SEISMIC CODE EVALUATION

VENEZUELA

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NAME OF DOCUMENT: "EDIFICACIONES SISMORRESISTENTES" NORMA COVENIN 1756-98 (Review 2001)

YEAR: Approved December 9, 1998. Reviewed March 2001

GENERAL REMARKS: The Norm is mandatory by law for the entire country. It replaces "EDIFICACIONES ANTISÍSMICAS" COVENIN-MINDUR 1756-80-82 printed in November 17, 1983 and reprinted in July, 1988 as COVENIN 1756-87

NOTE: Bracketed numbers refer to Code specific chapters or articles: [1.2], [C4.1.1]. The C preceding a number refers to the Code Commentaries. Parentheses numbers refer to Items of this document: (see 2.2)

1. SCOPE

1.1 Explicit concepts. [1.1; 1.2; 3.5]

The Code applies to the analysis and design of new buildings of concrete, steel and steel-concrete composites.

It does not include prefabricated concrete buildings or other type of non building structures such as bridges, tanks or dams.

It is accepted that the earthquake resistant structure can be deformed into the inelastic range without sensible loss of strength.

The final reliability of the building to resist earthquakes will depend not only on the compliance with the Code regulations but on an adequate process of execution, inspection and maintenance of the actual building.

1.2 Performance Objectives. [1.1; C4.1.1]

The purpose of the Code is to ensure that in the event of earthquakes:
- Human lives are protected

- Building damage is reduced
- Essential facilities remain operational.

The design earthquake has a 10% probability of exceedence in 50 years (return period of 475 years)

2. SEISMIC ZONING AND SITE CHARACTERIZATION

2.1 Seismic Zoning (Quality of Data). [4.1]

The country is divided in 8 seismic zones (0 to 7) with higher seismicity along the coast and descending towards the interior (see figure).
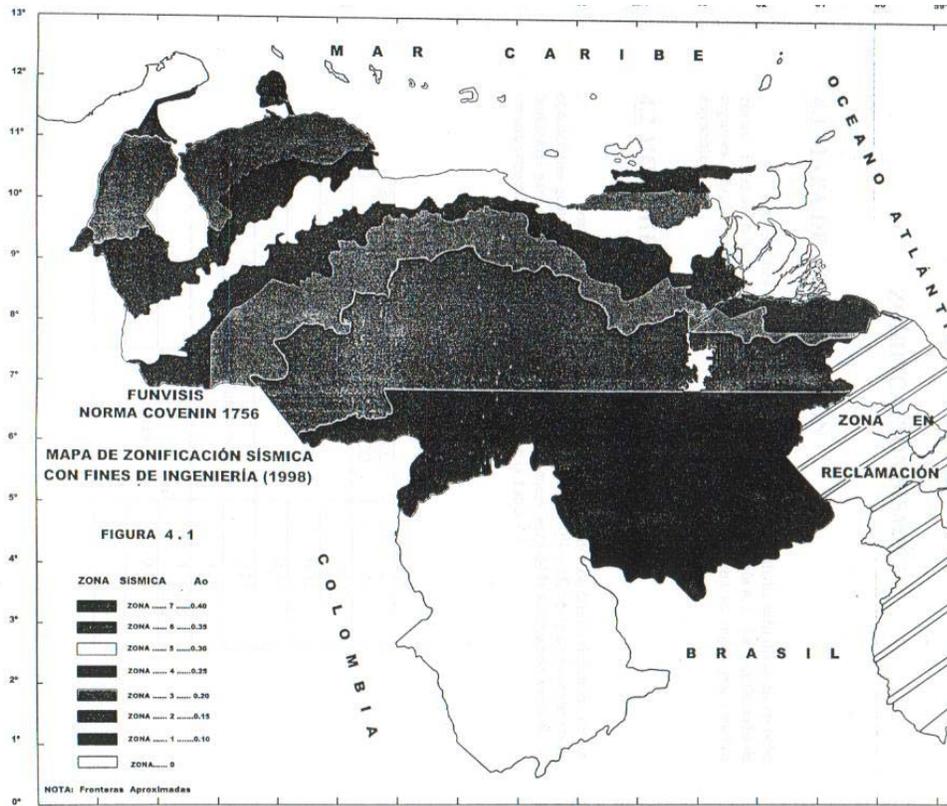
The quality of the data used for the seismic zoning is very good; it is based in more than 100 years of seismic zoning maps (1898-1998) and more than seven seismic risk studies performed during the past 15 years.

