THE PROPOSAL FOR THE COLOMBIAN ANTISEISMIC BUILDING CODE

by

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SYNOPSIS

For many years, Colombia has been deprived from an antiseismic building code. Such a document is very important to guarantee a minimum standard of public safety, given the seismic position of the country. In November, 1972, the author presented before the National Engineering Council the first proposal for the Colombian Antiseismic Building Code (1), based on several years of study and research on the subject. Today, this is still the only existing proposal, and even though it is still under discussion and consideration, city authorities in Bogotá (the Capital) and other metropolitan areas in the country, have already accepted tall buildingsdesigned according to it. Several consulting firms have implemented it in their computer systems, and are currently using it. This document has also served as a source for the corresponding proposals of other Latin American countries. A brief summary is presented to give an idea of its contents and the scope of its stipulations.

CHAPTER 1 - SEISMICITY

1.1 Introduction.

Stipulations given in this chapter are temporary while more information is gathered by the seismic network about the seismicity of the country.

1.2 Seismic Scales.

Richter magnitude is generally used. When impossible to determine it, then us e should be made of the Modified Mercalli Intensity Scale.

1.3 Seismic Zones.

The country has been devided into the following seismic zones:

	Maximum acceleration, % g	Magnitude
Zone 0	4	5.0
Zone 1	8	5.6
Zone 2	22	6.5
Zone 3	40	6.9

1.4 Seismic Risk.

Seismic risk for a return period of 100 years will have to be assessed on the basis of existing data, for magnitudes from 5 up.

1.5 Seismic Spectra.

1.5.1 Pseudo-velocity or tripartite spectra may be used for seismic design.

1.5.2 For those places where accelerograms are not available, other spectra may be used, but scaled by the following coefficients:

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a) For the constant acceleration region, a coefficient equals to the ratio of the acceleration for such seismic zone and the maximum spectral acceleration shall be used.
b) For the constant velocity region the coefficient will be half that indicated above.
c) For the constant displacement region the scailing coefficient is the same as that for the constant acceleration band.

CHAPTER 2 - SOILS

2.1 Introduction.

Only general rules are given since dynamic characteristics of foundation soils in the major cities in Colombia have not been determined yet.

2.2 Dynamic Spectra.

Dynamic spectra for foundation soils shall be determined for Type A and massive structures. By the same token, vibration tests should be performed upon soil samples for these types of structures. When applicable, soil liquefaction shall be checked.

2.3 Foundations.

2.3.1 Foundations shall be designed according to the allowable dynamic stresses in the structure, as well as the overturning moments specified in Chapter 4.

2.3.2 Connections between foundations and structures shall be carefully designed to resist those shear stresses indicated in Chapter 4.

CHAPTER 3 - STRUCTURAL ARCHITECTURE

3.1 Kinds of Structures.

The following two kinds of structures are considered:
a) Discrete structures (composed of descrete elements).
b) Massive structures.

3.2 Types of Structures.

Three types of structures are considered:
Type A: structures having more than 60 m. of height or length.
Type B: structures having between 10 and 60 m. in height or length.
Type C: structures having less than 10 m. in height or length.

3.3 Dynamic Behavior.

Two basic patterns of dynamic behavior are considered and defined:
a) Flexible structures.
b) Shear structures.

3.4 Idealization of the Structure.

3.4.1 Architectural layout shall be subjected to the structural system; not viceversa.

3.4.2 Behavior of the structural system as a whole shall be defined and preserved throughout the design process.

3.4.3 Longitudinal elements intended to sustain earthquake loads in addition to static loads shall be continued all the way to the foundation.

3.4.4 Type A structures shall be separated from adjacent structures by a distance that will prevent hammering.

CHAPTER 4 - DYNAMIC ANALYSIS

4.1 Dynamic Characteristics.

Dynamic characteristics of structures shall be given in terms of stiffness, mass, natural period and modal shapes, and expressed in metric units.

4.2 Seismic Loads.

4.2.1 Seismic loads shall be those set forth in Chapter 1.

4.2.2 A portion of the live load consistent with the use of the structure, but not less than 20 %, will be included in the mass, in addition to that part corresponding to dead loads.

4.3 Damping.

A minimum damping ratio of 5 % shall be used. For inelastic behavior, an additional 4 % shall be included.

4.4 Natural Period.

4.4.1 Natural period shall be determined for Type A and B structures by dynamic programs or generally accepted methods. A formula is suggested.

4.4.2 The natural period shall fall between these limits:

$$\sqrt{2}\ T' \leq T \leq T'/\sqrt{2}$$

where T' is the natural period of the soil, to avoid resonance, and to limit transmissibility from soil to structure.

4.4.3 Resonance should be checked in all cases.

4.4.4 The natural period shall be also limited by the human perception threshold. (A tentative value of 10 milli g is given).

4.5 Dynamic Loads.

Minimum dynamic loads are calculated according to a quasi-static method (2, 3, 4). A base reaction is first computed and then distributed along the height of the structure in a parabolic pattern. A standard tripartite spectrum is given to be used in conjuction with the indicated procedure.

