SEISMIC CODE EVALUATION

CUBA

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NAME OF DOCUMENT: NC 46 – 1999. Construcciones sismorresistentes. Requisitos básicos para el diseño y construcción. (Earthquake resistant constructions. Basic requirements for design and construction.)

YEAR: 1999

GENERAL REMARKS: Official approval by "Oficina Nacional de Normalización (NC).

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]

This Standard establishes the basic requirements for the design and construction of buildings and similar behavior structures, as well as roads, bridges and dams located in areas of seismic risk, with the purpose of to diminish or to mitigate its vulnerability degree, except such special structures as nuclear, electric, mechanical and similar plants; for such cases specify considerations are required for them that are in agreement with that settled down in this standard.

1.2 Performance Objectives.[5.1]

The basic philosophy of the design of structures to the seismic events is the following one:

a) to Protect the life of people.
b) to Assure the continuity of the vital services.
c) to Minimize the damages to the constructions.

2. SEISMIC ZONING AND SITE CHARACTERIZATION [4]

2.1 Seismic Zoning (Quality of Data). [4.1, 4.1.1 and Table 4.1 and Figures 4.1 and 4.2]

The national territory for purpose of application of this standard has been divided in four areas which are indicated in the Maps of Seismic Zoning. These areas are described in 4.1.1 and they are assigned values of acceleration as fractions of gravity.

The presented maps are the result of a qualitative evaluation of the seismic risk with probability criterion with the available information so far.

2.2 Levels of Seismic Intensity. [4.1.1 and 4.2]

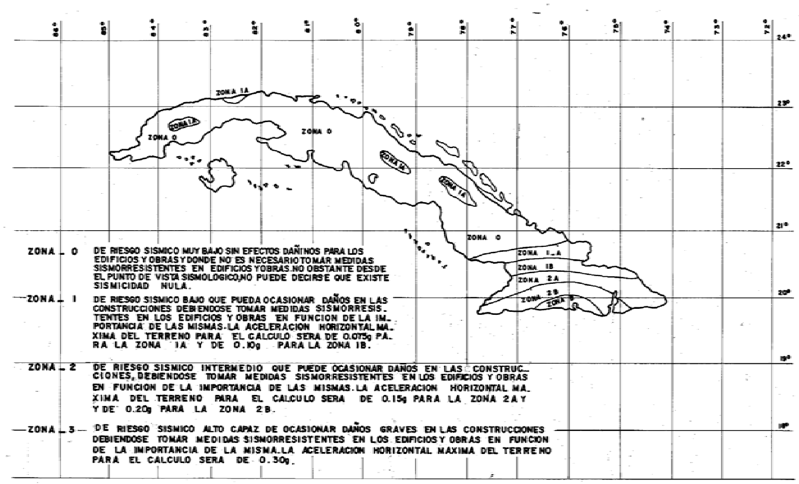

FIG. 4.1 MAPA DE ZONIFICACION SISMICA CON FINES DE INGENIERIA.

They are defined four levels of seismic intensity. From null until very severe.

The design movements are defined in function of the maximum acceleration of the horizontal component obtained for rock, they were obtained for a probability from 15% to 10 % exceed and 50 years of life useful corresponding return period of 475 years.

2.3 Near Fault considerations.

Not considered.

2.4 Site Requirements. [6.4]

2.5 Site classification. [6.4]

Four soil types:

Type S1: Rock or very stiff soil (C_s > 800 m/s).

Type S2: Stiff to medium stiff or dense to medium soil more than 60 m deep.

Type S3: Soft to medium stiff clay or non – cohesive low to medium dense soil 10 m deep (C_s < 240 m/s).

Type S4: Soft clay or C_s < 150 m/s more than 12 m deep.

2.6 Peak Ground Accelerations (Horizontal and Vertical). [Tables 6.2 and 6.3 and Figure 6.1]

ZONA	1A	1B	2A	2B	3
A	0,075	0,10	0,15	0,20	0,3

3. PARAMETERS FOR STRUCTURAL CLASSIFICATION

3.1 Occupancy and Importance. [Table 6.4]

Five group with corresponding importance factors I.

