SEISMIC CODE EVALUATION

COSTA RICA

Evaluation conducted by Jorge Gutiérrez

NAME OF DOCUMENT: "Código Sísmico de Costa Rica – 2002" ("Seismic Code o f Costa Rica – 2002")

YEAR: 2002

GENERAL REMARKS: Officially approval by "Colegio Federado de Ingenieros y de Arquitectos de Costa Rica", CFIA (Engineers and Architects Professional Society) in November 2002. Printing expected for first semester of 2003.

SPECIFIC ITEMS:

NOTE: Bracketed numbers refer to Code specific chapters or articles: [4.1.b]
Parenthesis numbers refer to Items of this document: (see 2.2)

1. SCOPE

1.1 Explicit concepts. [1.1]

Scope of Code is for Buildings and similar behavior structures (towers, elevated tanks).

Seismic design is controlled by displacements and deformations. Inelastic deformations are accepted, adequate ductility is essential.

Adobe is forbidden as a structural material for seismic loads.

1.2 Performance Objectives. [1.2 and 4.1.b]

Main objective is to protect human life and reduce economic loss caused by earthquakes [1.2].

Five performance Objectives are defined [4.1.b]:

- Life Safety Performance for Normal Occupancy (see 3.1) and Severe EQ (see 2.2).
- Operational Performance for Special Occupancy Facilities (see 3.1) and Severe EQ (see 2.2).

- Life Safety Performance for Hazardous Facilities (see 3.1) and Extreme EQ (see 2.2).
- Operational Performance for Essential Facilities (see 3.1) and Extreme EQ (see 2.2)
- Life Safety Performance for Low Hazard Facilities (see 3.1) and Moderate EQ (see 2.2)

2. SEISMIC ZONING AND SITE CHARACTERIZATION

2.1 Seismic Zoning (Quality of Data). [2.1, 2.4.a; Table 2.1 and Figure 2.1]

The country is divided in three seismic zones named Zones II, III and IV, with corresponding effective Peak Ground Accelerations a_{ef} on Rock of 0.2, 0.3 and 0.4 of gravity for Severe EQ (see 2.2).

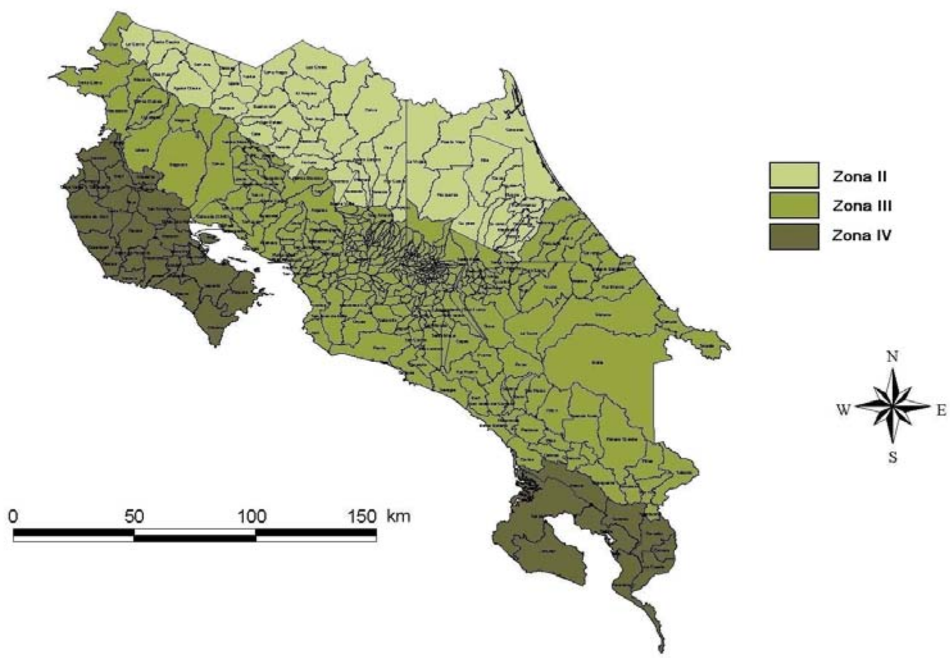


Figura 2.1. Zonificación sísmica

2.2 Levels of Seismic Intensity. [2.3]

Three levels of Seismic Intensity are defined:

- **Severe EQ.** Corresponding to a Return Period of 500 years.