4.6 Methods of Analysis.

4.6.1 Type A structures require a rigurous dynamic analysis.

4.6.1.1 Maximum possible and probable spectral responses shall be determined using the first 3 + N/10 natural modes, where N is the number of stories.

4.6.1.2 Dynamic analyses shall reflect structural behavior as set forth in Arts. 3.3 and 3.4.

4.6.1.3 The set of degrees of freedom used should correspond to such structural behavior.

4.6.1.4 Axial deformations of columns shall be kept in the analytical process, and not eliminated by matrix compression.

4.6.1.5 Pseudo-velocity or tripartite spectra with damping ratios up to 20 % ma be used.

4.6.1.6 An amplification factor not larger than 2 shall be included whenever the natural period of the soil is larger than that of the structure.

4.6.2 Type B and C structures can be analyzed by quasi-static methods.

4.6.3 Massive structures shall be analized by finite element methods.

4.7 General Considerations.

4.7.1 The minimum design magnitude for any seismic zone is 5.

4.7.2 Two orthogonal directions shall be considered in the analysis.

4.7.3 Vertical components of at least 50 % of the horizontal maxima shall be taken into account.

4.7.4 A minimum design overturning moment is calculated by a given formula. Building plan domentions and foundation shall be checked for such values of overturning moments.

4.7.5 Horizontal torsion due to asymetry in shape, mass or stiffness, shall be considered in the analysis.

4.7.6 Setbacks can be considered as integral part of the structure if local stresses are taken into account at the discontinuity points. Otherwise, two different structures shall be treated and separated accordingly.

CHAPTER 5 - ANTISEISMIC DESIGN

5.1 Design Criteria.

5.1.1 Type B and C structures should be proportioned to have enough strength to behave elastically during those earthquakes expected to occur 5 or more times during a 100 year period, and to have enough ductility to absorb the energy of those likely to occur more than 5 times during the same period, for Type A structures, and 10 times for Type B and C structures, so in no event there shall be a complete collapse.

5.1.2 Members shall be proportioned to sustain the dynamic stresses set forth in Arts. 3.3, 3.4 and 3.5.

5.2 Ductility.

5.2.1 Ductility ratio is defined as the ratio of the curvatures at ultimate and yielding states of the members.

5.2.2 Minimum ductility for those structural members subjected to seismic loads is 6 for Type A structures and 4 for Type B and C structures.

5.3 Allowable Stresses.

Allowable stresses may be increased by up to 30 % for seismic loads. For prestressed concrete members a 30 % decrease in seismic loads is permissible.

5.4 Reinforced Concrete Beams.

5.4.1 Appropriate ductility shall be attained by adequate inclusion of compression reinforcement. In no section of a beam subjected to seismic loads there shall be a smaller steel ratio than required for minimum ductility as set forth in Art. 5.2.

5.4.2 The minimum percentage of compression reinforcement shall be present along the entire beam, and shall extend through member joints.

5.4.3 The formation of plastic hinges should be checked in beams subjected to seismic loading. Adequate tension and compression reinforcement should be placed in those sections where plastic hinges are expected to occur.

5.4.4 Bond and anchorage should be checked at cut-off points.

5.4.5 Closed loop stirrups shall be used all the way along the beam at spacings not larger than half the depth of the beam.

5.5 Reinforced Concrete Columns.

5.5.1 Columns shall be designed for those axial loads induced by overturning moments in addition to common static forces.

5.5.2 Same lower bound ductilities apply for columns as for beams.

5.5.3 Closed loop stirrups shall be used all the way along the column at spacings not larger than $\frac{1}{2}(d-d')$, where $d-d'$ is the largest dimention of the cross section.

5.5.4 Splicing of longitudinal bars should be carefully determined. Stirrup number shall be doubled alung splices.

5.6 Shear Walls.

Shear walls shall extend all the way down to the foundation.

5.7 Structural Joints.

5.7.1 Spetial attention shall be given to structural joints to avoid failure at those places.

5.7.2 Upper and lower bars at ends of beams shall extend into adjacent joints.

5.8 Partition Walls.

5.8.1 Partition walls shall be attached to any structure in a way that they will not change its fundamental dynamic behavior.

5.8.2 Partition walls shall be attached to any structure in a way that prevents pieces and debris from falling down.

5.9 Appendages.

All appendages shall be anchored to the structure to prevent them from falling off.

5.10 Building Spacing and Sliding Joints.

Those building elements that do not sustain seismic loads in conjunction with the main structure, but are attached to it, shall be spaced an appropriate distance to avoid hammering.

CHAPTER 6 - CONSTRUCTION AND CONTROL

6.1 Construction.

6.1.1 High quality materials shall be used for earthquake resistant structures. The quality of such materials shall be controlled by periodical laboratory tests.

6.1.2 There shall be a close supervision of workmanship during construction.

6.2 Tests and Control.

6.2.1 Type A structures shall be subjected to vibration tests upon completion.

6.2.2 Accelerometers shall be installed at appropriate places in Type A structures.

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