NEW PROPOSAL OF CUBAN STANDARD FOR STRUCTURAL DESIGN

1995

MINISTRY OF CONSTRUCTION

CHAPTER 1 INTRODUCTION

1.1 OBJECTIVES

This code provides the specifications of construction, design and aseismic calculation methods of buildings, towers, chimneys and another structures.

These principles are applicable to another structures such as bridges, dams, harbor installations, tunnels, oil tanks and chemical plants.

The main purpose of this code is to guarantee the integrity of structures avoiding fails that can threat the security of structures and people.

The structures which are not included in these sections shall be subjected to a special study, depending upon the importance and complexity of the structure under consideration.

CHAPTER 3 SEISMIC ZONING

To the application of this code the national territory is dividing into four zones:

	SEISMIC ZONE	ACCELERATION % (g)
Zone 0	Very low seismic risk	-
Zone 1	Low seismic risk	0.075 - 0.10
Zone 2	Middle seismic risk	0.11 - 0.20
Zone 3	High seismic risk	> 0.20

In zone 0 (Very low seismic risk) is not necessary to take into account aseismic measures to the structures construction.

The iso-acceleration values (iso acceleration curves) are corresponding to a probability of exceedance between 10-15%, 50 years of lifetime of the structures and return period of 475 years.

CHAPTER 4 GENERAL SPECIFICATIONS

4.1 BASES OF EARTHQUAKES DESIGN

The objective of this seismic code is to secure that every structure are planned, designed and constructed so as to:

a) Resist against minor earthquakes without any damage.

b) Resist against moderate earthquakes without structural damage, some non-structural damage are allowed.

c) Resist against strong earthquakes without collapse, some structural damages are allowed as far as they remain repairable.

4.2 CONSIDERATION ABOUT SEISMIC DESIGN

Every structure must be designed and built following next provisions:

- The buildings shall be designed and constructed to resist seismic force according to seismic risk zone, soil profile and importance factor.

- It will be considered that the seismic force will act in the two principal directions, or in the most unfavorable direction. The analysis could be done in each direction and considering the full seismic force in each case.

- When the structural seismic behavior can be affected by non structural elements, these elements will have to be considered in the structural analysis and the project must include all the details related to the reinforcement and/or anchorage according to this condition.

- When the seismic behaviour is not affected by non structural elements, the project must include all the details of reinforcement and/or anchorage in order to satisfy that condition.

- When a single element, shear wall or column takes more than 30% of the total horizontal force in any level, that level has to be designed to carry 125% of that force in total.

- The vertical seismic force will be considered simultaneously with the horizontal one.

4.3 STRUCTURAL EARTHQUAKE RESISTANT CONCEPTION

It has to be considered the following conditions which improve the seismic behaviour of buildings:

a. Symmetry in mass and stiffness distribution in a plane.

b. Least weight, specially in the upper most levels.

c. Appropriate use and selection of construction materials.

d. Structural continuity as in plan as in elevation.

e. Ductility as a necessary requirement for a good structural behaviour.

f. Limit to the deformation, otherwise the structural damage may be large.

g. Resistant devices due to consecutive resistant lines which approximate the total structure's behaviour to a ductile one.

h. Use of structural systems according to the existing local conditions based on the soil foundation's characteristics.

i. A good construction practice and a strict inspection help in a good seismic behaviour.

4.4 HEIGHT OF BUILDINGS

4.4.1. Concrete and steel structures will have no height limitation excepting this code's requirements.

4.4.2. Masonry constructions will be limited to 5 stories and they will have to be less than 16 meters high.

4.4.3. Wood constructions will be restricted up to 2 stories and they will have to be less than 7 meters high.

4.4.4. Adobe constructions will have only 1 story and they have to be less than 2.4 meters high, except when they ties around their roof level horizontally, where they can be as large as 3 meters in the highest part.

CHAPTER 5 CALCULATION OF SEISMIC ACTIONS

5.1 DUCTILITY LEVELS

For purposes of application of these regulations, there are three ductility levels:

- Ductility Level 1. Does not apply provisions for seismic zone design.

- Ductility Level 2. Apply the some aseismic requirements of the Cuban Standard (group 53) that permit to the structure work in elastic range.