2.2 Levels of Seismic Intensity. [4.2]

Only one level of seismic intensity is assigned to each particular seismic zone and it correspond to a 475 years return period (see 1.2). However,

there is an Importance Factor (see 3.1) that increases the seismic forces, but it is not associated to a specific seismic intensity.

2.3   Near Fault considerations.

Not considered

2.4   Site Requirements. [5.2; 11.6]

If, under seismic actions, it is determined that the soils on the site are likely to experience liquefaction, volumetric changes or loss of strength, special studies must be performed to evaluate the dynamic response of the soil profile and to establish its spectral form and acceleration coefficients based on the actual properties of such soils under cyclic load effects.

Site stability must be checked when geological conditions suggest potential instabilities due to ground slope, geological discontinuities, original topography modifications or high pore pressure.

2.5   Site Classification. [5.1]

Six types of soil materials are defined in terms of their shear wave velocity. Additionally the site depth and the seismic zones are used to define the Spectral Form Type and the Correction Factor φ.

Site classification, Spectral Forms and Correction Factors φ

Soil Material	Wave Velocity (m/s)	Height (m)	Seismic Zones 1 to 4		Seismic Zones 5 to 7	
			Spectral Form	Factor φ	Spectral Form	Factor φ
Hard rock	> 500	--	S1	0.85	S1	1.00
Soft rock, very hard or very dense soils	> 400	< 30	S1	0.85	S1	1.00
		30-50	S2	0.80	S2	0.90
		> 50	S3	0.70	S2	0.90
Hard or dense soils	250-400	< 15	S1	0.80	S1	1.00
		15-50	S2	0.80	S2	0.90
		> 50	S3	0.75	S2	0.90
Firm or semi dense soils	170-250	≤ 50	S3	0.70	S2	0.95
		> 50	S3	0.70	S3	0.75
Soft or loose soils	< 170	≤ 15	S3	0.70	S2	0.90
		> 15	S3	0.70	S3	0.80
Soft or loose soils with layers of stiffer soils	--	H_1	S2	0.65	S2	0.70

2.6   Peak Ground Accelerations (Horizontal and Vertical). [4.2]

The 8 seismic zones (see 2.1) are grouped into three levels of seismic hazard. Each seismic zone has a corresponding horizontal acceleration coefficient A_o according to the following table:

Seismic Zones	Seismic Hazard	Horizontal Acceleration Coefficient A_o
7	High	0.40
6		0.35
5		0.30
4	Intermediate	0.25
3		0.20
2	Low	0.15
1		0.10
0		----

The vertical acceleration coefficient is defined as 0.7 times the corresponding horizontal acceleration coefficient

3.   PARAMETERS FOR STRUCTURAL CLASSIFICATION

3.1   Occupancy and Importance. [6.1]

There are four Groups with corresponding Importance Factor α (see 2.2):

Group A: Essential or hazardous facilities (α = 1.30)
Group B1:   Densely occupied public or private buildings (α = 1.15)
Group B2:   Normal occupancy public or private buildings (α = 1.00)
Group C: Buildings not classified as A, B1 or B2, not intended for housing or public use. No enforcement of the norm is necessary as long as adequate constructive details are provided.

3.2   Structural Type. [6.3.1]

Five Structural Types:

Type I: Frame structures.
Type II: Combinations or Types I and III. The frames must be able to resist at least 25% of the seismic forces.

Type III: Braced frames or structural walls capable of resisting 100% of the seismic forces. Also, those Type II structures whose frames are unable to resist 25% of the seismic forces.

