SEISMIC CODE EVALUATION

DOMINICAN REPUBLIC

Evaluation conducted by Jorge Gutiérrez

NAME OF DOCUMENT: "Recomendaciones Provisionales para el Análisis Sísmico de Estructuras" ("Provisional Recommendations for the Seismic Analysis of Structures"). Norm M-001

YEAR: Approved in December of 1979. Reprinted in October 2001.

GENERAL REMARKS: Drafted by SODOSISMICA (Dominican Society of Seismology and Seismic Engineering) and Approved by the "Departamento de Normas, Reglamentos y Sistemas" (DNRS) ("Department of Norms, Regulations and Systems") of the "Secretaría de Estado de Obras Públicas y Comunicaciones" (SEOPC) ("Secretary of Public Works and Communications").

At present time work for a new Seismic Code together with a General Construction Code ("Código General de Construcciones") is in a very advanced stage. The draft has been finished and SEOPC has requested a final review from SOSOSISMICA. It is expected that it will be ready for publication sometime this year (from Hector O'Reilly, President of SODOSISMICA, personal e-mail communication).

SPECIFIC ITEMS:

NOTE: Bracketed numbers refer to Code specific chapters or articles: [ ]
Parentheses numbers refer to Items of this document: (see 2.2)

1. SCOPE

1.1 Explicit concepts. [1.2]

The Code is intended for buildings and similar structures only.

As its name indicates, the Code refers specifically to the seismic analysis of buildings; for the design of structural elements and components the Code refers to USA or European Norms (ACI, AISC, CEB) or other national Norms from DNRS/SEOPC.

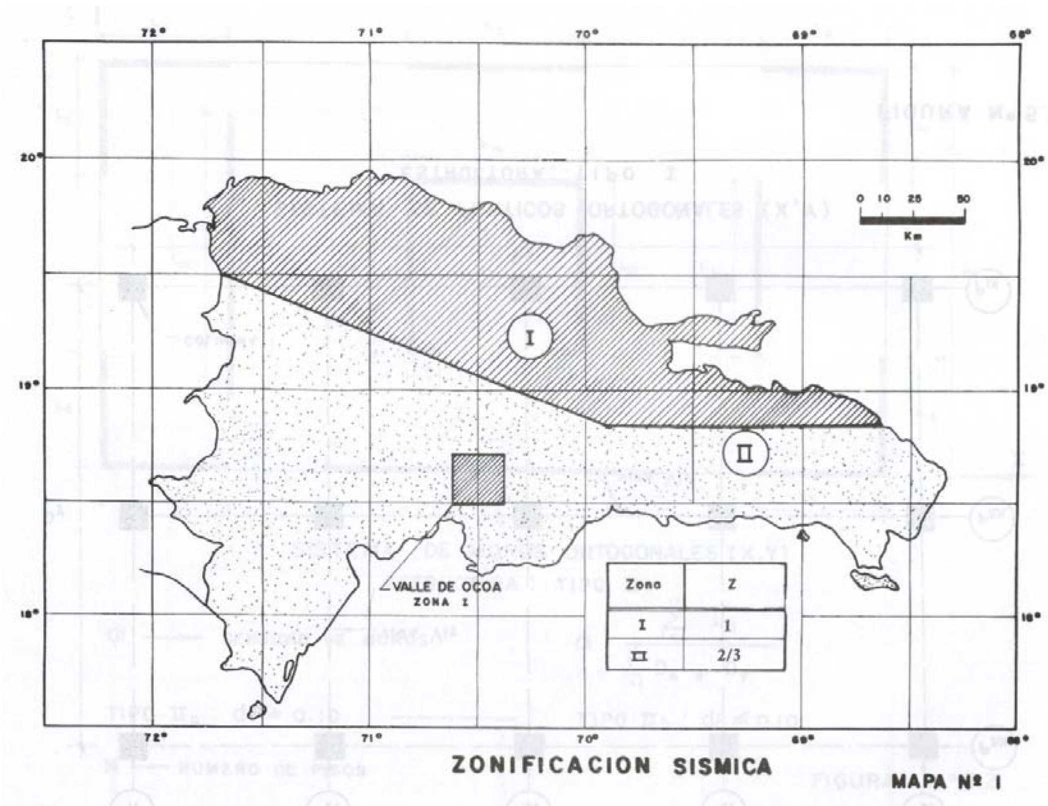
1.2 Performance Objectives.