- **Extreme EQ.** Corresponding to Effective Peak Ground Acceleration 50% higher than for Severe EQ.

- **Moderate EQ.** Corresponding to Effective Peak Ground Acceleration 25% lower than for Severe EQ.

2.3 Near Fault considerations.

Not considered.

2.4 Site Requirements. [1.3.d]

The Code is concerned with the strong ground shaking effects of earthquakes. No consideration is given to ground subsidence or excessive foundation settlements, liquefaction, landslides or fault rupture as the engineer must verify that the site is not prone to these problems.

2.5 Site Classification. [2.2]

Four Site Types are defined:

- **Type S_1.** Rock or very stiff soil (C_s > 760 m/s (2500 fps)

- **Type S_2.** Stiff to medium stiff or dense to medium dense soil more than 50m (165ft) deep.

- **Type S_3.** Soft to medium stiff clay or non-cohesive low to medium dense soil 6 to 12 m (20 to 40 ft) deep.

- **Type S_4.** Soft clay or C_s < 150 m/s (500 fps) more than 12m (40 ft) deep.

2.6 Peak Ground Accelerations (Horizontal and Vertical). [2.4]

Horizontal Effective Peak Ground Accelerations are defined for Severe EQ (see 2.2) according to the corresponding Seismic Zone (see 2.1) and Site Classification (see 2.5):

Effective Peak Ground Accelerations for Severe EQ

Site Type	Zone II	Zone III	Zone IV
S_1	0.20	0.30	0.40
S_2	0.24	0.33	0.40
S_3	0.28	0.36	0.44
S_4	0.34	0.36	0.36

There is no reference to vertical component accelerations.

3. PARAMETERS FOR STRUCTURAL CLASSIFICATION

3.1 Occupancy and Importance. [4.1.a]

Five Groups, with their corresponding Importance Factor ***I*** are included (see 1.2 and 2.2):

- **Group A:** Essential Facilities (***I*** = 1.5)
- **Group B:** Hazardous Facilities (***I*** = 1.5)
- **Group C:** Special Occupancy Facilities (***I*** = 1.0)
- **Group D:** Normal Occupancy Facilities (***I*** = 1.0)
- **Group E:** Low Hazard Facilities (***I*** = 0.75)

3.2 Structural Type. [4.2]

Five Structural Types are considered. Their structural characteristics and materials are as follows:

- **Frame Type.** Only structural frames of steel, concrete or timber.
- **Dual Type.** Frame and Wall combination; frames able to resist at least 25% of shear demand at each story; possible structural materials are steel, concrete, masonry or timber.
- **Wall Type.** Only shear walls or braced (concentric or eccentric) frames. Possible structural materials are either concrete, masonry or timber plywood for shear walls or steel or timber for braced frames.
- **Cantilever Type.** Also called Inverted pendulum systems. Isolated or single line columns acting essentially as cantilever systems.
- **Others Type.** None of the above Structural Types or structural materials.

3.3 Structural Regularity: Plan and Vertical. [4.3]

Six Plan Regularity Requirements: eccentricity, separation of lateral and rotational frequencies, no reentrant corners, no diaphragm openings, orthogonal or symmetrical structural systems, two or more axis of strength in each direction.

Seven Vertical Structural Regularity Requirements: Continuity, setbacks, stiffness, floor horizontal diaphragms, lateral strength, weight, mass and stiffness centers.

Irregularities are classified as Moderate and Severe Plan and Vertical Irregularities.