Type IIIa: Concrete coupled shear walls and steel eccentric braced frames.

Type IV: Structures with flexible diaphragms, with columns in cantilever or with flat slabs.

3.3   Structural Regularity: Plan and Vertical. [6.5]

Nine types of vertical irregularities: soft diaphragms, weak diaphragms, irregular mass distribution, masses increasing with height, setbacks, excessive slenderness, vertical structural discontinuities, lack of connectivity of vertical structural elements to diaphragms and short column effects.

Four types of plan irregularities: large eccentricity, high torsional risk, non orthogonal systems and flexible diaphragms.

3.4   Structural Redundancy. [6.2.2]

Some structural types are penalized with a Design Level 3 (ND3) requirement (see 3.5) for their limited redundancy (i.e. buildings with column discontinuities and buildings with less than three axis of strength in any direction.

3.5   Ductility of elements and components. [6.2.2]

No specific classification of elements according to their ductility is included in the Code. However, three different Design Levels are defined for the detailing of structural elements.

Design Level 1 (ND1). Structural systems whose structural elements have been dimensioned and detailed without compliance to any specific requirements for seismic zones.

Design Level 2 (ND2). Structural systems whose structural elements have been dimensioned and detailed complying only with some specific requirements for seismic zones that will provide for some global ductility to the structural system and prevent fragile failures in critical zones.

Design Level 3 (ND3). Structural systems whose structural elements have been dimensioned and detailed with strict enforcement of all specific requirements for seismic zones.

The Design Levels are selected according to the Importance Factor Group (see 3.1) and the Seismic Zone (see 2.1) as indicated in the following Table:

**Possible Design Levels (Niveles de Diseño, ND)
according to Importance Factor and Seismic Zone**

Importance Factor Group	Seismic Zone		
	1, 2	**3, 4**	**5, 6, 7**
A, B1	ND2 ND3	ND3	ND3
B2	ND1 ND2 ND3	ND2 ND3	ND3 ND2

According to structural material, Structural Type (see 3.2) and Design Level (see 3.5) Reduction Factors R are defined in the following Table and used for the calculations of the Design Spectra (see 4.2)

Reduction Factors R

Design Level	Structural Concrete				
	Structural Type				
ND	**I**	**II**	**III**	**IIIa**	**IV**
ND3	6.0	5.0	4.5	5.0	2.0
ND2	4.0	3.5	3.0	3.5	1.5
ND1	2.0	1.75	1.5	2.0	1.25
	Structural Steel				
Design Level	Structural Type				
ND	**I**	**II**	**III**	**IIIa**	**IV**
ND3	6.0	5.0	4.0	6.0	2.0
ND2	4.5	4.0	---	---	1.5
ND1	2.5	2.25	2.0	---	1.25
	Steel-Concrete Composite				
Design Level	Structural Type				
ND	**I**	**II**	**III**	**IIIa**	**IV**
ND3	6.0	5.0	4.0	6.0	2.0
ND2	4.0	4.0	---	---	1.5
ND1	2.25	2.25	2.25	---	1.0

