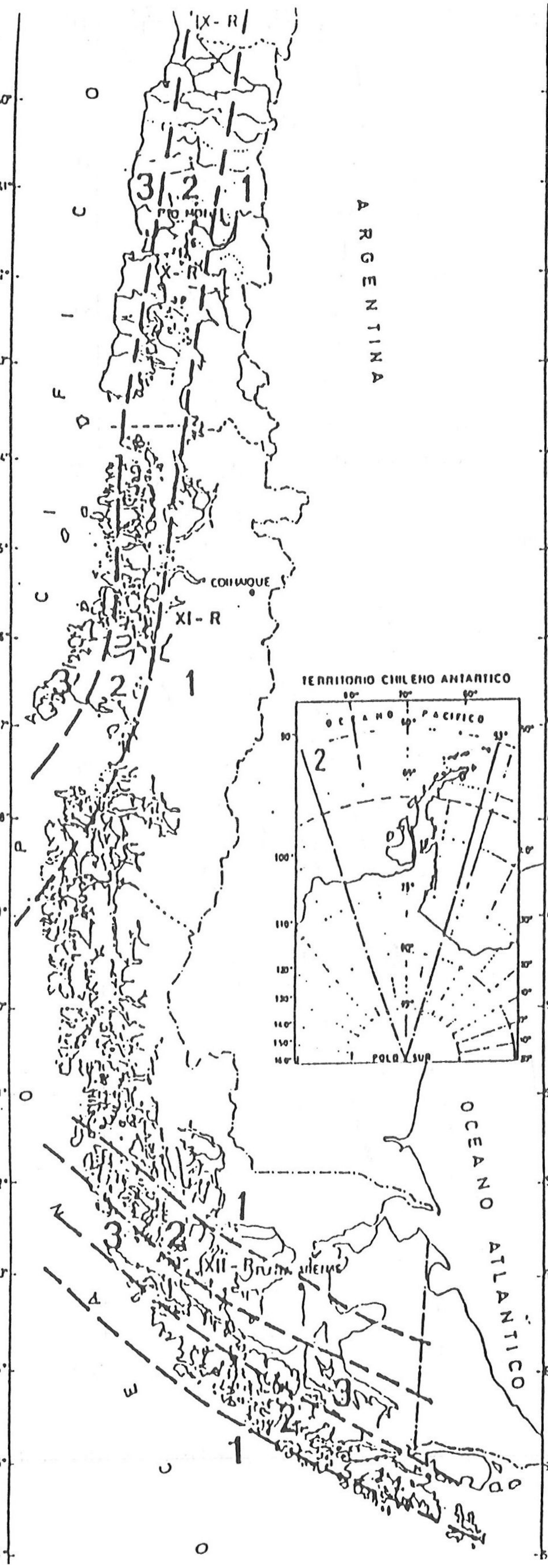

Figure 4.1 c) Seismic zoning of regions XI and XII

5 General provisions for design and analysis methods

5.1 Basic principles and hypothesis

5.1.1 This code applied together with the specific design code for each one of the materials named in paragraph 5.3, aims to achieve structures that:

a) resist moderate intensity seismic actions without damages;

b) limit damage to non-structural elements during earthquakes of regular intensity;

c) prevent collapse during earthquakes of exceptionally severe intensity, even though they show some damage.

The compliance with the provisions of this code does not guarantee, in every case, that the aforementioned objectives will be achieved.

In particular, the provisions for reinforced concrete wall buildings, are based on their satisfactory behavior during the earthquake of March, 1985. The design of those buildings was performed in accordance with the NCh433.Of72 code.

5.1.2 The analysis to determine the internal stress due to the seismic action must be based on the linear-elastic behavior of the structure; however, the design of the structural elements must be carried out using the method specified in the design code related to each material, which could be done using the method of allowable stresses, or the method of load and resisting factors. The analysis of the effects of other loads that could combine with the effects of the seismic action, must also be based on the linear-elastic theory of structural behavior.

5.2 Combination of seismic loadings with other loadings

5.2.1 The combination of seismic loadings with permanent loads and live loads must be made with the use of the following superposition rules:

a) when designed with the allowable stress method:

permanent loads + live loads ± earthquake;

permanent loads ± earthquake;

b) when designed with the method of load and resisting factors:

1.4 (permanent loads + live loads ± earthquake);

0.9 permanent loads ± 1.4 earthquake.

5.2.2 When the allowable stress method is used in the design of the structural elements, the allowable stresses can be incremented in 33.3% with respect to the normal design values.

5.2.3 Dead and live loads indicated in paragraph 5.2.1 should be determined according to the NCh1537 code. The reduction indicated in paragraph 5.5.1 only applies to the calculation of the seismic action, and not to the forces produced by the live loads that the superposition rules refer to in paragraph 5.2.1.

5.2.4 The seismic action is considered as an eventual load and it is not necessary to combine it with other eventual loads.

5.2.5 When the design is controlled by the wind loadings, specified in the NCh432 code, the detailing and limiting provisions of the seismic design code for each material must still be complied.

5.3 Coordination with other analysis and design codes

The provisions of the present code shall be applied in combination with the established in other analysis and specific design standards, for each one of the materials indicated below. In the event of contradiction, the provisions of the present code shall govern.

5.3.1 Dead and live load analysis, according to the provisions of the NCh1537 code.

5.3.2 Analysis of snow loadings, according to the provisions of the NCh431 code.

5.3.3 Steel structures, according to the provisions of the NCh427 [*)] code.

5.3.4 Reinforced concrete structures, according to the provisions of the NCh430 [*)] code.

5.3.5 Reinforced masonry structures -clay brick or concrete blocks-, according to the provisions of the NCh1928 code.

5.3.6 Masonry structures -clay brick or concrete blocks- confined with reinforced concrete beams and columns, according to the provisions of the NCh2123 code.

