Venezuela

Regulations for Earthquake-Resistant Buildings
(Edificaciónes Antisísmicas, Norma Venezolana)
1982
Comisión de Normas Industriales, COVENIN
Av. Andres Bello Torre Fondo Comun. Piso 11
Caracas

A COMMENT ON MATERIAL STRENGTH REQUIREMENTS AND RELATED BASIC POLICIES FOR THE DESIGN OF BUILDINGS

1. Material Code Format

Ultimate Strength Design

Remarks A one-phase design procedure is used for severe earthquake motions (10% excess in 50 years, and, for exceptionally important, 5% in 50 years). The ultimate strength design is used to ensure the factored resistance against gravity and earthquake loads (similar strategy to ACI 318)

2. Brief Descriptions

a. Material Strength (Concrete and Steel)

The ultimate strength of members is used in the capacity determination of members.

b. Strength Reduction Factors

As per ACI 318 and new AISC ultimate strength design methods.

c. Load Factors for Gravity Loadings and Load Combination

See b. A particular standard: criteria and minimum actions for building design, COVENIN 2002-88 is currently used.

d. Typical Live Load Values

Office Buildings	2.5 kN/m^2 is mostly used; may vary according to use.
Residential Buildings	1.75 kN/m^2 is mostly used; may vary according to use.

e. Special Aspects of Material Code

See b. Emphasis is given to masonry interaction: short columns, soft stories and torsion (center of rigidity displaced due to interaction).

CHAPTER 1 VALIDITY AND SCOPE

1.1 VALIDITY AND SCOPE

These Regulations provide the criteria for analyzing and designing buildings located in zones where seismic motions may occur, and supersede the MOP-1967 Provisional Regulations for Earthquake-Resistant Construction.

The provisions of these Regulations cover the design of new buildings whose behavior can be classified by type and on which certain simplifications may be used based on previous experience. For those cases involving reinforcement, alterations and repair of existing buildings, the pertinent authorities must determine the criteria to be followed pursuant to the guidelines contained in these Regulations.

These Regulations do not include the requirements for the analysis and design of buildings with prefabricated load-bearing elements, nor of special structures including, but not limited to: bridges, transmission towers, docks, hydraulic structures, nuclear plants, electric and mechanical installations, etc. In these cases, special considerations supplementary to the basic guidelines of these Regulations must be taken into account.

CHAPTER 2 DEFINITIONS AND SYMBOLS

2.1 DEFINITIONS

The terms generally used in these Regulations are defined below:

ACCELEROGRAPH: an instrument especially designed to record the time history of acceleration due to strong ground motion.

ACCIDENTAL EXCENTRICITY: a value additional to the static excentricity which takes into account effects due to irregularities in the distribution of the masses and of the rigidities, as well as the effects of the rotational ground excitation.

APPENDAGES: architectural parts such as marquees, parapets and elements on the façade.

BASE LEVEL: the level of the building where it is admitted that the seismic actions are transmitted to the structure.

BRACED FRAMES: vertical truss or equivalent systems placed in such a way as to resist seismic actions and in which the members are subject primarily to axial forces.

CENTER OF RIGIDITY OF A GIVEN LEVEL: the point at a given level where, upon applying a horizontal shear force, the level shifts without rotating with regard to the level immediately below.

DESIGN FORCES: the forces which the seismic action, including the torsional effects, brings to bear on the building or its components; these are specified at yield level.

DESIGN LEVEL: a series of regulatory specifications associated with a specific ductility factor applied in designing the members of the earthquake resistant system.

DESIGN MOVEMENTS: those ground motions selected in such a way that their probabilities of being exceeded shall be relatively low during the useful life of the structure; these are characterized by their response spectra.

DIAPHRAGM: a part of the structure, generally horizontal, sufficiently rigid within its plane, designed to transmit the forces to the vertical elements of the earthquake-resistant system.

DUCTILITY: the capacity of a structural system's components to make alternating incursions into the inelastic domain without an appreciable loss of their resistant capacity (see the definition of ductility factor).

DUCTILITY FACTOR: the value describing the overall ductility expected of the earthquake-resistant system, which quantifies the ratio of the maximum true displacements and the displacements calculated assuming a linear elastic behavior of the structure.

DYNAMIC AMPLIFICATION FACTOR: the quotient of the dynamic excentricity and the static excentricity.

DYNAMIC ANALYSIS: a modal superposition analysis in which seismic action is characterized by means of a design spectrum.

DYNAMIC EXCENTRICITY: the quotient of the torsional moment stemming from a dynamic analysis with three degrees of freedom per level, calculated relative to the rigidity center, and the shear force at that level.

EARTHQUAKE-RESISTANT SYSTEM: is that part of the structural system which is considered to provide the building with the necessary resistance, rigidity and ductility to withstand seismic actions.

PERMANENT LOAD: the gravity loads caused by the weight of all the structural and non-structural components, such as walls, floors, roofs, partitions, service equipment connected to the structure and any other fixed service load.

P-Δ EFFECT: the secondary effect produced by the axial loads and the lateral deflections on the flexural or bending moments of the members.

RESPONSE REDUCTION FACTOR: the factor dividing the ordinates of the elastic response spectrum so as to obtain the design spectrum.

SEISMIC COEFFICIENT: the quotient of the horizontal design shear force which acts at the base level, and the total weight above the same.

SHEAR CENTER: the point where the shear force acts at a given level, given that the horizontal forces at each level act through the respective center of mass.

SPECTRUM: the maximum response of single degree of freedom oscillators having the same damping, to a given time history of accelerations, expressed in terms of their period. The design spectra incorporate the response reduction factor for the earthquake-resistant system adopted.

STATIC EXCENTRICITY: the smallest distance between the line of action of the shear force and the center of rigidity.

STRUCTURAL WALLS: those walls designed especially to resist combinations of shears, moments and axial forces induced by seismic movements and/or gravitational actions.

TORSIONAL COUPLE: the vector moment normal to the plane considered and referred to its center of rigidity.

TORSIONAL MOMENT: the sum of the torsional couples at each level above, and including, the level considered, plus the torsional moment product of the shear force of the level multiplied by its excentricity with regard to the center of rigidity.

TOTAL OR BASE SHEAR FORCE: the horizontal shear force at the base level brought about by the seismic action.

VARIABLE LOAD: the load caused by the use and occupancy of the building, excluding permanent, wind or seismic loads.

YIELDING: the condition characterized by entrance into the plastic range of at least the most highly stressed region of the earthquake-resistant system, such as formation of the first plastic hinge in an important component of the same.

2.2 SYMBOLS

The subscripts x or y indicate the corresponding X or Y directions. The subscripts i,j,k are used to indicate any level whatsoever; the letter N indicates solely the last level.

A_d = Ordinate of the design spectrum expressed as a fraction of the acceleration of gravity (Section 7.2).

A_o = Maximum horizontal ground acceleration expressed as a fraction of the acceleration of gravity (Section 7.2).

B = Width of the floor level in the direction normal to the direction being analyzed (Section 9.5).

C = Seismic coefficient (Section 7.1).

CM = Effects due to permanent loads (Table 7.3).