4. SEISMIC ACTIONS

4.1 Elastic Response Spectra (Horizontal and Vertical). [7.2]

There are four Horizontal Elastic Response Spectra (S1, S2, S3 and S4, see Table in 2.5), with spectral values A_d as defined in the following Figure. The Vertical Spectra is 0.7 times the Horizontal (see 2.6).
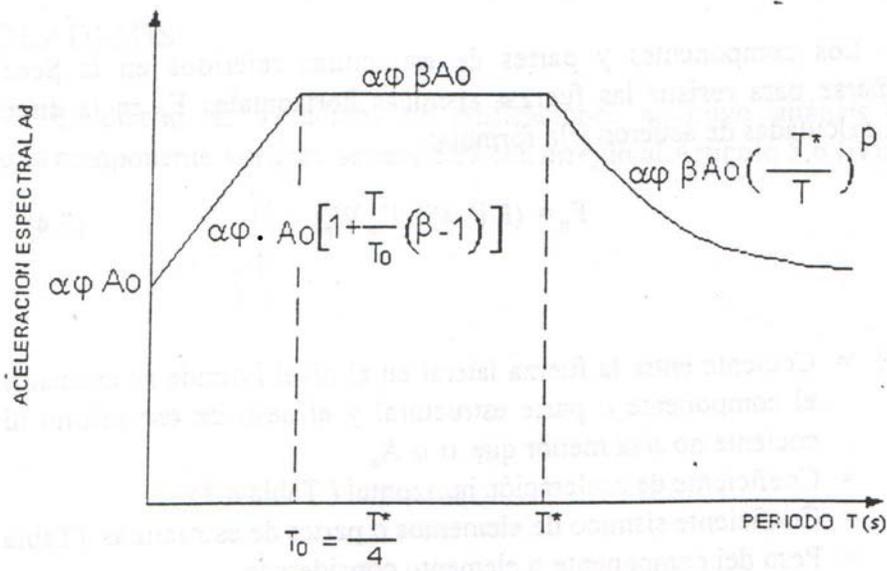
FIGURA 7.1   ESPECTRO DE RESPUESTA ELASTICO (R=1)

Where:

A_d = Acceleration Elastic Response Spectra (as a fraction of g).
A_o = Horizontal Acceleration Coefficient (see 2.6)
α   = Importance Factor (see 3.1)
φ = Horizontal acceleration Correction Factor (see 2.5)
β = Average Magnification Factor, depends of the Spectral Form (see 2.5)
      according to next Table.
T = Structural Period
T^* = Value of Period that depends of the Spectral Form according to next
   Table.
T_o = 0.25 T^*
p = Descending branch factor that depends of the Spectral Form
      according to next Table.

Values of T^*, β and p according to Spectral Forms

Spectral Forms	T^* (secs)	β	p
S1	0.4	2.4	1.0
S2	0.7	2.6	1.0
S3	1.0	2.8	1.0
S4	1.3	3.0	0.8

4.2 Design Spectra. [7.1; 7.2]

The Design Spectra [7.2], also called A_d, is obtained by dividing the Elastic Response Spectra (see 4.1) by factors that depend on the structural Period. For Periods $T > T^+$ (where $T^+ = 0.1\,(R-1)$ for $R<5$ and 0.4 for $R \geq 5$) it is divided by the Reduction Factor R. For $T<T^+$ it is divided by a factor equal to $[1+(T/T^+)^c\,(R-1)]$, with $c = (R/\beta)^{1/4}$. An example is presented in the following figure:
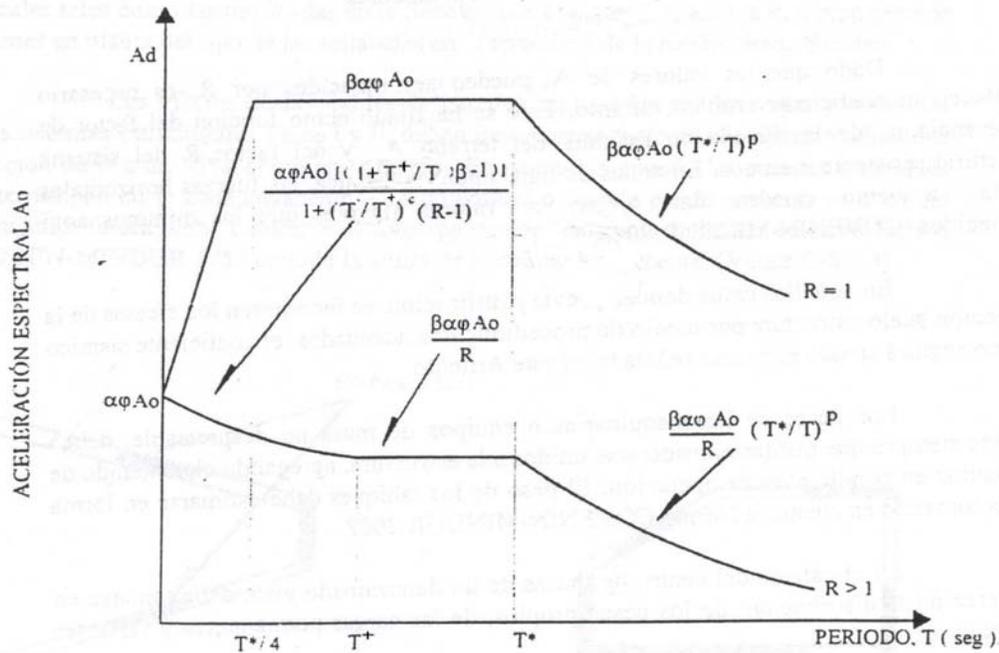
In any case [7.1] the Seismic Coefficient defined as V_o / W can never be less than $\alpha\, A_o / R$, where V_o is the base shear and W is the total building weight for seismic purposes (100% of DL plus a fraction of LL).