5.3.7 Stone masonry structures with reinforced concrete beams and columns, according to the provisions of the Ordenanza General de Urbanismo y Construcciones.

5.3.8 Wood structures according to the provisions of the NCh1198 code.

5.4 Structural systems

5.4.1 The transmission of the forces from its point of application to the resisting elements and foundation soil, must be carried out in the most direct way, through elements provided with the adequate resistance and stiffness.

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*) See annex B transitory references.

5.4.2 In this code the following types of structural systems are distinguished:

5.4.2.1 Shear wall and other braced systems

Seismic and gravitational actions are resisted by shear walls, or, by braced frames that resist the seismic action through elements that work mainly due to axial forces.

5.4.2.2 Space moment-resisting frame systems

Seismic and gravitational actions are resisted by frames in both directions of analysis.

5.4.2.3 Dual systems

Gravitational and seismic loads are resisted by a combination of the prior systems.

5.5 Structural models

5.5.1 To calculate masses, permanent loads plus a percentage of the live load must be considered, which cannot be less than 25% in constructions intended for private or public use where the agglomeration of persons or things is not common, or 50% in constructions where agglomerations are usual.

5.5.2 Floor diaphragms

5.5.2.1 Diaphragms will have to be verified for sufficient resistance and stiffness in order to achieve the distribution of the inertial forces among the vertical planes or resisting substructures. If there is any doubt with respect to the stiffness of the diaphragm, its flexibility will have to be taken into account, adding the necessary degrees of freedom or introducing structural separations.

5.5.2.2 When buildings with irregular plans (in H, in L, in T, in U, etc.) are designed as one structure, diaphragms shall be designed and constructed so that the construction will behave as an integrated unit during earthquakes, and the provision 5.5.2.1 taken into account. Otherwise, each part will have to be designed as a separate structure, in conformance with the provisions of paragraph 5.10.

5.5.2.3 If the building of irregular plan is designed as one structure, special attention shall be given to the design of the connections between its different parts.

5.5.2.4 At the levels where there is a stiffness discontinuity in the resisting planes or other vertical substructures, it must be verified that the diaphragm will be capable of redistributing the forces.

5.5.3 Horizontal deformation compatibility

5.5.3.1 In buildings with horizontal diaphragms, the analysis methods shall satisfy compatibility between the horizontal displacements of the vertical substructures and of the horizontal diaphragms. This condition must be fulfilled at all levels which have diaphragms.

5.5.3.2 On floors without a rigid diaphragm, the resisting elements shall be calculated for the horizontal forces that directly impact them.

5.5.4 The structural model shall be defined in accordance with paragraphs 7.2.3, 7.2.4 and 7.2.5.

5.6 Limitations for the use of the methods of seismic analysis

In chapter 6 two methods of analysis are established:

a) a static analysis method;

b) a spectral modal analysis method.

The static analysis method may be used if the limitations set forth in paragraph 6.2.1 are satisfied. The limitations for the use of the spectral modal analysis method are specified in paragraph 6.3.1.

5.7 Response modification factor

5.7.1 The response modification factor R_o *(o R)* is established in table 5.1. This factor reflects the energy absorption and dissipation characteristics of the resisting structure, as well as the practical experience on the seismic behavior of the different types of structures and materials used.

5.7.2 In buildings that have stories with different systems or structural materials, the seismic loading shall be determined with the R_o *(o R)* value that corresponds to the subsystem with the lowest R_o *(o R)*, except for the cases that are explicitly indicated in table 5.1.

5.7.3 If the resisting structure of the building has systems with different R_o *(o R)* values according to different horizontal directions of analysis, the seismic analysis must be carried out with the lowest R_o *(o R)* value.

5.8 Seismic actions on the structure

5.8.1 The structure must be analyzed, at least, for independent seismic actions acting along two perpendicular or approximately perpendicular horizontal directions.

5.8.2 The marquees, balconies, eaves and other elements vulnerable to the vertical action of the earthquake, shall be designed for a vertical force equal to the live loads plus the total dead load, both increased by 30%.

5.9 Seismic deformations

5.9.1 The horizontal displacements and rotations of floor diaphragms shall be calculated for the design seismic action specified in chapter 6, including the effect of the accidental torsion.

5.9.2 The maximum relative displacement between two consecutive floors, measured in the center of their masses in each one of the directions of analysis, shall not be greater than the story height multiplied by 0.002.

5.9.3 The maximum relative displacement between two consecutive floors, measured in any point of their plans in each one of the directions of analysis, shall not exceed the corresponding relative displacement measured in the center of their masses in more than 0.001 h, where h is the story height.

5.9.4 When there is no floor diaphragm, the maximum value of the transversal story displacement of the beams, relative to that of the wall base below the beam, produced by the loadings that act perpendicularly to the wall plane, must be equal to or less than the story height multiplied by 0.002.

5.10 Separations between buildings or building parts

In buildings or in parts of a same building that are not designed and constructed as an interconnected unit, the following provisions shall be adopted to permit their relative movement due to lateral forces.

5.10.1 The distance of a building to the dividing plane at any level shall not be less than $R^*/3$ times the displacement at that level, calculated with the methods of analysis established in paragraphs 6.2 and 6.3, neither to a two per thousand of the height of the same level nor to 1.5 cm. Adjacent buildings to a public occupancy site not intended for construction are exempted.

5.10.2 The distances between the parts of a same building or between the building in study and an existing one, measured at each level, shall not be less than the double set forth in paragraph 5.10.1.