C_p = Seismic coefficients of elements or parts of structures; given in Table 7.3.

CV = Effects due to variable loads (Table 7.3).

D = Ductility factor (Section 5.4.1).

ED = Effect due to the thrust of the ground or other material under dynamic conditions (Section 11.4).

F = Lateral force (Section 9.2.3).

F_p = Forces due to seismic action on elements or parts of a structure (Section 7.3.2).

F_t = Concentrated lateral force acting on the last level considered (Section 9.2.3).

L = Overall length of the story in the direction analyzed (Section 9.2.2).

M_t = Torsional moment (Section 9.5).

N = Number of levels of a building (Section 9.2.1).

N_1 = The number of modes to be considered in the dynamic analysis (Section 9.4.4 and Section 9.6.2).

P = Vertical force (Section 8.5).

P-Δ = Secondary order effects (Section 8.5).

Q = Loads for verification of the ground's resistant capacity (Section 11.3.1).

R = Response reduction factor (Section 5.4.2).

R_s = Admissible pressure under static loads (Section 11.3.4).

S = Effects due to seismic actions (Section 11.2).

T = Fundamental period of the building in seconds.

T_a = Fundamental period, in seconds, estimated on the basis of empirical relations (Section 9.2.2).

T* = Maximum value of the period in the interval where the design spectra have a constant value, in seconds (Section 7.2).

U = Ultimate resistance (Table 7.3).

V = Shear force.

V_o = Shear force at the base (Section 7.1.1).

W = Total weight of the building over the base level (Section 7.1.1).

W_p = Weight of the elements or parts of structures (Section 7.3.2).

e = Static excentricity (Section 9.5).

g = Acceleration of gravity, equal to 9.81 m/sec^2.

h = Height.

p = Exponent defining the descending branch of the spectrum (Section 7.2).

q_{ult} = Ultimate resistant capacity of the soil (Section 11.3.4).

Δ = Total lateral displacement including the inelastic effects; the subscript e indicates the elastic part of the same (Section 10.1).

θ = Stability coefficient (Section 8.5).

Φ_{im} = Modal coordinate of level i in mode m (Section 9.4.5).

α = Use coefficient (Section 5.1.3).

β = Average magnification factor (Section 7.2).

δ = Difference between total lateral displacement (Δ) between two consecutive levels (Section 10.1).

μ = Shear modification factor (Section 9.2.1).

ρ = Overturning reduction factor (Section 9.2.4).

τ = Dynamic amplification factor of the torsional moment (Section 9.5).

CHAPTER 3 GENERAL SPECIFICATIONS

3.1 RANGE OF APPLICATION

For purposes of application of these Regulations, every building must be assigned to one of the seismic zones provided for under Chapter 4 and must be duly classified pursuant to Chapter 5. The foundation soil must be classified on the basis of the types specified in Chapter 6.

3.2 METHODS AND CRITERIA FOR ANALYSIS

The criteria for analysis are described in Chapter 8 and the methods of analysis to be applied are set forth in Chapter 9. The design spectra are specified in Chapter 7.

3.3 DESIGN AND DETAILING REQUIREMENTS

The quality of the materials to be used, the design and detailing of the resisting elements and their joints must meet the COVENIN Standards presently in force.

3.4 DISPLACEMENT LIMITATIONS

Maximum displacements shall not exceed the limits set forth in Chapter 10.

3.5 OTHER BUILDINGS

The analysis and design of buildings which cannot be classified as one of the types described in Chapter 5 must follow the basic guidelines contained in these Regulations, having received the prior approval of the pertinent authority.

CHAPTER 4 SEISMIC ZONING

4.1 ZONING MAP

For purposes of the application of these Regulations, the country has been divided into five (5) zones. These are indicated on the Map in Figure 4.1 and in Table 4.1. The zoning of regions adjacent to dams more than 80 meters high shall be governed by special studies.

4.2 DESIGN MOVEMENTS

For each zone, the design movements for each typical subsoil profile are given in Tables 7.1 and 7.2 in Section 7.2.

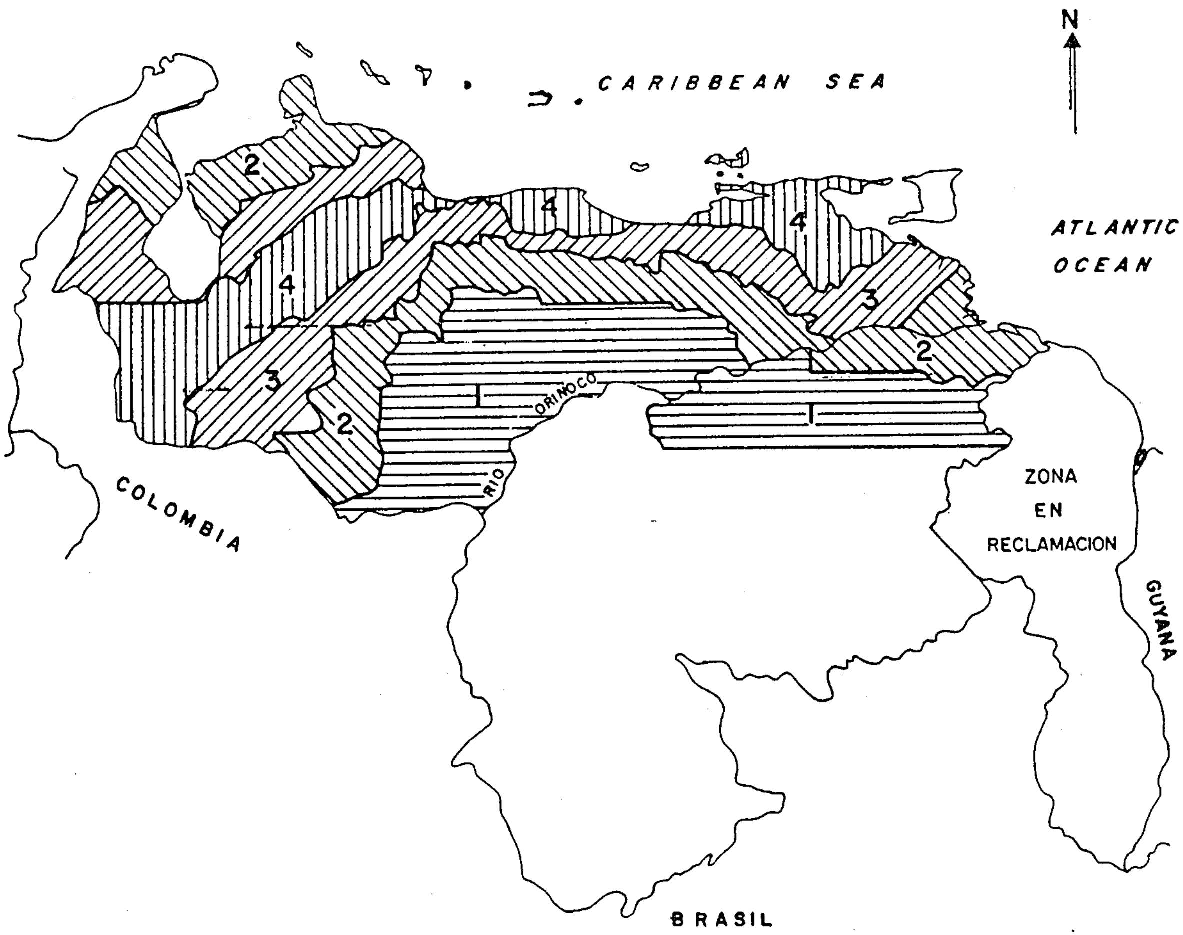
N
CARIBBEAN SEA
ATLANTIC
OCEAN
2
4
4
4
3
2
3
2
2
1
1
ORINOCO
RIO
ZONA
EN
RECLAMACION
GUYANA
COLOMBIA
BRASIL