Group 1: Buildings and structures of exceptional importance. (I ≥ 1,25)
Group 2: Buildings and structures of special importance. (I = 1,25)
Group 3: Buildings and structures of medium importance. (I = 1,00)
Group 4: Buildings and structures of secondary importance. (I = 0,60)
Group 5: Buildings and structures of not important. (I = 0,00)

3.2 Structural Type. [Table 6.5]

Seven Structural Types.

1. Frame Type (Concrete, steel).
2. Dual Type (Frame + Shear Wall combination. Frame with 25 % of shear demand. (Concrete)
3. Shear Wall or Diagonal Reinforcing Frames with 100 % of shear demand. (Concrete, steel and timber).
4. Grand Panel Structures.
5. Reinforcing Masonry.
6. Confined Reinforcing Masonry.
7. Other structures no considered previously.

3.3 Structural Regularity: Plan and Vertical. [6.2, 6.2.1 and 6.2.2]

Seven Plan Regularity Requirements: Orthogonal o symmetrical structural systems, eccentricity, mass and stiffness center, width / lengthy relationship no greater than 3, no diaphragm openings, no reentrant corners, two o more axis of strength in each directions.

Nine Vertical Regularity Requirements: Continuity, setback, stiffness, floor horizontal diaphragms, lateral strength, weight, height / minimum base dimension relationship no greater than 4.

Moderate and severe Plan and Vertical Irregularities.

3.4 Structural Redundancy.

Not considered.

3.5 Ductility of elements and components. [6.1 and 6.1.1 and Table 6.1]

The systems defined in this standard can be projected so that they possess different levels of ductility (three levels). Those ductility levels are function of Importance of structure and seismic zone.

4. SEISMIC ACTIONS [6.4, Table 6.2 and Figure 6.1]

4.1 Elastic Response Spectra (Horizontal and Vertical).

This has three branches defined by the following expressions:

a) $C = 1 + (Fa - 1)\dfrac{T}{T_1}$ for $0 \le T \le T_1$, where *T* is the structural period.

b) $C = Fa$ for $T_1 \le T \le T_2$, *Fa* is the amplification coefficient that depends on the profile of the soil.

c) $C = Fa\left(\dfrac{T_2}{T}\right)^p$ for $T > T_2$, p is the exponent that defines the descending branch of the spectrum in function of the profile of the soil.

4.2 Design Spectra [Figure 6.1]

4.3 Representation of acceleration time histories.

Not considered.

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. [6.3.1]

In the Standard of Construction Designs.Reinforced Concrete Works. General Principles and Calculation Methods (Obras de Hormigón Armado.Principios Generales y métodos de cálculo.) are defined the load combinations. Here in [6.3.1] only they are specified the percent to consider of temporary live loads.

5.2 Simplified Analysis and Design Procedures.

Not considered.

5.3 Static Method Procedures. [6.4, 6.4.2 and 6.4.3]

Equivalent Static Analysis. Restricted only to Plan and Vertical Regular Structures with height no more than 80 m and fundamental period less than 2 s. For Irregular Structures no more than 5 levels and 20 m of height.

$$V = \frac{A\ I\ C}{R_d} W \qquad \text{in kN.}$$

Where **A**, it is the maximum horizontal acceleration of ground expressed as a fraction of the gravity corresponding to a seismic area.

I, is the coefficient that take into account the seismic risk as function of the importance of the structure.

Rd, is the reduction coefficient for ductility which depend on the used structural system and the level of ductility according to the zone and the importance of structure.

W, is the weight of the construction in kN according to the requirements of the standard.

C, is the spectral seismic coefficient which depends on soil profile and the period of the structure.

Force distribution in proportion to each floor weight, W_i, and height, h_i

$$F_x = \frac{(V - F_t) W_x h_x}{\sum_{i=1}^{n} W_i h_i}$$

Natural period is calculated with empirical formulae according to the used structural system [6.4.2]. Any classic dynamic method is allowed.