5.10.3 It will be acknowledged the compliance with the conditions of paragraphs 5.10.1 and 5.10.2, when the separations on every floor meet them.

5.10.4 The separations between buildings or between parts of a same building are not applicable to the foundations, unless it is established in the structural drawings. The separation spaces should be free from debris, and permit relative movements in any direction. The protection elements of separations shall insure the prior provision, without transmitting among the buildings or parts of adjoining buildings, forces whose magnitude will be of significance.

5.11 Drawings and calculation report

5.11.1 Structural drawings shall specify:

- the quality of the materials considered in the project;

- the seismic zone of the construction site;

- the type of foundation soil, according to the classification of table 4.2 of this code.

5.11.2 The calculation report must contain the following information, in addition to the requirements of the Ordenanza General de Construcciones y Urbanismo:

- a description of the earthquake resistant system;

- a description of the seismic analysis method, with an identification of the parameters used to determine the seismic loading;

- the main results of the analysis (fundamental periods, base shears in each direction of analysis, maximum absolute deformations, and maximum story drifts);

- the form in which the dividing partitions have been considered in the analysis and design, when applying paragraph 8 .4.

Table 5.1 - Maximum values of the response modification factor [1)]

Structural system	Structural material	R	R_o
Space moment-resisting frames	Structural Steel	7	11
	Reinforced Concrete	7	11
Shear walls and braced systems	Structural steel	7	11
	Reinforced Concrete	7	11
	Reinforced Concrete and Confined Masonry		
	- If criterion A [2)] is met	6	9
	- If criterion A [2)] is not met	4	4
	Wood	5.5	7
	Confined Masonry	4	4
	Reinforced Masonry		
	- Of concrete blocks or units of similar geometry with full grouting and double-wythe masonry.	4	4
	- Of clay bricks with partial or full grouting and concrete blocks or units of similar geometry which have partial grouting.	3	3
Any type of structure or material that cannot be classified in one of the above categories.[3)]		2	-

1) The values indicated for structural steel and reinforced concrete in this table assume the compliance of annex B.

2) Criterion A: Reinforced concrete shear walls shall take in each story, 50% of the story shear, as a minimum.

3) The spectral modal analysis for this type of structure or material shall not be used. Therefore, a value for R_o is not established.

6 Methods of Analysis

6.1 General

6.1.1 A structural model with a minimum of three degrees of freedom per floor, two horizontal displacements, and the floor rotation with respect to a vertical axis, should be considered when using any of the methods of analysis. To choose the number of degrees of freedom included in the analysis, the provision of paragraph 5.5.2.1 shall be taken into account.

6.1.2 The effects of accidental torsion may be neglected in the design of structural elements, when the analysis indicated in paragraph 6.3.4 a), lead to variations of the horizontal displacements at all the points of the building plans equal to or less than 20%, with respect to the result obtained from the model with its centers of masses at their natural location.

6.2 Static analysis

6.2.1 The method of static analysis can only be used in the seismic analysis of the following resisting structures:

to) all the structures of categories C and D located in seismic zone 1 of the zoning indicated in paragraph 4.1;

b) all the structures that do not exceed more than 5 stories nor 20 m in height;

c) 6 to 15 story structures, provided that they comply with the following conditions for each direction of analysis:

  i) the quotients between the total building height H, and the modal periods with the highest translational equivalent mass in "x" and "y" directions, T_x T_y, respectively, must be equal to or more than 40 m/s;

  ii) the distribution of the horizontal seismic forces of the static method must be such that shears and overturning moments at each level, shall not differ in more than 10% with respect to those obtained through a spectral modal analysis with the same base shear.

If the above conditions (i) and (ii) are met, but the base shear obtained from the application of horizontal static seismic forces is less than the one determined in 6.2.3, the horizontal forces shall be multiplied by a factor so that the base shear can equal the mentioned value, as a minimum.

6.2.2 In the method of analysis, the seismic action is assimilated to a force system whose effects on the structure are calculated with static procedures. This horizontal force system applied in the center of masses of each one of the structure parts is defined in paragraphs 6.2.3 to 6.2.7.

6.2.3 The base shear is determined from:

$$Q_o = CIP \tag{6-1}$$

where:

C = is the seismic coefficient defined in paragraphs 6.2.3.1 and 6.2.7;

I = is the coefficient relative to the building, whose values are specified in table 6.1 according to the classification indicated in paragraph 4.3;

P = is the total weight of the building above the base level, calculated in the form indicated in paragraph 6.2.3.3.

6.2.3.1 The seismic coefficient C, is obtained from the expression:

$$C = \frac{2.75 A_0}{gR}\left(\frac{T'}{T^*}\right)^n \tag{6-2}$$

where:

n, T' = parameters relative to the foundation soil type determined from table 6.3, according to the classification of table 4.2;

A_o = has the meaning indicated in paragraph 6.2.3.2;

R = reduction factor established in paragraph 5.7;

T^* = period of mode with the highest translational equivalent mass in the direction of analysis.

6.2.3.1.1 In no case the value of C will be less than $A_o / 6g$.

6.2.3.1.2 The value of C need not be greater than the one indicated in table 6.4.

6.2.3.1.3 In the case of buildings that are structured to resist seismic loadings through reinforced concrete walls, or a combination of reinforced concrete walls and rigid frames, and reinforced masonry walls, the maximum value of the seismic coefficient obtained from table 6.4 may be reduced multiplying it by factor f determined from the expression:

$$f = 1.25 - 0.5q \qquad (0.5 \le q \le 1.0) \tag{6-3}$$

where q is the lowest quotient between the shear taken by the reinforced concrete walls divided by the total shear, at each level, in both directions of analysis, considering the lower half of the building.