FIGURE 4.1

TABLE 4.1 SEISMIC ZONING OF VENEZUELA

STATE	ZONE 4	ZONE 3	ZONE 2	ZONE 1
ANZOATEGUI	Sotillo District and the cities of Barcelona, Puerto La Cruz and adjacent areas	Peñalver, Bruzual, Cagigal, Bolívar, Libertador Districts and the northern part of Freites District (limited approximately by the Anaco Parallel)	Aragua, Anaco, Simón Rodríguez, Independencia, Guanipa District and areas of Freites District not included in Zone 3	Miranda and Monagas Districts
APURE	Areas west of La Victoria in Páez District	Rest of Páez District	Muñoz and Rómulo Gallegos Districts	Achaguas, San Fernando and Camejo Districts
ARAGUA	-----	The entire State except for those areas in Zone 2	Areas in the southern part of Urdaneta District limited approximately by the Camatagua Parallel	-----
BARINAS	Bolívar District. Areas northeast of Ezequiel Zamora, Pedraza, Obispos and Arevalo Torrealba Districts, limited approximately by a line 5 Km northeast and parallel to the Santa Barbara-Boconoíto road. Areas of Zamora District west of El Cantón	Rest of the State, except the areas in Zone 4 and Sosa and Arismendi Districts	Sosa District	Arismendi District

TABLE 4.1 SEISMIC ZONING OF VENEZUELA (cont.)

STATE	ZONE 4	ZONE 3	ZONE 2	ZONE 1
BOLIVAR	-----	-----	The capital, Ciudad Bolívar and adjacent areas. Caroní District and areas north of 8° N of Piar District	Areas north of 7° N of Sucre, Heres, Piar and Roscio Districts which are not included in Zone 2
CARABOBO	Puerto Cabello District	Rest of the State	-----	-----
COJEDES	Areas of Anzoátegui District located north of Cojedes (located at approximately 9.6° N) including the latter and adjacent areas	Rest of the State except the areas in Zone 4 and Zone 2. Zone claimed by Portuguesa State	Girardot and Pao Districts	-----
FEDERAL DISTRICT	The entire District	-----	-----	-----
FALCON	Zone claimed by Yaracuy State	Federación, Silva and Acosta Districts; zone claimed by Zulia State	Rest of the State	-----
GUARICO	-----	Areas of Monagas District north of 9.7° N approximately	Rest of Monagas District, areas of Roscio, Ribas and Mellado Districts and areas of Infante and Zaraza Districts limited to the south by Parallel 9° N	-----

TABLE 4.1 SEISMIC ZONING OF VENEZUELA (cont.)

STATE	ZONE 4	ZONE 3	ZONE 2	ZONE 1
LARA	The entire State except Urdaneta District and the western region of Torres District. Zone claimed by Portuguesa State	Urdaneta District western region of Torres District, including Carora. Zones claimed by Zulia and Trujillo States	-----	-----
MERIDA	The entire State including zone claimed by Zulia State	-----	-----	-----
MIRANDA	The entire State	-----	-----	-----
MONAGAS	The entire State except Sotillo District and the areas southwest of Maturín District, limited approximately by a line some 5 Km southwest and parallel to the El Furrial-Maturín-El Temblador road	Sotillo District and areas of Maturín District not part of Zone 4	-----	-----
NUEVA ESPARTA	The entire State	-----	-----	-----

TABLE 4.1 SEISMIC ZONING OF VENEZUELA (cont.)

STATE	ZONE 4	ZONE 3	ZONE 2	ZONE 1
PORTUGUESA	Sucre and Araure Districts. Areas located northwest of Guanare and Ospino Districts, limited approximately by a line some 5 Km to the southeast and parallel to the Boconoito-Guanare-Ospino-Acarigua road. Zone claimed by Lara State	Rest of the State including the zone claimed by Cojedes State	-----	-----
SUCRE	The entire State	-----	-----	-----
TACHIRA	The entire State	-----	-----	-----
TERRITORIO FEDERAL AMAZONAS	-----	-----	-----	-----
TERRITORIO FEDERAL DELTA AMACURO	Pedernales Department and the capital of the Territory, Tucupita, including adjacent areas	Tucupita Department, except the capital, Tucupita, and adjacent areas	Antonio Díaz Department	-----
TRUJILLO	The entire State except Betijoque District	Betijoque District and zones claimed by Lara and Zulia States	-----	-----

TABLE 4.1 SEISMIC ZONING OF VENEZUELA (cont.)

STATE	ZONE 4	ZONE 3	ZONE 2	ZONE 1
YARACUY	The entire State including the zone claimed by Falcón State	-----	-----	-----
ZULIA	Sucre District and areas south of 9° N of Colón District. Zones claimed by Mérida State	Baralt and Perijá Districts; areas north of 9° N of Colón District. Zones claimed by Falcón, Lara and Trujillo States	Rest of the State	-----
ZONE SUBJECT OF TERRITORIAL CLAIM	-----	-----	-----	Essequibo Region
CARIBBEAN ISLANDS	All the islands in the Caribbean Sea	-----	-----	-----

CHAPTER 5 BUILDING CLASSIFICATION BY USE, DESIGN LEVEL, STRUCTURAL TYPE AND REGULARITY

For purposes of the application of these Regulations, buildings shall be classified according to the following criteria:

5.1 CLASSIFICATION BY USE

5.1.1 GROUPS

Depending upon the use to be given them, they are divided into the following groups:

GROUP A

Buildings containing essential facilities whose capacity to function under emergency conditions is vital or whose failure to function could give rise to sizeable losses of human life or economic losses, and/or those having a long useful life, including but not limited to:

- Hospitals, first-aid or health centers
- Important government or municipal buildings, highly valued monuments or temples
- Buildings containing highly valued objects, such as certain museums and libraries
- Educational institutions
- Fire stations, police stations or barracks
- Power stations, telephone or telegraph exchanges, radio and television stations. Pumping stations
- Warehouses containing toxic or explosive materials and centers using radioactive materials

GROUP B

Buildings for public or private use, such as but not limited to:

- Houses
- Apartment or office buildings or hotels
- Banks, restaurants, movie theaters and theaters
- Industrial plants and facilities
- Storage and warehouses
- Any building whose collapse would endanger buildings listed either in this Group or in Group A

GROUP C

Buildings which cannot be classified under either of the two preceding groups which are not for housing or public use and whose collapse would not cause damages to buildings in the first two groups.