3.4 Structural Redundancy.

Not considered

3.5 Ductility of elements and components. [4.4.1]

Optimum Local Ductility: Elements and components satisfy Optimum Ductility requirements defined in specific chapters of the Code for each structural material. Alternatively, lateral relative drift capacity (see 5.7) of 0.025 with loss of strength no larger than 20%, verified by tests.

Moderate Local Ductility: Elements and components satisfy Moderate Ductility requirements defined in specific chapters of the Code for each structural material.

4. SEISMIC ACTIONS

4.1 Elastic Response Spectra (Horizontal and Vertical). [5]

Horizontal Spectra:

Constant Plateau $S_{a\ max}$ = 2.5 times Effective Peak Ground Acceleration (see 2.6).

Descending Branch $S_a = S_{a1} / T$ starting at $T_s = S_{a1} / S_{a\ max}$

where:

S_{a1} Spectra at T = 1 sec.
T_s Defined for each Seismic Zone (see 2.1) and Site Type (see 2.4) according to following Table (T_s in seconds)

T_s values according to Seismic Zone and Site Type (sec)

Site Type	Zone II	Zone III	Zone IV
S1	0.400	0.400	0.400
S2	0.533	0.545	0.560
S3	0.571	0.600	0.582
S4	0.753	0.933	1.067

Vertical Spectra:

Not considered.

4.2 Design Spectra. [4.4.2; Table 4.3; 5]

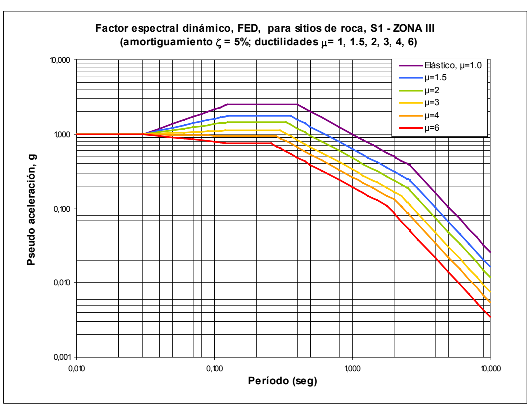
For each structure a Global Ductility is assigned in terms of Structural Type (see 3.2), Structural Plan and Vertical Regularity (see 3.3) and Ductility of Elements and Components (see 3.5). Global Ductility values are 1 (elastic), 1.5, 2, 3, 4 and 6.

The Design Spectra is defined as a Seismic Coefficient C:

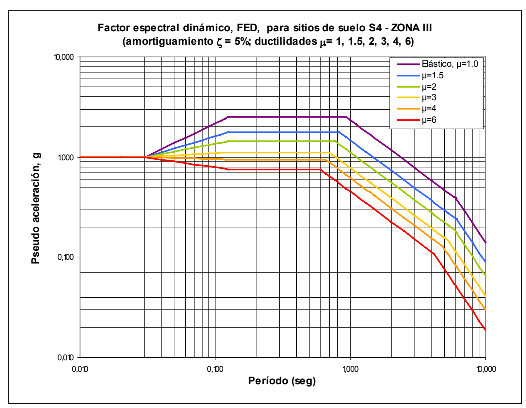
$$C = (a_{ef}\, I\, FED) / SR$$

where

- *C* = Seismic Coefficient
- a_{ef} = Effective Peak Ground Acceleration (see 2.6)
- *I* = Importance Factor (see 3.1)
- *SR* = Overstrength. Defined for each Structural Type as follows:
  SR = 2.0 for Structural Types Frame, Dual and Wall (see 3.2) with Static (see 5.3) or Mode Superposition (see 5.4) Methods.
  SR = 1.2 for Structural Types Cantilever or Others (see 3.2) with Static (see 5.3) or Mode Superposition (see 5.4) Methods or all Structural Types with Non Linear Methods (see 5.5).
- *FED* = Spectral Dynamic Factor, dependant of Seismic Zone (see 2.1), Site Type classification (see 2.5), Assigned Global Ductility of Structure and its Natural Period. *FED* is presented in 12 figures [figures 5.1 to 5.12], two of them are presented here as examples:



FED for Seismic Zone III and Site Type S_1. Global Ductility 1, 1.5, 2, 3, 4, 6



FED for Seismic Zone III and Site Type S_4. Global Ductility 1, 1.5, 2, 3, 4, 6

4.3 Representation of acceleration time histories. [7.7.c]

For Non Linear Time History analysis (see 5.5), the Code requires at least three accelerograms, real or artificially generated, in each direction. The average of their acceleration spectra for 5% damping should approximate the Code horizontal elastic response spectra (see 4.1).