6.2.3.2 The maximum effective acceleration A_o is determined from table 6.2, according to the national seismic zoning indicated in paragraph 4.1.

6.2.3.3 The total building weight P above the base level must be calculated, according to the disposed in paragraph 5.5.1. In relation to this calculation, the roof live load may be considered null.

6.2.4 The value of the period of vibration T^* in each one of the directions of the seismic action considered in the analysis, must be calculated through a substantiated procedure.

6.2.5 For structures of no more than 5 stories, the horizontal seismic forces may be calculated by the expression:

$$F_k = \frac{A_k \; P_k}{\sum_{j=1}^{N} A_j \; P_j} \, Q_o \qquad (6\text{-}4)$$

where:

$$A_k = \sqrt{1 - \frac{Z_{k-1}}{H}} - \sqrt{1 - \frac{Z_k}{H}} \qquad (6\text{-}5)$$

For structures of more than 5 floors but less than 16 floors, the force system defined by the expressions (6-4) and (6-5) or any other horizontal force system, can be used, as long as the conditions (i) and (ii) specified in paragraph 6.2.1 are fulfilled.

The forces should be applied independently in each one of the two directions of analysis referred to in paragraph 5.8, all in the same direction.

6.2.6 Buildings of two or more stories without a rigid diaphragm at the uppermost level may be analyzed assuming the existence of a rigid diaphragm at said level. However, for the design of the floor without a diaphragm, each seismic resisting element must be calculated applying a horizontal acceleration equal to 1.20 F_N g/P_N to the tributary mass. In particular, it must be verified that the magnitude of the horizontal displacements perpendicular to the resisting plane, obtained from the prior analysis, conform to the established in 5.9.4.

6.2.7 To determine the base shear of one-story buildings with a rigid diaphragm at their upper level, a seismic coefficient equal to 80% of the one determined by 6.2.3.1 may be used.

6.2.8 Accidental torsion analysis

The results of the analysis carried out for the static forces applied in each one of the directions of the seismic action, shall be combined with those of the accidental torsion analysis. For this purpose, torsional moments shall be applied at each level, calculated as the product of the static forces that act at that level by an accidental eccentricity given by:

$$\pm 0.10 \; b_{ky} \; Z_k \, / \, H \textit{ for seismic action in the X direction;}$$

$$\pm 0.10 \; b_{kx} \; Z_k \, / \, H \textit{ for seismic action in the Y direction.}$$

The same sign shall be considered for the eccentricities at each level; therefore, it is necessary to consider two cases for each direction of analysis.

6.3 Spectral modal analysis

6.3.1 This method can be applied to structures that have classical normal modes of vibration, with modal dampings about 5% of the critical damping.

6.3.2 Once the natural periods and modes of vibration have been determined, the equivalent masses for each mode n are given by the following expressions:

$$M_{nx} = \frac{L^2_{nx}}{M_n} \qquad M_{ny} = \frac{L^2_{ny}}{M_n} \qquad M_{n\theta} = \frac{L^2_{n\theta}}{M_n} \qquad (6\text{-}6)$$

where:

$$\begin{aligned} L_{nx} &= \{\phi_n\}^T \; [M] \; \{r_x\} \\ L_{ny} &= \{\phi_n\}^T \; [M] \; \{r_y\} \\ L_{n\theta} &= \{\phi_n\}^T \; [M] \; \{r_\theta\} \\ M_n &= \{\phi_n\}^T \; [M] \; \{\phi_n\} \end{aligned} \qquad (6.7)$$

6.3.3 The analysis shall include all normal modes, ordered according to increasing values of the natural frequencies, that are necessary so that the summation of the equivalent masses for each one of the seismic actions be greater than or equal to 90% of the total mass.

6.3.4 Accidental Torsion Analysis

The effect of the accidental torsion must be considered in one the following alternatives:

a) displacing transversely the location of the centers of mass of the model in $\pm$ 0.05 b_{ky} for the earthquake in the X direction, and in $\pm$ 0.05 b_{kx} for the earthquake in the Y direction. The same sign shall be taken for displacements at each level k, so that generally it is necessary to consider two models in each direction of analysis, in addition to the model with the center of masses at their natural locations;

b) applying static torsional moments at each level, calculated as the product of the combined shear variation at that level, multiplied by the accidental eccentricity given by:

$\pm$ 0.1 $b_{ky}Z_k/H$ for seismic action in the X direction

$\pm$ 0.1 $b_{kx}Z_k/H$ for seismic action in the Y direction

The same sign must be taken for the eccentricities at each level, so generally, it is necessary to consider two cases for each direction of analysis. The results of these analyses shall be added to those of the spectral modal analyses that consider the earthquake acting along the directions X or Y of the model, with the centers of masses at their natural locations.

6.3.5 Design spectrum

6.3.5.1 The design spectrum that determines the seismic resistance of the structure is defined by:

$$S_a = \frac{I\, A_o\, \alpha}{R^*} \tag{6-8}$$

where the values of I and A_o are determined in conformance with paragraph 6.2.3.

6.3.5.2 The amplification factor α is determined for each vibration mode n using the following expression:

$$\alpha = \frac{1 + 4.5\left(\frac{T_n}{T_o}\right)^p}{1 + \left(\frac{T_n}{T_o}\right)^3} \tag{6-9}$$

where:

T_n = vibration period of mode n;

T_o, p = parameters relative to the foundation soil type determined from table 6.3 according to the classification of table 4.2.