5.1.2 MIXED USE

Buildings having both A and B use areas shall be classified under Group A.

5.1.3 USE COEFFICIENT

In keeping with the foregoing classification, a use coefficient α is established as set forth in Table 5.1.

TABLE 5.1

USE COEFFICIENT

GROUP	α
A	1.25
B	1.00

The buildings in Group C do not require a seismic analysis.

5.2 CLASSIFICATION BY DESIGN LEVEL

For purposes of application of these Regulations, there are three design levels which are specified in Section 5.2.1.

5.2.1 DESIGN LEVELS

DESIGN LEVEL 1

Does not require application of the provisions for seismic zone design.

DESIGN LEVEL 2

Requires the application of the provisions covering this design level set forth in the COVENIN Standards 1753-81.

DESIGN LEVEL 3

Requires the application of all the provisions for seismic zone design set forth in the COVENIN Standards 1753-81.

5.2.2 DESIGN LEVELS REQUIRED IN THE DIFFERENT SEISMIC ZONES

One of the design levels ND specified in Table 5.2 shall be used. Different design levels may not be used in one same building.

TABLE 5.2

DESIGN LEVELS ND

GROUP	SEISMIC ZONE			
	1	2	3	4
A	ND2 ND3	ND2 ND3	ND3*	ND3
B	ND1 ND2 ND3	ND2 ND3	ND2 ND3	ND3*

* In buildings which may be analyzed by means of the simplified static method in Section 9.3, ND2 may be used.

5.3 CLASSIFICATION BY TYPE OF STRUCTURE

For purposes of these Regulations, four types of structural systems have been established, based on the elements of the earthquake-resistant system described in Section 5.3.1.

5.3.1 TYPES OF EARTHQUAKE-RESISTANT STRUCTURAL SYSTEMS

TYPE I

Structures capable of resisting the total seismic actions by means of deformations due essentially to flexure of its structural members, such as structural systems consisting primarily of frames.

TYPE II

Structures consisting of frames and structural walls of reinforced concrete or braced frames, whose joint action is capable of resisting the total seismic forces. The frames per se must be capable of resisting at least 25% of these forces.

TYPE III

Structures capable of resisting the total seismic action by means of braced frames or reinforced concrete structural walls which bear the entire permanent and variable loads. These are the systems which are generally called shear walls. Type II structures whose frames alone are not capable of resisting 25% of the total seismic forces but do contribute to resisting the gravity load will also be considered to form part of this group.

TYPE IV

Structures supported by a single column. Structures whose diaphragms do not have the rigidity and resistance necessary to effectively distribute the seismic forces among the different vertical members.

All the types of structures, with the exception of Type IV, must have enough diaphragms to effectively distribute the seismic actions among the different members of the earthquake-resistant system.

5.3.2 COMBINATION OF STRUCTURAL TYPES

In the event that in one direction of analysis more than one type of structural system is used, the value of D in that direction will be the lowest of the corresponding values given in Table 5.3. When, within a combination of two systems, one of the components bears a weight equal to or below 10% of the total weight of the building, this requirement does not have to be met.

5.4 DUCTILITY AND RESPONSE REDUCTION FACTORS

5.4.1 DUCTILITY FACTOR

The maximum values of the ductility factor D for the different types of structures and design levels are given in Table 5.3.

TABLE 5.3

DUCTILITY FACTOR D

DESIGN LEVEL	TYPE OF STRUCTURE			
	I	II	III	IV
ND3	6	5	4	1.5
ND2	4.5	3.75	3	1.25
ND1	2.5	2	1.5	1.0

The use of ductility factors greater than those indicated in Table 5.3 must be duly justified

5.4.2 RESPONSE REDUCTION FACTOR

For calculation of the ordinates of the design spectra a reduction factor R shall be used, as given by:

$$R = 1 + \frac{T}{0.15}(D-1) \quad \text{for } T < 0.15 \text{ sec.} \quad (5\text{-}1)$$

$$R = D \quad \text{for } T \geq 0.15 \text{ sec.} \quad (5\text{-}2)$$

5.5 CLASSIFICATION ACCORDING TO THE STRUCTURE'S REGULARITY

In order to select the analysis methods set forth in Chapter 9 of these Regulations buildings must be classified as regular or irregular.

5.5.1 REGULAR STRUCTURES

Those buildings meeting all of the following specifications shall be considered regular:

a) The vertical distribution of masses, or rigidities, or shear resistance does not vary substantially between adjacent levels.

b) The distance between the line of action of the shear and the center of rigidity does not exceed 8% of the dimension of the floor perpendicular to the direction analyzed.

c) The dimensions of the floors do not increase substantially with height.

5.5.2 IRREGULAR STRUCTURES

Buildings which do not meet the foregoing specifications shall be considered irregular.

CHAPTER 6 FOUNDATION SOILS

These Regulations provide for three types of foundation soils, characterized by their subsoil profiles given in Section 6.1 and by the response spectra given in Section 7.2.

6.1 TYPICAL SUBSOIL PROFILES

The local effect of the soil on the building's response shall be determined on the basis of the soil's general conditions; the various types are set forth in Sections 6.1.1 through 6.1.4.

6.1.1 S1 PROFILE

A profile consisting of one of the two following:

a) Rock of any type, whether shale or crystalline rock.

b) Hard and/or dense soils, where the proven depth of the rock base is less than 50 meters. The soil covering the rock may be dense to very dense sands and gravel, very hard silts or clay or a mixture of these. In those cases in which the depth of the deposit is not proven the S2 profile shall be used.

6.1.2 S2 PROFILE

This is a profile with great soil depth which may be made up of medium to very dense sands or gravels and/or hard to very hard silts or clay, or a mixture of these.

6.1.3 S3 PROFILE

This is a profile with not very dense granular soils and/or cohesive soils having a soft to medium consistency, with a depth of more than 10 meters within the first 30 meters, measured from the ground surface.

6.1.4 DOUBTFUL CASES

In those cases in which doubts arise between two types of profile for the classification of the subsoil profile, the profile giving rise to the seismic action most unfavorable for the structure shall be used.

6.2 SOILS SUSCEPTIBLE TO LIQUEFACTION

In cases involving soils susceptible to liquefaction, their liquefaction potential must be assessed pursuant to the conditions specified in Section 11.6.

Those soils which are not potentially liquefiable should be classified pursuant to Section 6.1 and potentially liquefiable soils are excluded from this classification.

CHAPTER 7 BASE SHEAR AND DESIGN SPECTRA

7.1 BASE SHEAR

7.1.1 DETERMINATION

The building must be designed to withstand a base shear equal to:

$$V_0 = C\ W \qquad (7\text{-}1)$$

where:

C = the seismic coefficient determined pursuant to the analysis methods set forth in Chapter 9 on the basis of the design spectra given in Section 7.2;

W = the total weight of the building above the base level; for this the permanent and variable loads specified in Sections 7.1.2 and 7.1.3 are to be taken into account.