- Ductility Level 3. Apply special procedures for the design, selection of construction materials, to realize structures with large energy dissipation capacity.

5.1.1 DUCTILITY LEVELS REQUIRED IN THE DIFFERENT SEISMIC ZONES

IMPORTANCE OF THE BUILDING	DUCTILITY LEVELS SEISMIC ZONE 1	2	3
1 and 2	ND2	-	-
	ND3	ND3	ND3
3	ND1	-	-
	ND2	ND2	-
	ND3	ND3	ND3
4	ND1	ND1	ND2
5	ND1	ND1	ND1

5.2 IMPORTANCE COEFFICIENT (I)

According to the building use and level of importance just after an earthquake occurrence, the buildings are classified as follow:

CHARACTERISTICS OF BUILDINGS BY THEIR IMPORTANCE	I
1. BUILDINGS AND CONSTRUCTIONS OF EXCEPTIONAL IMPORTANCE Special buildings, whose failure is very dangerous and besides that, their collapse may represent important additional risk. In this category are included the nuclear power plant, big ovens, inflammable deposits and others similar.	will be fixed by competent authority
2. BUILDINGS AND CONSTRUCTIONS OF SPECIAL IMPORTANCE. Buildings used for vital services, whose functions are important and can not be interrupted immediately following an earthquake, or buildings whose failure after an earthquake will cause direct or indirect damage exceptionally high comparing with the required cost necessary to increase their safety. In this category are: the hospitals, telephone centrals, broadcasting stations, fire stations, electrical substations silos, water tanks, schools, stadiums, auditoriums, temples, show theaters, public registers and files, museums, etc. In general places that provide lodge for big	1.25

quantity of persons or every expensive equipment.

3. BUILDINGS AND CONSTRUCTION OF MIDDLE IMPORTANCE. Common buildings, whose failure could cause intermediate damages as: dwellings, office buildings, hotels, houses, commercial buildings restaurants, warehouses, deposits and industrial buildings	1.0
4. BUILDINGS AND CONSTRUCTION OF SECONDARY IMPORTANCE. Buildings whose failures due to earthquakes mean a low cost, and normally they do not cause damage. This category includes: walls whose height is less than 1.50 m, temporal warehouses, provisional small houses and others similar.	0.6

5.3 DUCTILITY FACTOR VALUES (Rd)

Type	Building Characteristics	Nd	Rd
I	Reinforced concrete buildings having ductile frames. They are able to resist 100% of the horizontal force, considering that they work independently of any of the other rigid elements. Steel frame buildings.	3 2 1	6 4.5 2.5
II	Reinforced concrete buildings having special ductile frames and special shear walls designed according to the following criteria: - The frames and shear walls should resist the total horizontal force according to their relative stiffness taken into account the interaction between frames and shear walls. - The frames should have enough capacity to resist not less than 25% the horizontal force, if they act independently.	3 2 1	5 3.75 2
III	Reinforced concrete buildings similar to the previous case, except that their frames and/or shear walls do not satisfy completely the special ductility requirements. - Wooden and steel structures which are not included in other cases.	3 2 1	4 3 1.5
IV	Building where the horizontal force is taken only by shear walls or similar structures.	3 2	4 4

		1	4
V	Masonry reinforcement buildings	3	3.5
		2	3.5
		1	3.5
VI	Confined buildings in masonry cement.	3	2.5
		2	2.5
		1	2.5
VII	Confined building without reinforcement.	3	1.5
		2	1.5
		1	1.5
	- Adobe buildings and others not included in this classification.		

5.3.1 SOIL PROFILES

PROFILE TYPES	DESCRIPTION
S1	Any rock, (sedimentary, crystalline) with velocity of shear waves propagation more than 800 m/s. Their oscillation periods are between 0.3 and 0.5 sec.
S2	Composed by stable deposits of dense sand, gravel, hard clay or combination of these materials with velocity of shear waves propagation between 240 and 450 m/s. Their oscillation periods are between 0.5 and 0.8 sec.
S3	Composed of deposits which contain sandy and clayey strata of varying soft-to-medium hardness and the local thickness of which exceeds 10 m of depth, with velocity of shear waves propagation less than 240 m/s. Their oscillation periods are between 0.8 and 1.2 sec.
S4	Profile characterized by velocity of shear waves propagation less than 150 m/s with soft clay strata more than 12 m. Their oscillation period will be more than 1.2 sec.