Not explicitly considered.

2. SEISMIC ZONING AND SITE CHARACTERIZATION

2.1 Seismic Zoning (Quality of Data). [3]

The country is divided in two seismic zones, Zone I = High Seismicity and Zone II = Medium Seismicity according to the following figure:



Being a 1979 Code, it would be expected that the data considered is already outdated.

2.2 Levels of Seismic Intensity. [6.4.4]

A Seismic Zone Coefficient Z, affecting the Seismic Coefficient C_b (see 4.2) is assigned to each Zone:

Seismic Zone	Z
I	1
II	2/3

2.3 Near Fault considerations.

Not considered.

2.4 Site Requirements.

Not mentioned.

2.5 Site Classification. [6.4.6]

Four types of sites related to the soil conditions are defined, whose corresponding S coefficients that affect the Seismic Coefficient C_b (see 4.2) are given by the following Table.

Soil Type	Properties	S
1	Rock or rock derived firm soils	1.00
2	Soils from sedimentary marine deposits	1.20
3	Recent alluvial soil deposits	1.50
4	Undefined soils	1.35

2.6 Peak Ground Accelerations (Horizontal and Vertical).

No peak ground accelerations are given in the Code. However, the plateau for the Elastic Response Spectra (see 4.1) is given as 0.635 for all types of soils on Seismic Zone I. Therefore, an effective horizontal peak ground acceleration, estimated as 40% of the plateau, could be estimated as 0.25g. For Zone II it would be 2/3 of this value (see 2.2) or 0.17g.

3. PARAMETERS FOR STRUCTURAL CLASSIFICATION

3.1 Occupancy and Importance. [4; 6.4.5]

Four groups A, B, C and D are defined and a Use Factor U defined according to the following Table:

Group	Description	Factor U
A	Essential, hazardous or high occupancy buildings	1.30
B	Ordinary buildings	1.00
C	Buildings not included in Groups A or B whose collapse will not cause loss of life or affect other buildings.	0.75
D	Buildings that can not be classified as Group A, B or C. In these cases the DNRS/SEOPC criteria is required.	-----

3.2 Structural Type. [5]

There are five structural types defined as follows:

Type I: Structural frames.
Type II. Structural walls. It is divided into:
Type II-A. Concrete structural walls
Type II-B. Masonry structural walls.
Type III. Dual systems, where the total seismic load is resisted by frames and structural walls according to their stiffness. Additionally, the structural walls must be able to resist 100% of the seismic forces and the frames, acting alone, must be designed to resist 25% of those loads.
Type IV. Cantilever structures either with a single column (includes elevated tanks) or a single line of columns.
Type V. Any building structure not classified in any of the previous types. In these cases the DNRS/SEOPC criteria is required.

A Reduction Factor R_d is defined for each Structural Type as follows:

Structural Type		Reduction Factor R_d
I		7.0
II-A	$d_i < 0.10$	5.0
	$d_i \geq 0.10$	4.5
II-B	$d_i < 0.10$	4.0
	$d_i \geq 0.10$	3.5
III		6.5
IV		1.5

Where d_i is the wall density (the ratio of total wall length in both directions to area). This is a dimensional quantity, supposedly in the metric system (1/m).

3.3 Structural Regularity: Plan and Vertical. [7]

Structural regularity is not specifically evaluated but it is considered in Chapter 7, Structural Configuration, where five recommendations for regularity are included:

- Procure symmetry of mass and stiffness.
- Proper distribution of resistant elements and components; trying to locate them in the periphery of the building.
- Avoid diaphragm discontinuities.
- Proper mass distribution along height.
- Avoid reentrant corners in plan.
- Avoid large stiffness changes along height. [6.2.3]

If these recommendations are not met, the Mode Superposition Method (see 5.4) must be applied [6.2.3].