In any event, the value of C shall not be less than $\frac{\alpha A_0}{6}$, where α and A_0 are defined in Section 7.2.

7.1.2 PERMANENT LOADS

Permanent loads must include the weight of the construction elements in themselves, whether structural or not, as well as the weight of machinery and equipment whose mass is not negligible.

7.1.3 VARIABLE LOADS

In order to determine the total weight W, the percentages of the variable loads specified below must be added to the permanent loads:

a) Containers for liquids: 100% of the service load, for a full container.

b) Storage and warehouses in general, where the load is permanent: 80% of the service load.

c) Parking lots: the weight of the vehicles assuming full parking must be calculated; in no case, however, shall the value adopted be less than 50% of the variable service load provided for under the respective regulations.

d) Story slabs in buildings, not included in (b) and (c): 25% of the variable service load.

e) Inaccessible roofs and terraces: 0% of the variable load.

7.2 DESIGN SPECTRA

The ordinates A_d of the design spectra are defined on the basis of the period T as follows:

$$T < 0.15 \text{ sec} \qquad A_d = \frac{\alpha A_o \left[1 + \frac{T}{0.15}(\beta - 1)\right]}{R} \qquad (7\text{-}2)$$

$$0.15 \leqq T < T^* \qquad A_d = \frac{\alpha\beta A_o}{R} \qquad (7\text{-}3)$$

$$T \geqq T^* \qquad A_d = \frac{\alpha\beta A_o}{R}\left[\frac{T^*}{T}\right]^p \qquad (7\text{-}4)$$

where:

α = use coefficient given in Section 5.1.3;

R = response reduction factor given in Section 5.4.2;

A_o = maximum horizontal ground acceleration expressed as a fraction of g according to Table 7.1;

β = average magnification factor according to Table 7.2;

T^* = period given in Table 7.2;

p = exponent defining the descending branch of the spectrum according to Table 7.2.

TABLE 7.1
VALUES OF A_o

ZONE	A_o (g)
4	0.30
3	0.22
2	0.15
1	0.08

TABLE 7.2
VALUES OF β, T^* AND p

Soil Profile	β	T^* (sec)	p
S1	2.2	0.4	0.8
S2	2.2	0.6	0.7
S3	2.0	1.0	0.6

7.3 SEISMIC COEFFICIENTS FOR PARTS OF THE STRUCTURE

7.3.1 ANALYSIS AND DESIGN CRITERIA

The elements which are not an integrated part of the building's structure, the minor structures linked to it, their connections to the princi_ pal structure as well as the flexible elements which may oscillate vertically, referred to in Table 7.3,must be designed to resist the seismic actions resulting from the application of one of the following criteria:

a) Actions resulting from application of the method in Sections 9.4 or 9.6 presuming that they form part of the structure.

b) Those deduced from applying the actions provided for in Section 7.3.2. In this case their weight shall be incorporated to level N of the principal structure for the seismic analysis of the latter.

The actions on components and mechanical and electrical systems which are considered vital or essential must be evaluated taking the dynamic response of the system into consideration.

7.3.2 VALUES OF C_p

The elements and parts of structures listed in Section 7.3.1 must be designed to resist the seismic actions, F_p calculated according to the following formula:

$$F_p = \alpha C_p W_p \qquad (7-5)$$

where:

α = use coefficient given in Section 5.1.3;

C_p = coefficient given in Table 7.3;

W_p = weight of the part considered

For seismic zones 3, 2 and 1 the values for C_p given in Table 7.3 shall be multiplied by 0.72, 0.50 and 0.25, respectively.

TABLE 7.3

VALUES OF C_p

PART OF THE STRUCTURE	DIRECTION OF THE FORCE	C_p
a) Exterior or interior walls, whether load bearing or not; partitions and other dividing walls	Normal to the surface of the wall	0.30
b) Ledges and any overhanging vertical parapet	Normal to the surface of the wall	1.00
c) Exterior or interior ornaments and appendages	Any direction	1.00
d) Marquees, balconies, eaves, roof projections or any other overhang	Vertical	(1)
e) Floors and roofs acting as diaphragms	Any horizontal direction	(2)
f) Joints of external prefabricated walls or partition elements	Any direction	2.00
g) Engine room structures, water tanks and their contents and lookouts over buildings	Any horizontal direction	$\frac{1.8}{R}$

NOTES:

(1) These must be designed for the joint effect of seismic and gravitational actions, according to the following two directions:

downward $U = + 1.8\ (CM + CV)$

upward $U = + 0.2\ (CM + CV)$

(2) See Section 8.3.3.

CHAPTER 8 GENERAL REQUIREMENTS AND CRITERIA FOR ANALYSIS

8.1 GENERAL COMMENTS

The earthquake-resistant system must be conceived in such a way that the premature failure of a few elements does not threaten the stability of the building.

8.2 DIRECTION OF ANALYSIS

The structures shall be analyzed in two orthogonal, or approximately orthogonal, horizontal directions. The effects of the earthquake and of the gravitational actions shall be combined pursuant to Section 8.6.

8.3 ANALYSIS REQUIREMENTS

The analysis of the effects of seismic actions must meet the following requirements:

8.3.1 HYPOTHESIS FOR THE ANALYSIS

The effects of the seismic actions shall be analyzed assuming linear elastic behavior in keeping with the principles of the Theory of Structures.

8.3.2 COMPATIBILITY OF DEFORMATIONS

It is necessary to verify that the deformations of the structural elements are compatible among each other and do not exceed their resistant capacity.

8.3.3 FLOOR RIGIDITY

In the analysis methods given in these Regulations it is assumed that the floors, roofs and their joints act as diaphragms which cannot be deformed in their plane and that they are designed to transmit the forces to the vertical elements of the earthquake-resistant system.

These diaphragms must be capable of transmitting in their plane the lateral forces, F_i, which are obtained by applying the methods given in Chapter 9, however in no case less than 0.15 times the weight of the story.

Prefabricated slabs may be accepted as diaphragms, provided the effectiveness of the joint among the different members has been proven.

If the floors do not have the necessary rigidity, their flexibility must be taken into account in the analysis and design.

8.4 SUPERPOSITION OF TRANSLATIONAL AND TORSIONAL EFFECTS

The effects of translational and torsional vibrations due to the seismic action in a specific direction may be statically modeled by the action of a horizontal shear force applied to each floor in each direction, together with a torsional moment calculated according to the methods indicated in Chapter 9.

8.5 P-Δ EFFECTS

The P-Δ effects must be taken into account when, at any level, the quotient given by formula (8-1) exceeds the value of 0.08.

$$\theta = \frac{\delta_i \sum_{j=i}^{N} W_j}{V_i \, D \, (h_i - h_{i-i})} \qquad (8\text{-}1)$$

where:

δ_i = difference between the total lateral displacements between two consecutive levels;

W_j = weight of level j of the building, defined in Section 7.1

8.6 DESIGN REQUIREMENTS

The structures and their elements must be designed pursuant to COVENIN Standard 1753-81 and must be capable of resisting the combinations indicated in Chapter 18 of said Standards. These combinations include the effects of vertical acceleration. For overhanging horizontal elements the C_p factor given in Section 7.3.2 must be used. It is not necessary to consider simultaneous wind and seismic action.