6.3.5.3 The reduction factor R^* is determined from:

$$R^* = 1 + \frac{T^*}{0.10\,T_o + \dfrac{T^*}{R_o}} \qquad (6\text{-}10)$$

where:

T^* = period of mode with the highest translational equivalent mass in the direction of analysis;

R_o = value for the structure, in accordance with paragraph 5.7.

6.3.5.4 For shear wall buildings, the reduction factor R^* may be calculated using the alternative expression:

$$R^* = 1 + \frac{N R_o}{4\,T_o\,R_o + N} \qquad (6\text{-}11)$$

where:

N = number of stories of the building.

6.3.6 Modal superposition

6.3.6.1 The displacements and rotations of the horizontal diaphragms and the internal forces in each structural element shall be calculated for each of the directions of analysis, by superposition of modal contributions. The base shear limitations indicated in 6.3.7, shall be considered.

6.3.6.2 The superposition of the maximum modal values shall be carried out using the expression:

$$X = \sqrt{\Sigma_i\, \Sigma_j\, \rho_{ij}\, X_i X_j} \qquad (6\text{-}12)$$

in which the sums Σ_i and Σ_j are carried out for all the modes considered; the cross-modal coefficient ρ_{ij} must be determined by one of the following alternatives:

a) CQC method

$$\rho_{ij} = \frac{8\,\xi^2\, r^{3/2}}{(1 + r)(1 - r)^2 + 4\,\xi^2 r\,(1 + r)} \qquad (6.13)$$

where:

$$r = \frac{T_i}{T_j}$$

ξ = damping ratio, that shall be 0.05 for all modes of vibration.

b) The CQC method with white noise filtered through a soil characterized by T_o.

$$\rho_{ij} = \rho^* \qquad if\ T_i / T_o \geq 1.35 \tag{6.14}$$

$$\rho_{ij} = 1 - 0.22\,(1 - \rho^*)\,[\log\,(T_i / T_o) + 2]^2 \quad if\ T_i / T_o \prec 135$$

where ρ^* is given by:

$$\rho^* = 0 \qquad if\ T_i / T_j \geq 1.25 \tag{6.15}$$

$$\rho^* = 1 + 4(1 - T_i / T_j) \quad if\ T_i / T_j \prec 1.25$$

In the expressions (6-14) and (6-15), $T_i \succ T_j$ shall be considered.

6.3.7 Base shear limitations

6.3.7.1 If the base shear component in each direction of seismic analysis turns out to be less than $IA_o P / 6g$, the displacements and rotations of the horizontal diaphragms and the internal forces in structural elements shall be multiplied by a factor such that the base shear reaches the indicated value, as a minimum.

6.3.7.2 The base shear component in each direction of seismic analysis need not be greater than $IC_{max}P$, where C_{max} is determined as in 6.2.3.1. In the event that said component is greater than the aforementioned value, the internal forces in the structural elements may be multiplied by a factor so that the base shear does not exceed the value of $IC_{max}P$. This provision does not apply to the calculation of the displacements and rotations of the story horizontal diaphragms.

6.3.8 When designing structural elements it must be considered that the internal stresses and displacements do not satisfy conditions of equilibrium and compatibility, if they are obtained using the Spectral Modal Analysis method. The designer must consider this fact in the earthquake resistant design, in order to guarantee that the design remains on the safe side.

Table 6.1 - Coefficient I value

Building Category	I
A	1.2
B	1.2
C	1.0
D	0.6

Table 6.2 - Effective acceleration value A_o

Seismic Zone	A_o
1	0.20 g
2	0.30 g
3	0.40 g

Table 6.3 - Parameter values that depend on the soil type

Soil type	S	T_o s	T' s	n	p
I	0.90	0.15	0.20	1.00	2.0
II	1.00	0.30	0.35	1.33	1.5
III	1.20	0.75	0.85	1.80	1.0
IV	1.30	1.20	1.35	1.80	1.0

Table 6.4 -Maximum values of seismic coefficient C

R	C_{max}
2	0.90 SA_o/g
3	0.60 SA_o/g
4	0.55 SA_o/g
5.5	0.40 SA_o/g
6	0.35 SA_o/g
7	0.35 SA_o/g

7 Design and construction of foundations

7.1 General design specifications

7.1.1 The loadings transferred to the soil by the foundations should be verified for the superposition of effects set forth in paragraph 5.2.1 a).

7.1.2 It should be checked that the foundations have a satisfactory behavior when subjected to either static or to seismic loads, verifying that the contact pressure between the soil and the foundation will be such that the induced deformations will be admissible for the structure.

7.2 Shallow foundations

7.2.1 At least 80% of the area under each isolated foundation must be in compression. Lower percentages of the area in compression, should be justified so that the global stability is insured, and that the induced deformations will be admissible for the structure. The prior provisions do not govern if anchorages between the foundation and soil are used.

7.2.2 The foundations on isolated footings that do not have the appropriate restriction to lateral movements, should be tied through tie beams designed for a compression or a tension load, not less than 10% of the vertical loading on the footing.

7.2.3 The lateral restriction of the soil that surrounds the foundation can be considered for design as long as the stiffness and strength of the soil guarantee its collaboration, and that the foundation has been concreted against undisturbed natural soil. In the event of placing fills around the foundations, the lateral restriction that is considered must be properly substantiated and the placing of said fills must be carried out following clearly specified compaction and control procedures.

7.2.4 To calculate the seismic forces that are developed at the base of the foundation buried in flat terrain, it is possible to neglect the inertia forces of the masses of the structure that are below the natural ground level and the seismic pressure of the soil, as long as the lateral restriction of paragraph 7.2.3 exists.