4.4 Design Ground Displacements.

Not considered.

5. DESIGN FORCES, METHODS OF ANALYSIS AND DRIFT LIMITATIONS

5.1 Load Combinations including Orthogonal Seismic Load Effects. [6.2; 7.3]

The Code defines four Load Combinations for Strength Design [6.2]:

$CU = 1.4\ CP$
$CU = 1.2\ CP + 1.6\ CT$
$CU = 1.05\ CP + f_1\ CT \pm CS + CE$
$CU = 0.95\ CP \pm CS + CE$

where
CU Combined Load (for LRFD or Strength Design)
CP Permanent (Dead) Load
CT Temporary (Live) Load
CS Seismic Load
CE Lateral pressure of soils
f_1 = 1.0 for public assembly, parking or other high probability of occupancy sites.
= 0.5 for usual places
= 0.0 for roofs.

For each element *CS* will be the most critical of the following combinations [7.3]:

$CS = 1.0\ CS_x + 0.3\ CS_y$ or
$CS = 0.3\ CS_x + 1.0\ CS_y$

where
CS_x, CS_y Seismic Loads due to EQ in the x and y horizontal directions. No vertical EQ component is explicitly considered.

These combinations are not required for structures whose resistant systems are either parallel or orthogonal to each other in plan.

5.2 Simplified Analysis and Design Procedures.

Not considered, except for Small Residential Buildings (see 7).

5.3 Static Method Procedures. [7.4]

This procedure is restricted to Plan and Vertical Regular Structures (see 3.3) having five stories of less. The Total Base Shear V is:

$$V = C\,W$$

where
V = Total Base Shear
C = Seismic Coefficient (see 4.2)
W = Total Weight, estimated as 100% of Permanent (Dead) Load + 15% of Temporary (Live) Load.

Forces are distributed in proportion to each floor weight W_i and height h_i :

$$F_i = V\,[\;w_i\,h_i\;/\,\Sigma_k\,W_k\,h_k\;]$$

Natural Period is calculated with Rayleigh Method

5.4 Mode Superposition Methods. [7.5]

Required whenever Static Method Procedures (see 5.3) are not allowed. Combination of modes according to SRSS or CQC.

5.5 Non Linear Methods. [7.7]

Two Non linear methods of analysis are allowed as alternative methods:

- Spectrum Capacity Methods with Constant Ductility Spectra combined with a Pushover analysis.
- Non Linear Time History analysis (see 4.3).

5.6 Torsional considerations. [7.5.e]

All structures with Plan Structural Irregularities (see 3.3) require coupled lateral-torsional three dimensional analysis with at least three dof per floor.

5.7 Drift Limitations. [7.6; 7.8.a]

When Static (see 5.3) or Mode Superposition (see 5.4) Methods have been used, Inelastic Story Drifts are calculated as:

$$\Delta_i = \Delta_e \, \mu \, SR$$

where

- Δ_i = Inelastic Story Drifts
- Δ_e = Elastic Story Drift (from Linear Elastic Analysis)
- μ = Ductility of Structure (see 4.2)
- SR = Overstrength (see 4.3)

Absolute Inelastic Floor Displacements calculations are further reduced by an Inelastic Displacement Factor α.

$$\delta_i = \delta_e \, \mu \, SR \, \alpha$$

where:

- δ_i = Absolute Inelastic Story Displacement.
- δ_e = Absolute Elastic Story Displacement (Linear Elastic Analysis)
- μ = Assigned Global Ductility of Structure (see 4.2).
- SR = Overstrength (see 4.2).
- α = Inelastic displacement factor. α =0.70 for Frame, Dual and Wall Structural Types (see 3.2); α =1.00 for Cantilever and Others Structural Types (see 3.2).