3.4 Structural Redundancy.

Not specifically considered.

3.5 Ductility of elements and components.

Not specifically considered.

4. SEISMIC ACTIONS

4.1 Elastic Response Spectra (Horizontal and Vertical). [6.3.2]

The Elastic Horizontal Spectrum is given by:

$C = 0.635$ for $T \leq 0.5$ s

$C = 0.4 / T^{2/3}$ for $T > 0.5$ s

No vertical spectrum is considered.

4.2 Design Spectra. [6.4]

For design purposes base shear coefficient C_b is defined as:

$$C_b = Z\ U\ S\ C / R_d \geq 0.03$$

Where:

- Z = Seismic Zone Coefficient (see 2.2)
- U = Use Factor (see 3.1)
- S = Soil Coefficient for the site (see 2.5)
- C = Elastic Spectrum (see 4.1)
- R_d = Reduction Factor according to Structural Type (see 3.2)

The product S times C must satisfy $S\ C \leq 0.635$

4.3 Representation of acceleration time histories. [6.3.2]

Specific acceleration time histories, either registered or simulated using any standard procedure, can be used for non linear dynamic analysis as long as their accelerations, frequency content and duration are in agreement with the country's seismicity. They must be approved for each case by DNRS/SEOPC.

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.

Being a document related with seismic analysis, no indications as how the seismic load effects are combined with gravitational or other types of loads is given. Presumably, these requirements are contained in complementary Norms issued by DNRS/SEOPC.

5.2 Simplified Analysis and Design Procedures. [6.2.1; 6.5.1]

This method can be applied for structures satisfying the following four conditions:

- Type II Structures (see 3.2) four stories or less.
- In each direction, the rigid diaphragm (slab) must be supported by walls with a length over 50% of the total length of the diaphragm.
- Slenderness (height to minimum dimension) not to exceed 1.5.
- For Type II-B Structures the story height does not exceed 20 times the wall thickness.

The Total Base Shear V will be:

$$V = C_b W$$

Where:

W = Total building weight for seismic purposes; $W = \Sigma_i W_i$

$$W_i = W_{mi} + (\varphi_i \varphi_{ri}) W_{vi}$$

Where

W_{mi} = Dead Load at level i
W_{vi} = Live Load at level i
φ_i = Reduction Live Load coefficient due to use.
φ_{ri} = Reduction Live Load coefficient due to dimensions of loaded area.

$(\varphi_i \varphi_{ri}) = 0.25$ unless a more detailed refined analysis is deemed necessary.

For calculation of C_d the structural period T can be estimated as:

$$T = K_o H / (D_s)^{1/2}$$

Where:

H = Building height (in m).
D_s = Building dimension in the direction of analysis (in m).
K_o = Coefficient related to Structural Type as follows:

Structural Type		K_o
I		0.13
II	$d_i < 0.10$	0.09
	$d_i \geq 0.10$	0.07
III		0.09

The Total Base Shear V will be distributed along height as level forces F_i

$$F_i = V [W_i h_i / \Sigma_k W_k h_k]$$

No torsional effects or overturning moments are considered in this method. Horizontal displacement are not calculated.

5.3 Static Method Procedures. [6.2.2; 6.5.1.6]

This method can be applied to buildings with less of 15 stories or 45 m in height that do not meet the requirements for the Simplified Analysis (see 5.2). The estimation of Total Base Shear V and structural Period T follows the Simplified Analysis procedure.

The Total Base Shear V will be distributed along height as level forces F_i :

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

Where F_t is a force applied at the top of the building and estimated as

$F_t = 0.07 \, T \, V \leq 0.25 \, V$ (F_t will be zero for $T \leq 0.7$ s)

Torsional effects must be considered (see 5.6). Overturning moments at level i can be reduced as follows:

$$M_{vi} = 0.8 \, \Sigma_{s=i+1} F_s (h_s - h_i)$$

5.4 Mode Superposition Methods. [6.2.3; 6.5.3]

This method must be applied to buildings that do not meet the requirements for the previous methods, to irregular buildings (see 3.3) or to buildings considered as unusual according to DNRS/SEOPC.