7.2.5 The base level of the building must be considered at the foundation base. The consideration of another position for the base level must be justified through an analysis.

7.2.6 The allowable contact pressure must be determined at the elevation of the contact between the soil and the base of the foundation element used. In the case of lean concrete fills under the foundations, the contact pressure must be defined at the base of said fill; the contact pressures and deformations should be checked, both at the lean concrete base as well as at the contact between the foundation and the lean concrete.

7.3 Piles

7.3.1 In the evaluation of the possibility of temporary or permanent deterioration of the resistance or the deformation characteristics of the foundation soils as the result of a seismic action, the soils that can be affected by isolated piles or groups of piles should be included, according to the following minimum standards:

a) **isolated piles**: up to two times the diameter of the pile below the level of its tip or base;

b) **group of piles**: up to two times the diameter or width of the group below the level of its tip or base.

7.3.2 The piles should be adequately connected to pile caps.

7.3.3 Individual piles or the pile caps of groups of piles should be connected through a tie beam designed to resist a compression or tension force, that is not less than 10% of the highest vertical load that acts on the pile or on the group.

7.3.4 In the calculation of the lateral resistance of piles or groups of piles it must be considered that the said resistance can be reduced by an increase in the pore water pressure or by soil liquefaction, or by the loss of contact between the soil and the longitudinal part of the pile due to plastic deformation of the ground.

7.3.5 Concrete piles without reinforcement shall not be accepted. The design of the pile shall consider the stresses that are produced during their transportation, installation, driving and operation.

7.3.6 A specialized inspection is required during the driving or pile construction.

7.4 Adjacent structures

7.4.1 In the foundation design of buildings adjacent or close to one that already exists, it must be verified that the influence of the new loads applied, do not affect the behavior thereof.

7.4.2 The design and calculation of works such as dewatering, underpinning, excavation, bracing system, and strutting, which are necessary to construct a building adjacent to an existing one must include the corresponding provisions to avoid deformations or loadings that will be hazardous for the existing building.

7.4.3 Before starting the construction of a new building, adjacent to one that already exists, it will be necessary to execute a detailed surveying of contiguous or nearby structures, including fissures, cracks splits and distortions, or uneven levels.

7.4.4 Due to the temporary nature of some of the structures indicated in paragraph 7.4.2 it is possible to design them using safety factors lower than the usual ones. For that reason, in the case of a construction shutdown, which implies an increase of the operation time projected for the protection structures, adequate reinforcement measures must be taken.

7.5 Earth pressure on underground walls

7.5.1 The evaluation of soil thrusts indicated below considers soils with a horizontal surface, acting on vertical perimeteral walls braced by floor slabs.

7.5.2 The static component of the soil thrust must be evaluated for a geostatic state of stress.

7.5.3 The seismic component of the soil thrust may be evaluated using the following expression:

$$\sigma_s = C_R \gamma H A_o / g \qquad (7\text{-}1)$$

where:

σ_s = seismic pressure evenly distributed along height H of the wall;

H = wall height in contact with the soil;

γ = total (wet) unit weight of the soil or fill placed against the wall;

A_o = maximum effective soil acceleration, determined from table 6.2, according to the seismic zoning of the country;

C_R = coefficient equal to 0.45 for hard, dense or compacted soils; equal to 0.70 for loose or soft soils; and equal to 0.58 for loose fills deposited between the wall and the slope of an excavation carried out in dense or compacted soils.

7.5.4 If there is a water table in the retained soil and the soil permeability or its drainage conditions are such that they avoid an increase of the pore pressure that lead to the deterioration of the soil or its eventual liquefaction, the expression (7-1) shall be used considering the modified unit weight γ * given by:

$$\gamma^* = \gamma_{sat} - \frac{D_w}{H}\left(\gamma_{sat} - \gamma\right) \qquad (7\text{-}2)$$

where:

γ = total (wet) unit weight of the retained material above the ground water;

γ_{sat} = saturated unit weight of the material under the ground water;

D_w = depth of the ground water;

H = wall height in contact with the soil.

8 Secondary Elements

8.1 General

8.1.1 The purpose of this chapter is to establish the requirements and loadings for the design and anchorage of secondary elements and the interaction thereof with the resisting structure, taking into account the building's occupancy and the need of continuity of the operation.

8.1.2 It need not be necessary to carry out the analysis specified in this chapter in the cases of vehicles or other mobile equipment.

8.1.3 When designing secondary elements the following seismic forces in conjunction with other loadings must be considered. The horizontal component shall be the one defined in paragraph 8.3. The vertical component shall have a magnitude equal to *0.67* $A_o \ P_p / g$, and it will be considered, upwards or downwards according to which is the most unfavorable situation.

8.2 Performance level criteria

8.2.1 Three performance levels regarding the seismic behavior of secondary elements can be distinguished, being the following: *excellent*, *good*, and *minimum*, which correspond to the values of performance factor K_d equal to 1.35, 1.0, and 0.75 respectively.

8.2.2 The performance level that must be demanded in each case depends on the secondary element considered, and the occupancy category of the building, according to the classification found in paragraph 4.3. The performance factors for various cases of frequent use are indicated in table 8.1.

8.3 Design forces for secondary elements and their anchorages

8.3.1 Secondary elements and their anchorages to the resisting structure shall be designed with the following horizontal seismic force acting in any direction.

$$F = Q_p \ C_p \ K_d \qquad (8\text{-}1)$$

in which Q_p is the shear developed at the base of the secondary element in conformance with an analysis of the building that has included the modeling of the secondary element. The coefficient C_p and the performance factor K_d are determined from table 8.1.