5.4 EQUIVALENT STATIC METHOD

5.4.1 BASE SHEAR FORCE

The base shear force V is determined following the expression:

$$V = \frac{A\,I\,C}{Rd}\,W$$

where: A = Maximum value of acceleration corresponding to an specific seismic zone.
I = Coefficient that take into account the seismic risk depending on importance of the building.
Rd= Reduction ductility factor.
W = Weight of the building.

C = Spectral seismic coefficient.

$$C = 1 + (Fa - 1)\ T/T1 \qquad 0 <= T <= T1$$

$$C = Fa \qquad T1 <= T <= T2$$

$$C = Fa\ (T2/T)^{p} \qquad T > T2$$

where: Fa = amplification coefficient depending on soil profile.
T = period of the structure

p = expectral exponent.

Soil profile	Fa	T1	T2	p
S1	2.5	0.15	0.4	0.8
S2	2.5	0.15	0.6	0.7
S3	2.0	0.2	1.0	0.6
S4	2.0	0.2	1.5	0.5

The value of C can't be less than 0.45

VALUES OF MAXIMAL HORIZONTAL ACCELERATION PER EACH SEISMIC ZONE:

ZONE	1	2	3
A	0.10	0.20	0.30

5.4.2 ESTIMATED FUNDAMENTAL PERIOD

The estimated value Ta of the fundamental period T shall be calculated as follow:

a) For type I structures:

- Steel frames $Ta = 0.085 hn^{3/4}$

- Reinforced concrete frames and steel frames excentrically arriostred.

$$Ta = 0.073hn^{3/4}$$

b) For type II and III structures:

$$Ta = 0.09hn / \sqrt{L}$$

c) For type IV, V, VI, VII structures:

$$Ta = 0.05hn / \sqrt{L}$$

where: hn = heigth 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 analized, in meters.

Fundamental period of the structure:

$$T = 2 \sqrt{\frac{\sum_{i=1}^{n} Wi\, si^2}{g \sum_{i=1}^{n} Fi\, si}}$$

where: Wi = weight of level i

si = elastic deformation at level i

Fi = lateral force at level i

g = gravity

5.5 MODAL ANALYSIS METHOD

5.5.1 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.

5.5.2 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.

5.5.3 MODAL BASE SHEAR

The contribution of Vm of the m-th mode to the base shear V shall be determined according to the following formula:

$$Vm = \frac{A \; I \; Cm}{Rd} Wm$$

where: Vm = modal base shear due to m-th vibration mode

Cm = spectral seismic coefficient

Wm = m-th effective modal weight

A = maximum value of acceleration corresponding to a specific seismic zone.

5.5.4 MODAL SHEAR FORCES

The modal forces Fim at each level shall be determined by means of the expression:

$$Fim = Nim \; Vm$$

where: Nim = distribution coefficient of shear modal force on the building

Aim = displacement of level i, in vibration mode m

Wi = weight

$$Nim = \frac{Wi \; Aim}{\sum_{j=1}^{n} Wj \; Aim}$$

5.5.5 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.

5.5.6 TOTAL SEISMIC FORCE

The total seismic force will be determined by means of the expression:

$$Fp = A \; I \; Cp \; Wp$$

Where: Fp = Total seismic force

Wp = weight of element or component

Cp = coefficient given to each part or portion of the structure

A = maximum value of acceleration corresponding to an specific seismic zone.

VALUES OF Cp:

PART OF THE STRUCTURE	Cp
- Exterior or interior walls, whether load bearing or not, partitions and other dividing walls.	2.00
- Ledges and any overhanging vertical parapet.	2.00
- Exterior or interior ornaments and appendages.	0.75
- Marquees, balconies, eaves, roof projections or any other overhang.	0.75
- Floors and roofs acting as diaphragms.	see 5.7
- Joints of external prefabricated walls or partition elements.	0.75
- Engine room structures, water tanks and their contents and lookouts over buildings.	0.75

Editorial Notes This is an unauthorized English translation prepared by Ms. Belmis Avich Duran.