Torsional effects must be considered. Overturning moment reductions are the same as for the Static Method Procedure (see 5.3).

The Total Base Shear can not be less than 65% of the value calculated with the Static Method Procedure (see 5.3).

All modes with $T \geq 0.4$ s must be considered (no less than 3 or the number of stories for less than 3 story buildings). Modes will be combined with SRSS rule.

5.5 Non-Linear Methods. [6.5.3.4]

This is an optional method. At least 4 independent time history accelerations (see 4.3) must be used. Material characterization and structural models must have DNRS/SEOPC approval.

5.6 Torsional considerations. [6.1.5; 6.5.2.10; 6.5.2.11; 6.5.3.1]

Required for Static and Mode Superposition Methods. At each level a torsional moment M_{ti} must be applied, calculated as:

$$M_{ti} = V_i \, e_{in}$$

Where

V_i = Direct shear force at level i.
e_{in} = Normative Eccentricity, given as $e_{in} = 1.5\, e_i + e_{in}$

Where

e_i = Eccentricity calculated at level i.
e_{in} = Accidental eccentricity, equal to 5% of plan dimension in each direction.

At each level, for each resistant element, shear will be incremented (never diminished) by Torsional Moment effects. Alternatively, 3D models (3 dof per level) can be used.

5.7 Drift Limitations. [6.5.2.18; 7.7]

Elastic displacements must be increased by the Displacement Factor C_d given in the following Table

Structural Type		Factor C_d
I		5.6
II-A	$d_i < 0.10$	4.4
	$d_i \geq 0.10$	4.0
II-B	$d_i < 0.10$	3.4
	$d_i \geq 0.10$	3.0
III		5.4
IV		1.5

Relative Story Drifts (Δ_i / Δh_i) should not exceed 0.008. If non-structural components are not affected by the displacements, this limit can be increased to 0.016.

5.8 Soil-Structure Interaction Considerations.

Not considered.

6. SAFETY VERIFICATIONS

6.1 Building Separation. [7.7]

The separation among adjacent buildings should not be less than twice the maximum displacement calculated without the Displacement Factor C_d nor 2.5 cm. When displacements are not calculated (see 5.2) the separation should be no less than 5 cm or 0.006 times the smaller building height. Minimum separation from site boundaries should be half these values.

6.2 Requirements for Horizontal Diaphragms. [6.5.2.7; 6.5.2.8; 6.5.2.9; 7.8.2]

Solid or hollow concrete slabs can be considered as rigid diaphragms. Prefabricated concrete diaphragms or those with concrete cast on top of a steel deck can be considered as rigid if their support conditions are able to transmit the required forces.

If diaphragms are not rigid, each earthquake resistant system should resist their corresponding tributary seismic loads.

6.3 Requirements for Foundations. [7.9]

A few general indications are given:

- Isolated footings for buildings with 5 of more stories or taller than 17 m should be interconnected in their upper part in both horizontal directions.
- Buildings separated by construction joints can share a common foundation.
- Different foundation systems for the same building are not allowed unless calculations demonstrate that there are no problems regarding forces or deformations.
- Overturning effects must be considered.

6.4 P-Δ Considerations.

Not considered.

6.5 Non-Structural Components.

Not considered.

6.6 Provisions for Base Isolation.

Not considered.

7. SMALL RESIDENTIAL BUILDINGS

No specific recommendations are given for small residential buildings but the provisions for Simplified Analysis (see 5.2) are applicable to many of these buildings.

8. PROVISIONS FOR EXISTING BUILDINGS

Not considered.

RECOMMENDATIONS FOR CODE IMPROVEMENT

The Code is indeed a very outdated document. The need for a modern Code is evident. It is expected that the work currently in progress will fulfill this acute need within a short period of time.