8.3.2 As an alternative, the design of rigid elements and of relatively light flexible secondary elements (whose weight is less than 20% of the seismic weight of their floor level) may be performed with the following horizontal seismic force acting in any direction.

$$F = (F_k / P_k)\ K_p\ C_p\ K_d\ P_p \qquad (8\text{-}2)$$

in which the dynamic amplification factor K_p is determined in compliance with the set forth in paragraph 8.3.3, and C_p and K_d are obtained from table 8.1. In the case of using the static analysis method stated in paragraph 6.2, the F_k / P_k value shall not be less than A_o/g.

8.3.3 The coefficient K_p must be determined alternatively through one of the following procedures:

a) $$K_p = 2.2 \qquad (8\text{-}3)$$

b) $$K_p = 0.5 + \frac{0.5}{\sqrt{(1 - \beta^2)^2 + (\sqrt{0.3\beta})^2}} \qquad (8\text{-}4)$$

where:

$\beta = 1$ $\quad$ $for\ 0.8\ T^* \leq T_p \leq 1.1\ T^*$

$\beta = 1.25\ (T_p / T^*)$ $\quad$ $for\ T_p \prec 0.8\ T^*$

$\beta = 0.91\ (T_p / T^*)$ $\quad$ $for\ T_p \succ 1.1\ T^*$

where T_p is the period of the fundamental mode of vibration of the secondary element, including its anchorage system, and T^* is the period of the mode with the highest translational equivalent mass of the building in the direction where resonance with the secondary element may develop. To determine β the value of T^* shall not be less than 0.06 seconds.

8.4 Partition Walls

8.4.1 For the interaction between the building structure and the partition walls, these are classified as follows:

- **integrated**, if they must follow the structure deformation;

- **floating**, if they can deform independently from the structure.

8.4.2 The interaction between integrated partition walls and the resisting structure of the building must be analyzed with special attention to deformation compatibility; for this purpose these elements shall be incorporated in the model used in the seismic analysis, unless the relative displacement of the story measured at the location point of the partition wall is equal to or less than 0.001 times the story height.

8.4.3 The integrated partition walls must endure, without suffering damage that will prevent its normal use, the lateral deformation that is obtained amplifying by $R^* K_d / 3$ the lateral story deformation at the location of the partition wall, calculated using the methods in chapter 6.

8.4.4 The free lateral distance between the floating partition walls and the resisting structure must be equal to or greater than the lateral deformation obtained by amplifying by $R^* K_d / 3$ the lateral story deformation at the location of the partition wall, calculated using the methods in chapter 6.

8.4.5 The anchorage of the floating partition walls must be designed to allow the free deformation of the structure and at the same time to guarantee its transversal stability.

8.5 Complementary Aspects

8.5.1 The anchorage design shall be carried out neglecting the possible friction between the supporting surfaces.

8.5.2 To avoid shear stresses in the anchorage bolts due to seismic forces, additional anchoring devices shall be provided. In those cases that this is not practical, the anchorage bolts must be designed to resist the seismic shear increased in 100%. Equipment without anchorage in no case will be accepted.

8.5.3 Secondary elements that must have a performance level *excellent* ($K_d = 1.35$) or *good* ($K_d = 1.0$), shall be capable to resist the design forces calculated through the expressions (8-1) and (8-2) when corresponds, without suffering damage.

8.5.4 All gas, steam, cooled-gas pipeline, high-temperature water or other hazardous liquid supply equipment of buildings that correspond to category A indicated in paragraph 4.3, must be provided with an automatic shutdown system that is activated when the base acceleration of the building reaches a value equal to λA_o. The values of λ are shown in table 8.2, and they depend on the relationship that exists between the danger of the direct effect that the damage may cause, and the possibilities of service interruption the equipment offers.

Table 8.1 - Values of coefficient C_p and performance factor K_d for the design of secondary elements

	C_p	Performance Factor K_d		
		Building Category		
		A	B	C
I Secondary Elements				
Appendixes and Wall Fixed Elements				
- Chimneys, parapets, cornices and wall fixed elements	2.0	1.35	1.35	1.0
- Isolated elements embedded at their base	1.5	1.0	1.0	0.75
- Ceiling, wall, and floor-mounted equipment	1.0	1.35	1.0	0.75
- Shelves including their permanent content	1.0	1.35	1.0	0.75
- Signs	2.0	1.0	1.0	0.75
Partition and other non-structural walls				
- Staircases	1.5	1.35	1.0	1.0
- Horizontal or Vertical Escapes	1.0	1.35	1.35	1.0
- Public Corridors	1.0	1.35	1.0	0.75
- Private Corridors	0.7	1.35	0.75	0.75
- Other total height divisions	1.0	1.35	1.0	1.0
- Other partial height divisions	0.7	1.0	0.75	0.75
- Non-resisting exterior and curtain walls	2.0	1.35	1.0	0,75

(continues)

Table 8.1- Coefficient C_p and Performance Factor K_d values for the design of secondary elements

	C_p	Performance Factor, K_d Building Category		
		A	B	C
II Electrical and Mechanical equipment - Electric emergency equipment - Smoke and fire alarm systems - Fire-extinguisher system - Emergency system	2.0	1.35	1.35	1.35
- Heaters, thermos, incinerators, chimneys, ventilations - Communication system - Electric distribution system - Pressure and hazardous liquid tanks	2.0	1.35	1.0	0.75
- Inert liquid tanks	1.5	1.35	1.0	0.75
- Elevators	1.5	1.35	1.0	0.75
- Distributing conduits and pipelines	1.5	1.35	1.0	0.75
- General machinery	0.7	1.35	1.0	0.75
- Lighting	0.7	1.35	1.0	0.75

Table 8.2 - Values of factor λ

Complications due to service interruption	Risk Level		
	High	Medium	Low
Few	0.8	1.1	1.4
Some	1.1	1.4	1.7
Many	1.4	1.7	N.R *)

*) N.R = Does not require a shutdown system.