4.3 Representation of acceleration time histories. [9.8.4]

Acceleration time histories, either registered or simulated using any standard procedure, can be used for non linear dynamic analysis (see 5.5). Their average spectra should approximate, on the conservative side, the design spectra with R=1, within the range of periods of the structure.

4.4 Design Ground Displacement.

Not considered

5. DESIGN FORCES, METHODS OF ANALYSIS AND DRIFT LIMITATIONS

5.1 Load Combinations including Orthogonal Seismic Load Effects. [8.6]

The seismic load EQ represents an extreme event and has no additional scaling factors. Except for foundations [11.4.4], no indications are given as how the other loads (dead, live) are combined.

For foundations
$$Q = 1.1\ DL + LL \pm EQ$$
$$Q = 0.9\ DL \pm EQ$$

The structure must be designed for the simultaneous action of both horizontal components, according to one of the following criteria:
a) Square root of the sum of the squares of each horizontal component.
b) Total value in one direction plus 30% of the value in the other direction.
c) Complete Quadratic Combination 3 (CQC3).

5.2 Simplified Analysis and Design Procedures.

Not considered

5.3 Static Method Procedures. [9.2; 9.3]

This method can be applied to regular buildings (see 3.3) no more than 10 stories or 30m high. For each horizontal direction, the base shear is given by

$$V_o = \mu\ A_d\ W \geq \alpha\ A_o\ W\ /\ R \text{ (see 4.1 and 4.2)}$$

Where:

W = Total weight of the building above base level (see 4.2)
μ = The larger of the following two values:

$$\mu = 1.4\ [(N+9)/(2N+12)]\ ,\ \mu = [0.80 - 0.05\ (T/T^*-1)]$$

The structural Period T can be determined by Rayleigh's Method.

Vertical distribution of the total base shear V_o is as follows:

A force $F_t = [0.06\ (T/T^*) - 0.02]\ V_o$ (within limits: $0.04\ V_o \leq F_t \leq 0.10\ V_o$) is applied at the top (level N). The remaining force ($V_o - F_t$) is distributed as:

$$F_i = (V_o - F_t)\ [\ W_i\ h_i\ /\ \Sigma_k\ W_k\ h_k\ ]$$

5.4   Mode Superposition Methods. [9.4; 9.6; 9.7]

Required whenever Static Method Procedures (see 5.3) are not allowed. Three mode superposition procedures are considered:

- Two Dimensional (1 dof per level) [9.4]
- Three Dimensional with Rigid Diaphragms (3 dof per level) [9.6]
- Three Dimensional with Flexible Diaphragms (more than 3 dof per level) [9.7]

Modes can be combined according to SRSS or CQC

5.5   Non-Linear Methods. [9.8; 9.9]

Two Non-Linear methods of analysis are allowed as alternative methods:

Spectrum Capacity Methods with a Pushover analysis [9.9].
Non Linear Time History dynamic analysis [9.8].