5.4 Mode Superposition Methods. [6.5, 6.5.1 to 6.5.6]

Modal Analysis Method: In the case of plane models the analysis should include for each one of the perpendicular axes all the vibration modes with period of vibration greater than 0,4 s, and as minimum the three with higher period.

For space models the analysis will include, for each direction of application of the seismic action, all the modes of vibration of superior period to 0,4 s, and as minimum four modes, two of them fundamentally translational and other two of them with rotational character predominantly.

5.5 Non-Linear Methods. [3]

It is pointed out when it should be used but any method is not specified.

5.6 Torsional considerations. [6.8]

It will take into account the effects of torsion when the structure possesses vertical elements able to transmit this effect to the foundation whenever the horizontal diaphragm that unites them possesses the rigidity and enough resistance to assure the distribution of the horizontal forces.

A calculation procedure is presented that takes into account this aspect.

5.7 Drift Limitations [7, 7.1 to 7.4]

According to Occupancy and Structural Element Type. Limited Story Drift, as related to story height and ductility coefficient, are defined by some specific formulae.

5.8 Soil-Structure Interaction Considerations.

Not considered.

6. SAFETY VERIFICATIONS

6.1 Building Separation. [7.8, 7.8.1 to 7.8.3]

The minimum joint separation in each level of the adjacent constructions won't be smaller than the sum of the absolute values of its corresponding maxima lateral displacements either smaller than:

$$J = 5 + 0{,}5\left(H - 10\right) \geq 5\ cm$$

where:

J is the width of the joint in, cm.

H is the height of the building in, meters.

6.2 Requirements for Horizontal Diaphragms. [6.7]

The deformation in the plane of the diaphragm won't exceed the permissible deformation from the jointed elements to him. The permissible deformation will be that allows that the jointed elements to the diaphragm maintain its structural integrity under their individual loads and continue supporting the design loads.

6.3 Requirements for Foundations. [8, 8.1 to 8.5 and Table 8.1]

This chapter includes the requirements for the earthquake resistant design of the substructure of buildings and civil engineering structures, which are considered formed by the foundations, be superficial or deep, and for its respective bracing. Also, it includes the specifications for the contention walls, and those corresponding to escarpment near to buildings.

6.4 P-Δ Considerations. [7.5 and 7.6]

It will be necessary to consider the effects of second order P – Δ as for moments and shear force when in any building level the value of the calculated index of stability exceeds the value of 0,1.

When the settled down limit is exceeded in some level of the building the shear force that acts in each one of this levels it will be increased being multiplied by an amplification factor.

6.5 Non-Structural Components [6.9 and Table 6.7]

They will be designed to resist the total seismic force according to:

$$F_p = A\, I\, C_p W_p \quad \text{in kN.}$$

where:

F_p is the total seismic force, in kN.

W_p weight of the element or component, in kN.

C_P is the coefficient given in the Table 6.7, adimensional.

Note: “A” and " I ", has the same meaning that in 6.4.

6.6 Provisions for Base Isolation

Not considered.

6.7 Orthogonal Seismic Load Effects. [6.8]

For each floor or level, the lateral forces due to the sum of 100% of the effects of the earthquake acting in the analyzed direction and 30% of the effects of the earthquake acting in the normal direction to the previous one and vice versa will be calculated, taking the greater one than result from analysis.

6.8 Liquefaction Effects. [8.6, 8.6.1, and Table 8.2, and Figures 8.1to 8.3]

When there are structures located in seismic areas 1, 2, or 3 and where the soil present layers of significant thickness formed by sands or not very dense oozy sands under the phreatic level, in the first 20 meters of the deposit, the liquefaction potential will be evaluated.

In the epigraph 8.6.1, three different criterions are defined.

7. SMALL RESIDENTIAL BUILDINGS

Not considered.

8. PROVISIONS FOR EXISTING BUILDINGS. [9, 9.1 to 9.5]

In the Chapter 9 all the requirements to guarantee the security of existent structures are defined.

RECOMMENDATIONS FOR CODE IMPROVEMENT

The Seismic Standard of Cuba can be considered a state of the art Standard. Although some Items are not considered, others, such as liquefaction effects, have been taking into account. May be a few modifications can be added in order to improve the Standard.