When design procedures different from those set forth in COVENIN Standard 1753-81 are used, equivalent levels of safety must be guaranteed.

CHAPTER 9 ANALYSIS METHODS

9.1 RANGE OF APPLICATION

The buildings must be analyzed taking into consideration the translational and torsional effects, following the analysis methods set forth in Sections 9.2 through 9.6, provided the hypothesis that the floors are rigid in their plane may be admitted. Methods different from those established herein may be used provided they are duly justified. The range of application of each method, according to the regularity classification given in Section 5.5, may be found in Table 9.1.

TABLE 9.1

METHODS FOR ANALYSIS

<table>
<tr><th rowspan="2">BUILDINGS</th><th rowspan="2">REGULAR</th><th colspan="3">IRREGULAR</th></tr>
<tr><th>$\frac{e}{B} \leq 0.08$</th><th>$0.08 < \frac{e}{B} \leq 0.12$</th><th>$\frac{e}{B} > 0.12$</th></tr>
<tr><td>No higher than 20 stories or 60 meters (1)</td><td>Sections 9.2 and 9.5</td><td rowspan="2">(2) (3)</td><td rowspan="2">Preferably Section 9.6; as an alternative Sections 9.4 and 9.5
(3)</td><td rowspan="2">Section 9.6</td></tr>
<tr><td>More than 20 stories or 60 meters high</td><td>Sections 9.4 and 9.5</td></tr>
</table>

(1) To verify the seismic effects on buildings belonging to Group B no more than 3 stories high, where the height between stories does not exceed 3.5 meters and having maximum total heights of 10.5 meters, the simplified method in Section 9.3 may be used.

(2) If the irregularity is due exclusively to the fact that it does not meet the specifications of paragraph (a) in Section 5.5.1, the method given in Sections 9.4 and 9.5 or that given in Section 9.6 must be used.

(3) If the irregularity is due to the fact that the building does not meet the specifications of paragraph (c) in Section 5.5.1, the method given in Section 9.6 must be used.

9.2 EQUIVALENT STATIC METHOD

9.2.1 BASE SHEAR FORCE

The base shear force V_o is determined following the expression:

$$V_o = \mu A_d W \quad (9\text{-}1)$$

where:

A_d = ordinate of the design spectrum defined in Section 7.2 for period T given in Section 9.2.2;

W = the weight of the building including the permanent and variable loads given in Sections 7.1.2 and 7.1.3;

μ = the greatest of the values given by:

$$\mu = \frac{3}{2} \left(\frac{N + 1}{2N + 1} \right) \quad (9-2)$$

$$\mu = 0.80 + \frac{1}{20} \left(\frac{T}{T^*} - 1 \right) \quad (9-3)$$

N = number of levels

T = fundamental period

T* = period given in Table 7.2

In any event the value $\frac{V_o}{W}$ shall not be below the minimum seismic coefficient given in Section 7.1.1.

9.2.2 ESTIMATED FUNDAMENTAL PERIOD

The estimated value T_a of the fundamental period T shall be calculated as follows:

a) For Type I structures:

$$T_a = 0.061\, h_n^{3/4} \quad (9-4)$$

b) For Type II and III structures:

$$T_a = \frac{0.09\, h_n}{\sqrt{L}} \quad (9-5)$$

where:

h_n = height of the building measured from the base level, in meters, up to the last significant level;

L = the largest dimension of the floor in the direction analyzed, in meters.

When the fundamental period T is calculated using Structural Dynamics procedures, the value finally used shall not exceed 1.2 T_a.

9.2.3 VERTICAL DISTRIBUTION OF THE DESIGN FORCES DUE TO TRANSLATIONAL EFFECTS

The lateral design forces at each level shall be obtained by vertically distributing the base shear force V_o, determined with Formula (9-1), according to the following expression:

$$F_t + \sum_{i=1}^{N} F_i = V_o \qquad (9\text{-}6)$$

where:

F_t = lateral force concentrated at level N calculated according to the following expression

$$F_t = (0.06 \frac{T}{T^*} - 0.02)\ V_o \qquad (9\text{-}7)$$

and set between the following limits:

$$0.04\ V_o \leq F_t \leq 0.10\ V_o \qquad (9\text{-}8)$$

F_i = lateral force for level i, calculated according to the following formula:

$$F_i = (V_o - F_t) \frac{W_i\ h_i}{\sum_{j=1}^{N} W_j\ h_j} \qquad (9\text{-}9)$$

W_j = weight at level j of the building, defined in Section 7.1

h_j = height measured from the base up to level j of the building

When there are structures such as water tanks, engine rooms, light signs, etc. over level N, the criterion set forth under Section 7.3.1 shall be applied.

9.2.4 OVERTURNING

Overturning moments can be reduced by following the criterion given below:

$$M_{vk} = \rho \sum_{i=k}^{N} F_i\ (h_i - h_k) \qquad (9\text{-}10)$$

where:

M_{vk} = overturning moment at level k;

F_i = lateral force for level i;

h_i and h_k = heights measured from the base up to level i and k, respectively;

ρ = reduction factor equal to 1.0 for the 5 topmost levels and equal to $(1 - 0.04 \frac{T}{T^*})$ for all levels under the 8 topmost levels. For the levels between 5 and 8 counting from the last, a linear interpolation shall be made.

9.3 SIMPLIFIED METHOD

9.3.1 BASE SHEAR FORCE

The shear force V_0 at the base of the building shall be determined by means of the following expression:

$$V_0 = \frac{\alpha A_0 (\beta + 1)}{D + 1} W \qquad (9\text{-}11)$$

where:

α = use coefficient given in Table 5.1;

A_0 = maximum horizontal acceleration given in Table 7.1;

β = average magnification factor according to Table 7.2;

D = ductility factor given in Table 5.3;

W = total weight of the building

9.3.2 VERTICAL DISTRIBUTION OF THE SEISMIC DESIGN FORCES

The shear force V_0 at the base shall be distributed vertically according to the expression given below:

$$F_i = V_0 \frac{W_i h_i}{\sum_{i=1}^{N} W_i h_i} \qquad (9\text{-}12)$$

where:

W_i = weight of level i of the building defined in Section 7.1;

h_i = height measured from the base up to level i of the building;

F_i = lateral force al level i

When there are structures such as water tanks, engine rooms, signs, etc. over level N, the largest of the forces resulting from this Section or from Section 7.3.1 shall be applied.

9.3.3 TORSIONAL EFFECTS AND LATERAL DISPLACEMENTS

The criteria for taking into account the torsional effects as well as verification of the lateral displacements are left to the judgement of the designer.

The torsional effects may be determined by means of the static method in Section 9.5; a value τ selected on the basis of the distribution of rigidities is to be used for this purpose.

9.4 ONE DEGREE OF FREEDOM PER LEVEL MODAL SUPERPOSITION METHOD

9.4.1 NOMENCLATURE

The nomenclature used in this analysis method has the same meaning as that of similar terms given in Section 9.2, the subscript m indicating the m mode.