Limit inelastic Story Drifts, as a ratio of story height ($\Delta_i / \Delta h_i$), are defined according to Occupancy and Importance (see 3.1) and Structural Type (see 3.2), according to the following Table:

Story Drift to Height Limits

Structural Type	Importance or Use Group	
	A, C	**B, D, E**
Frame	0.010	0.016
Dual	0.010	0.014
Wall	0.008	0.008
Cantilever	0.010	0.016
Other	0.005	0.008

These limits can be increased by 50% if P-Δ effects are considered in the analysis (see 6.4).

5.8 Soil-Structure Interaction Considerations.

Not considered.

6. SAFETY VERIFICATIONS.

6.1 Building Separation. [7.8.d]

All buildings must be separated from each other by a distance no less than the sum of their Absolute Inelastic Floor displacements δ_i (see 5.7).

6.2 Requirements for Horizontal Diaphragms. [3.e; 12.7]

It is highly desirable that horizontal floor Diaphragms be designed as in plane rigid components. Diaphragms are considered fragile (i.e. non-ductile) components; in consequence, they must be designed for internal forces equal to the overstrength *SR* times the forces derived from the analysis. If prefabricated beams or slabs are used it is necessary to pour a continuous reinforced concrete layer of at least 5cm for buildings up to 3 story high or 6 cm for higher buildings.

For flexible diaphragms, the assigned Global Ductility (see 4.2) can not be more than 1.5.

6.3 Requirements for Foundations. [13]

Foundations must be capacity protected against damage and collapse. If isolated foundations are used, they must be connected to each other by tie elements at the base level for an integrated in plan response (i.e. no horizontal differential displacements).

6.4 P-Δ Considerations. [7.8.b]

Not required if drift limitations (see 5.7) are satisfied. However, it is possible to increase these drift limits up to 50%. In this case, *P-Δ* effects must be considered and an alternative non linear method of analysis (see 5.5) is required.

6.5 Non-Structural Components. [14]

All non structural components and systems must be designed to resist forces F_p given by:

$F_p = 4.0\, a_{ef}\, I\, W_p$ *or*

$F_p = (X_p\, a_{ef}\, I / R_p)[1 + 3\, h_x / h_r]\, W_p$

with $0.7\, a_{ef}\, I\, W_p \leq F_p \leq 4.0\, a_{ef}\, I\, W_p$

Where:

F_p = Design Seismic Force for each non-structural component or system.
a_{ef} = Effective Peak Ground Acceleration (see 2.6).
I = Importance Factor (see 3.1).
W_p =Total weight of system or component.
X_p = System amplification Factor (tabulated, varies from 1.0 to 2.5).
R_p = Response Modification Factor (tabulated, varies from 1.5 to 4).
h_x = Height above base level of the center of mass of the system or component.
h_r = Total height of building above base level.

6.6 Provisions for Base Isolation.

Not considered.

7. SMALL RESIDENTIAL BUILDINGS. [17]

For one and two story dwellings, simple prescriptive requirements are presented for units up to 250 m^2 (2690 ft^2) whose structural system and construction materials and methods satisfy specific requirements.

8. PROVISIONS FOR EXISTING BUILDINGS. [15]

A complete Chapter refers to structural diagnosis and seismic retrofit. For existing buildings the emphasis is not on specific regulations but on satisfaction of the Performance Objectives (see 1.2). For old buildings, the Return Period (and the corresponding seismic forces) can be reduced.

CODE IMPROVEMENT RECOMMENDATIONS

The Seismic Code of Costa Rica can be considered a state of the art Code. Although some Items, as Near Fault EQ Effects (see 2.3), Soil-Structure Interaction (see 5.8) and Base Isolation (see 6.6) are not considered, no specific recommendations are deemed necessary for Code improvement.