Annex A
(Information Only)

Seismic damage and structural rehabilitation

A.1 General

A.1.1 The provisions of this annex have the purpose of establishing criteria and procedures for:

a) evaluating the damage produced in the resisting structure of the building as consequence of an earthquake;

b) guiding the structural rehabilitation of both buildings damaged by an earthquake, and potentially unsafe buildings in the event of a future seismic movement.

A.1.2 The characteristics of a structure that can be modified through a structural rehabilitation process, are their resistance, stiffness, ductility, mass and foundation system.

A.1.3 The structural rehabilitation is named *repair* when a damaged structure has at least its resisting capacity and original stiffness restored.

A.1.4 The structural rehabilitation is designated *reinforcement* when the characteristics of a damaged or undamaged structure are modified to achieve a predetermined safety level higher than the original.

A.2 Evaluation of the seismic damage and structural rehabilitation decisions

A.2.1 The degree of seismic damage of a building can be mild, moderate or severe.

A.2.2 The estimate of the degree of damage must be carried out by an expert, who must analyze and quantify the behavior of all the parameters that define the damage.

A.2.3 The Dirección de Obras Municipales can order the evacuation of a building that is severely damaged and, which may suffer a partial or total collapse in the event of aftershocks or future earthquakes.

A.2.4 The Dirección de Obras Municipales, in conformance with a written report of at least one expert, can order the demolition of buildings with severe seismic damage that may collapse, and jeopardize human lives or properties located in the vicinity of the building.

A.2.5 The decision on the type of structural rehabilitation of a building, must not only consider the degree of damage but also the seismic intensity in that location.

A.3 Requirements to be met by the structural rehabilitation project

A.3.1 The structural rehabilitation project of a building damaged by an earthquake must be elaborated by an expert and it must be approved by the Dirección de Obras Municipales. For category A buildings, indicated in paragraph 4.3, an additional expert must review the structural rehabilitation project.

A.3.2 The structural rehabilitation project must include the following data:

a) detailed survey of damage to the elements of the resisting structure;

b) estimate of the degree of damage;

c) determination of the causes and justification of the damages;

d) seismic safety level of the structural rehabilitation;

e) basic design criteria;

f) repair and reinforcement solutions;

g) general and detailed drawings;

h) technical construction specifications;

i) project inspection level;

j) approval by the project reviewer in conformance with paragraph A.3.1.

A.4 General provisions for repair methods

A.4.1 In the case that the structural rehabilitation includes additional resisting elements, special care must be taken so that their contribution to the seismic behavior of the structure will be effective, that is to say, that during the earthquake said reinforcement elements will receive and transmit the loadings in the form considered in the calculation.

A.4.2 The processes of the release and transfer of the loads considered in the structural rehabilitation project shall be carefully specified. If necessary, on site measurements should be taken to verify the compliance with the requirements of the project, and to keep the corresponding records.

A.5 Requirements that must be met by the construction process of the structural rehabilitation

A.5.1 The construction process of the structural rehabilitation shall be assigned to an experienced company in this field; it must include a specialized inspection, and the supervision of the expert that carried out the rehabilitation project.

A.5.2 The professional in charge of the inspection shall not belong to the company that is undertaking the construction, and must stay permanently during the construction of the resisting structure. The Inspection may be made by the author of the rehabilitation project.

A.5.3 The Dirección de Obras Municipales may exempt isolated individual houses from provisions A.5.1 and A.5.2 if they conform simultaneously to the following conditions:

a) a surface of less than 200 m^2;

b) two stories or less.

In this case, the construction process must be supervised by the author of the rehabilitation project.

A.6 Necessity of rehabilitation for buildings without damages

A.6.1 Buildings classified in category A, according to paragraph 4.3, shall be submitted every 10 years to a review process in order to establish their compliance with the requirements of this code.

Annex B

Transitory references

B.1 As long as the NCh427 code is not revised, the provisions of the *Specification for Structural Steel Buildings* from the American Institute of Steel Construction, Inc., in its versions *Allowable Stress Design*, 1989, or *Load and Resistance Factors Design*, 1993, complemented with *Seismic Provisions for Structural Steel Buildings*, from AISC, 1992, shall be used. For cold-formed members *Specification for the Design of Cold-Formed Members*, American Iron and Steel Institute, 1996, shall prevail.

B.2 Until the new version of the NCh430 code, which substitutes the NCh429.Of57 and NCh430.Of61 codes, become official, the provisions of the *Building Code Requirements for Reinforced Concrete, ACI 318-95*, shall be used. In particular, the structural elements that form part of reinforced concrete frames intended to resist seismic loadings, must be dimensioned and detailed according to the provisions for zones of high seismic risk, located in chapter 21 of said code.

B.2.1 In the case of buildings that are structured with reinforced concrete walls and frames, in which the walls take at each level and for each direction of analysis a percentage of the total shear of the level, equal to or greater than 75%, the frame design must meet, as a minimum, provisions 21.8.4 and 21.8.5 of the ACI 318-95 code, provided that the individual frame is responsible for taking less than 10% of the total shear at each one of its levels. Frames whose seismic loadings have been calculated with $R_0 = 1$ or $R = 2$ factors, may also resort to this provision.

B.2.2 When designing reinforced concrete walls it is not necessary to meet the provisions of paragraphs 21.6.6.1 through 21.6.6.4 of the ACI 318-95 code.