9.4.2 MATHEMATICAL MODEL

For the application of this method, the building must be modeled as a system of masses concentrated at each level, each of which has a degree of freedom as regards lateral displacement in the direction considered.

9.4.3 MODES

The modal forms and their corresponding period of vibration in the direction analyzed shall be calculated by using the system's elastic rigidities and masses.

9.4.4 ANALYSIS

In each direction the analysis must incorporate at least the number of modes, N_1, given below:

a) for buildings having less than 20 stories:

$$N_1 = \frac{1}{2}\left(\frac{T_1}{T^*} - 1.5\right) + 3 \quad \geq 3 \qquad (9\text{-}13)$$

b) for buildings having 20 or more stories:

$$N_1 = \frac{2}{3}\left(\frac{T_1}{T^*} - 1.5\right) + 4 \quad \geq 4 \qquad (9\text{-}14)$$

where:

T_1 = period of the fundamental mode

The N_1 values must be rounded out to the next highest integer. For structures having fewer than 3 stories, the number of modes to be incorporated equals the number of stories.

9.4.5 MODAL BASE SHEAR

The contribution V_{om} of the m mode to the base shear shall be determined according to the following formula:

$$V_{om} = \overline{W}_m A_{dm} \qquad (9\text{-}15)$$

where:

$$\overline{W}_m = \frac{\left[\sum_{i=1}^{N} W_i \Phi_{im}\right]^2}{\sum_{i=1}^{N} W_i \Phi_{im}^2} \qquad (9\text{-}16)$$

W_i = weight of level i;

Φ_{im} = modal coordinate of level i in mode m;

A_{dm} = value of A_d (Section 7.2) for the period corresponding to mode m

9.4.6 MODAL FORCES

The modal forces F_{im} at each level shall be determined by means of the expression:

$$F_{im} = C_{im} V_{om} \qquad (9\text{-}17)$$

where:

$$C_{im} = \frac{W_i \Phi_{im}}{\sum_{j=1}^{N} W_j \Phi_{jm}} \qquad (9\text{-}18)$$

where:

W_i = weight of level i;

Φ_{im} = modal coordinate of level i in mode m.

9.4.7 DESIGN VALUES

The design values for the base shear and the shear force at each level shall be determined by a combination of the respective modal values. The combination will be carried out taking the square root of the sum of the squares of each modal value. The base shear V_0 obtained from the modal combination must be compared with that calculated according to Section 9.2.1 with a period $T = 1.4\ T_a$, represented here by $\bar{V}_0$. When V_0 is less than $\bar{V}_0$, the values for the design must be multiplied $\bar{V}_0/V_0$. The V_0/W design quotient shall not be less than the minimum seismic coefficient given in Section 7.1.1.

The overturning moments at each level may be determined following the same modal combination procedure.

9.5 METHOD FOR DETERMINING THE EQUIVALENT STATIC TORSION

The torsional moment at each level and in each direction shall be evaluated by the following formulae:

$$M_{ti} = V_i\ (\tau e_i + 0.10\ B_i) \qquad (9\text{-}19)$$

$$M_{ti} = V_i\ (e_i - 0.10\ B_i) \qquad (9\text{-}20)$$

where:

e_i = static excentricity at level i in the direction normal to the direction analyzed;

B_i = width of the floor in the direction normal to the direction analyzed;

τ = dynamic amplification factor of the structure

In those cases in which the elements contributing to the lateral rigidity are located principally at the perimeter of the story, a value of τ equal to 1.5 may be used. If there is a high proportion of lateral rigidity towards the center of the building, a value of τ equal to 5 must be used. In the remainder of the cases a value of τ equal to 3 shall be used. However, the value of τ may be determined based on an analysis which takes the dynamic properties of the building into consideration.

For the design of the resistant elements, the most unfavorable stresses given by expressions (9-19) and (9-20) are to be selected.

9.6 THREE DEGREES OF FREEDOM PER LEVEL MODAL SUPERPOSITION METHOD

9.6.1 GENERAL COMMENTS

This method takes into account the coupling of the translational and rotational vibrations of the building and considers three degrees of freedom for each level.

9.6.2 DESIGN VALUES

A minimum of $3N_1$ modes of vibration shall be calculated, where N_1 is given by the formulae (9-13) and (9-14) in Section 9.4.4. The response values shall be determined by means of suitable modal combination criteria which take the coupling of modes having close frequencies between them into account.

The effects of an accidental excentricity of the shear force equal to 10% of the width of the floor in the direction perpendicular to that analyzed must be incorporated for each direction of the building and in each sense.

In each direction, the base shear V_0 calculated from the modal combination must be compared with that calculated according to Section 9.2.1 with a period $T = 1.4\ T_a$, represented here by $\overline{V}_0$. When V_0 is less than $\overline{V}_0$, the values for the design must be multiplied by $\overline{V}_0/V_0$. The V_0/W design quotient shall not be less than the minimum seismic coefficient given in Section 7.1.1.

CHAPTER 10 DISPLACEMENT CONTROL

10.1 TOTAL LATERAL DISPLACEMENT

The total lateral displacement Δ_i of level i is calculated as:

$$\Delta_i = D\, \Delta_{ei} \qquad (10\text{-}1)$$

where:

D = ductility factor given in Section 5.4.1;

Δ_{ei} = lateral displacement of level i calculated for the design forces, assuming that the structure's behavior is elastic

The difference between the total lateral displacement of two consecutive levels shall be called δ_i:

$$\delta_i = \Delta_i - \Delta_{i-1} \qquad (10\text{-}2)$$

10.2 DISPLACEMENT INCREASE DUE TO THE P-Δ EFFECTS

When the limit established in Section 8.5 is exceeded, the lateral displacement shall be increased by the P-Δ effects.

10.3 LIMIT VALUES

The quotient:

$$\frac{\delta_i}{(h_i - h_{i-1})} \qquad (10\text{-}3)$$

where $(h_i - h_{i-1})$ is the separation between two consecutive levels, shall not exceed the values given in Table 10.1 at any level. These limits are based on the premise that the elastic modulus of concrete is that provided for in COVENIN Standards 1753-81.

TABLE 10.1

Value Limits of $\frac{\delta_i}{(h_i - h_{i-1})}$		
Type and Layout of the Non-Structural Elements	Buildings	
	GROUP A	GROUP B
Susceptible to damage due to deformation of the structure	0.015	0.018
Not susceptible to damage due to deformation of the structure	0.020	0.024

10.4 MINIMUM SEPARATIONS

10.4.1 BOUNDARIES

Every building must be separated from its boundary by a distance of more than:

$$\left(\frac{D + 1}{2}\right) \Delta_{eN} \qquad (10\text{-}4)$$

but no less than 3.5 cm. over the first 6 meters plus 4 $^{o}/oo$ of the height in excess of the latter.

10.4.2 ADJACENT BUILDINGS

To determine the separation between adjacent buildings the values resulting from application of the criteria given in Section 10.4.1 shall be used. The minimum separation between adjacent buildings shall be equal to the square root of the sum of the squares of these values.