5.6   Torsional considerations. [9.5; 9.6.2.2; 9.7.4]

An Equivalent Static Torsion Method [9.5] is defined for the Static Method (see 5.3) with torsional moments at each level equal the horizontal design shear V_i at level i times its eccentricity (including accidental eccentricity). Accidental eccentricities are also considered in Three Dimensional Mode Superposition Methods [9.6.2.2; 9.7.4].

5.7   Drift Limitations. [10.2]

Inelastic drifts are estimated as $\Delta_i = 0.8 \, R \, \Delta_{ei}$

Where: R = Reduction Factor (see 3.5)
              Δ_{ei} = Elastic drift corresponding to the design forces
                     including P-Δ effects and torsional response.

Relative drifts are limited as follows:

Maximum Relative Drifts (Δ_i / Δh_i)

Types and arrangements of non structural elements	Importance Factor Groups (see 3.1)		
	A	B1	B2
Likely to experience damage under structural drifts	0.012	0.015	0.018
Unlikely to experience damage under structural drifts	0.016	0.020	0.024

5.8 Soil-Structure Interaction Considerations. [8.8]

A brief paragraph states that for regular buildings, soil-structure interaction effects can be included in the calculation of the seismic forces and the corresponding structure displacements.

6. SAFETY VERIFICATIONS

6.1 Building Separation. [10.3]

The Code specifies minimum separations from site boundaries and from adjacent buildings. However, adjacent buildings next to each other are allowed if all stories are at the same level and unfavorable effects are unforeseen.

6.2 Requirements for Horizontal Diaphragms. [8.3.3]

The code assumes that all diaphragms are stiff enough to behave as rigid in their own plane and strong enough to distribute the seismic forces among the lateral resistant systems according to their stiffness. If this is not the case the diaphragm flexibility must be considered in the analysis (see 5.4).

Prefabricated concrete systems are accepted as rigid diaphragms if their effectiveness is verified in the calculations.

6.3 Requirements for Foundations. [11]

A complete chapter defines requirements for different foundation types (isolated, in groups, with piles). Foundations must be dimensioned and designed to resist all the forces transmitted by the structure and to produce pressures into the soil within acceptable values. Settlements must be kept under control to prevent structural damage.

6.4 P-Δ Considerations. [8.5]

P-Δ effects should be considered when, at any level, the stability coefficient θ_i exceeds 0.08

Where $\qquad \theta_i = \delta_{ei} \, \Sigma \, W_i \, / \, V_i \, \Delta \, h_i \leq \theta_{max} = \text{Min} \, [\, 0.625 \, / \, R \, , \, 0.25]$

$\qquad\qquad \delta_{ei} \qquad$ = Elastic drift at the mass center at level i
$\qquad\qquad \Sigma \, W_i \quad$ = Total weight of building above level i
$\qquad\qquad V_i \qquad$ = Design shear at level i
$\qquad\qquad \Delta \, h_i \qquad$ = Story height at level i

If θ_i exceeds θ_{max} the structure must be redesigned.

6.5   Non-Structural Components. [7.3]

Two criteria are defined for non structural components:
a) They should be able to resist the seismic forces resulting from the corresponding method of analysis (see 5) or
b) They must be designed for specific seismic forces calculated with due consideration to their dynamic properties.

6.6   Provisions for Base Isolation. [8.7]

A brief paragraph states that control devices such as base isolation or passive energy dissipation systems can be used if justified by analytical and experimental results.

7. SMALL RESIDENTIAL BUILDINGS.

Housing in general is included in Group B2 (see 3.1) but no specific provisions for small residential buildings are included in the Code.

8. PROVISIONS FOR EXISTING BUILDINGS. [7]

A specific chapter contains requirements and regulations for the evaluation, retrofit and structural reinforcement of existing buildings.

RECOMMENDATIONS FOR CODE IMPROVEMENT

The Seismic Code of Venezuela is a state of the art Code. No specific recommendations are deemed necessary for Code improvement.