10.4.3 ABUTTING BUILDINGS

Two adjacent buildings may abut provided that all the slabs are at the same level and it has been proven that their interaction will not give rise to unfavorable effects.

CHAPTER 11 FOUNDATIONS, RETAINING WALLS AND SLOPES. LIQUEFACTION

11.1 VALIDITY AND SCOPE

This Chapter includes the requirements for the earthquake-resistant design of the building's infrastructure, which is considered to comprise the foundations, whether surface or deep, and their respective tie beams. It also includes the provisions for both inner and outer retaining walls and those for nearby slopes.

11.2 UNIFORMITY OF FOUNDATION TYPE

The foundations of a building shall preferably be of one same type. If the building is constituted by various parts, their foundations shall preferably be independent. When a mixed foundation system and/or extremely unequal rigidities must be used, the behaviour of the whole when subjected to seismic action must be verified by using a model appropriate for the foundation systems used.

11.3 INFRASTRUCTURE DESIGN REQUIREMENTS

The structural components of the foundations and walls shall be designed in keeping with the COVENIN Standard 1753-81, Chapter 15, provisions.

11.3.1 SUPERPOSITION OF EFFECTS

The forces transferred to the soil must be verified for the following load combinations:

$$Q = CM + CV \pm S$$

$$Q = CM \pm S$$

where:

Q = forces for verification of the resistant capacity of the soil;

CM = effects due to permanent loads;

CV = effects due to variable loads;

S = effects due to seismic actions

11.3.2 TIE BEAMS

The foundations shall be joined to each other in two directions, preferably orthogonal, by structural members capable of withstanding, as regards both compression and tension, a force equal to at least 10% of the greatest load transmitted by the columns it joins. In the usual case of reinforced concrete beams, the minimum section shall measure 0.30 x 0.30 mts.

11.3.3 PEDESTALS

The pedestal sections shall be designed for the stresses resulting from analysis. In any event, the minimum reinforcement of the pedestal shall be that of the column it supports.

11.3.4 SURFACE FOUNDATIONS

The stress transferred to the soil by the footings must be verified by means of the superposition of effects given in Section 11.3.1. These must not exceed the lesser of the following two values:

a) 50% of the soil's resistant capacity (0.5 q_{ult}), calculated under static conditions;

b) Two times the admissible pressure under static loads R_s

Values differing from the above shall require a special study of the soil's bearing capacity under dynamic conditions. Surface foundations in sand having a relative density below 40%, which require special measures, shall be excepted from this provision.

Under the most unfavorable conditions, a partial lifting of a foundation, not to exceed 25% of the total support area, shall be accepted.

11.3.5 DEEP FOUNDATIONS

The stresses transferred to the soil by the piles must be verified for the most unfavorable combination according to Section 11.3.1 and shall not exceed 75% of the load-bearing capacity of the soil calculated under static conditions nor generate stresses in the concrete section of the shaft exceeding 50% of the pile's structural capacity. Any other design hypothesis must be justified by a special study of the pile's load-bearing capacity.

The following requirements must also be met:

11.3.5.1 RESISTANCE TO TENSION

a) When one of the combinations of actions given in Section 11.3.1 generates tension in any pile, this must not exceed the pile's structural capacity. For prefabricated piles built by sections, the tension shall not exceed 75% of the capacity of the joint.

b) The maximum tension resulting from the combinations given in Section 11.3.1 must not exceed 50% of the tension capacity of the soil-pile unit. This capacity shall be determined on the basis of special criteria.

11.3.5.2 REINFORCEMENTS

a) All the piles shall be provided with longitudinal and cross section reinforcements along a length at least six times the diameter of the pile, measured from the underside of the pile cap, in no case less than 6.0 meters.

b) The minimum longitudinal reinforcement shall be equal to or more than 0.5% of the area of the pile's cross section.

c) The minimum cross section reinforcement shall consist of 3/8" (0.95 cm.) ties every 30 cms.

11.3.5.3 LATERAL FORCES ON PILES

In the case of piles subjected to lateral forces, this condition shall be taken into account in the design.

11.4 RETAINING WALLS

The parts making up the retaining walls, and retaining structures in general, excepting anchorings, shall be designed to resist the most stringent of the following load combinations:

$$U = 1.2\ CM + 1.0\ CV + 1.0\ ED \pm 1.0\ S$$

$$U = 0.9\ CM + 1.0\ ED \pm 1.0\ S$$

where:

CM = effects due to permanent loads other than thrusts from the soil or other material;

CV = effects due to variable loads other than thrusts from the soil;

ED = effects due to the thrust from the soil or other material under dynamic conditions;

S = effects due to the action of the earthquake other than the dynamic thrust of the soil, but including the inertial forces of the wall calculated with a seismic coefficient equal to 0.75 A_0;

A_0 = maximum horizontal ground acceleration, according to Table 7.1

The value of ED shall be calculated presuming that the wedge of land above the slide surface is stable under the action of the vertical loads and of those brought about by a horizontal acceleration equal to 0.75 A_0.

Verification of security against sliding and the equilibrium of the vertical forces and overturning moments will be based on the same superposition of effects criterion given in Section 11.3.1 adding to both formulae the ED effect defined in this Section.

11.5 SLOPES

The stability of the slopes near the entire building shall be as - sessed in the cases specified below, where H is the height of the slopes and the distances are measured horizontally;

a) Buildings close to the upper edge of the slope:

When one of its foundations or its parts is at a distance of less than H from the upper edge or at a distance of less than 2H from the foot.

b) Buildings close to the foot of the slope:

When any of its parts is at a distance of less than H from its foot or at a distance of less than 2H from the upper edge.

11.6 LIQUEFACTION

Potential liquefaction shall be assessed in the case of structures located in seismic Zones 2, 3 or 4 and where the soil has layers of significant depth made up of sands or not very dense silty sand under the phreatic level in the first 20 meters of the deposit.

CHAPTER 12 INSTRUMENTATION, ALTERATIONS AND REPAIRS

12.1 INSTRUMENTATION

The pertinent authority shall have the right to demand the installation of accelerographs in any building where it is deemed necessary, regardless of the seismic zone. The number of instruments and their placement shall be that needed to appropriately register both seismic excitation and the dynamic response of the structure. To this end, as a minimum, one instrument shall be placed at the base and another at the level immediately below the roof, as close as possible to the centers of mass. In view of this, the plans must provide the space required for these instruments.

In the case of buildings of a repetitive nature, instruments shall be placed in keeping with the above criteria to obtain a representative sample of at least one unit for each type of subsoil foundation profile.

The Fundación Venezolana de Investigaciones Sismológicas (FUNVISIS) shall be in charge of calibrating and maintaining the equipment and of processing the information gathered.

12.2 ALTERATIONS AND REPAIRS

In cases of changes in use or expansion of buildings, the pertinent authority must determine the criteria to be followed pursuant to the guidelines set forth in these Regulations.

As regards buildings affected by the action of seismic movements, the pertinent authority shall issue the guidelines for measures to be taken in each case.

When a building suffers severe damage as a result of an earthquake, a study must be made to evaluate its behavior on the basis of the intensity of the earthquake and in compliance with these Regulations.