NATIONAL BUILDING CODE

TECHNICAL STANDARD OF BUILDING
E.030

EARTHQUAKE-RESISTANT DESIGN

Lima, April 2nd 2003

TECHNICAL STANDARD OF BUILDING E.030
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EARTHQUAKE-RESISTANT DESIGN NTE E.030

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TECHNICAL STANDARD OF BUILDING E.030
EARTHQUAKE-RESISTANT DESIGN

1. OVERVIEW

1.1 Nomenclature

C	Seismic amplification coefficient
C_T	Coefficient to estimate the predominant period of a structure
D_i	Elastic lateral displacement of story "i" relative to the ground
e	Accidental eccentricity
Fa	Horizontal force in rooftop
F_i	Horizontal force in story "i"
g	Gravity acceleration
h_i	Height of story "i" with respect to ground level
he_i	Height of story "i"
h_n	Total height of the building in meters
Mt_i	Accidental torsional moment in story "i"
m	Number of modes used in modal superposition analysis
n	Number of stories in the building
N_i	Weight sumatory over story "i"
P	Total weight of the building
P_i	Weight of story "i"
R	Reduction coefficient of seismic solicitations
r	Maximum elastic structural response expected
r_i	Elastic responses corresponding to mode "i"
S	Soil factor
Sa	Spectral acceleration
T	Fundamental period of the structure for static analysis or dynamic analysis
T_P	Period that defines the spectral platform for each type of soil
U	Use and importance factor
V	Seismic-Base Shear of the structure
V_i	Shear force in story "i"
Z	Zone factor
Q	Stability coefficient for global P-delta effect
Δ_i	Relative displacement of story "i"

1.2 Scope

This Code establishes the minimum requirements for buildings to have an adequate seismic behavior according to the bases indicated on item 1.3.

This Code is applied to the design of all new buildings, to the evaluation and reinforcement of existing buildings and to the repairing of buildings that could be damaged due to the action of earthquakes.

For the case of special structures as reservoirs, tanks, silos, bridges, transmission towers, harbors, hydraulic structures, nuclear plants, and all whose behavior differs from edifications, it is required additional considerations that can complement the applicable requirements of the present Code.

Besides the indicated in the present code, measures to prevent disasters like fire, considerable sand sliding and other that can be produced as a consequence of seismic movements should be taken into account.

1.3 Bases and Philosophies of the Earthquake-Resistant Design

Earthquake resistant design philosophies are:
a. Avoid human loss.
b. Continuity of basic services.
c. Minimize structural damages.

It is recognized that to give complete protection against earthquakes is not technically nor economically for almost all the structures. In accordance with that philosophy the following bases are established in the Code for design:

a. Structures must not collapse or cause serious damages to persons due to severe earthquakes.
b. Structures must tolerate moderate earthquakes with the possibility of minor structural damages.

1.4 Presentation of the Structural Project (transitory disposition)

The drawings, descriptive memory and technical specifications of the structural project will be signed by a college civil engineer, who will be the only authorized to approve any modification to them.

The drawings of the structural project will include at least the following information:

a. Earthquake-Resistant Structural System.
b. Parameters to define the seismic force or the design spectra.
c. Maximum displacement of the last story and the maximum relative displacement of each middle story.

The building projects with more than 70 m of height will be supported by a calculus memory and vindicated calculus for its revision and approval by the competent authority.

The material employment, structural systems and constructive methods different to those indicated in this Code, must be approved by the competent authority nominated by the Ministry of Housing, Construction and Sanitation, and it must fulfill the present requirements indicated in this item and demonstrate that the proposed alternative produce adequate results of stiffness, seismic resistance and durability.

2. SITE PARAMETERS

2.1 Zonification

The national territory is considered to be divided in three zones, as shown in the figure Nº 1. The proposed zonification is based on the spatial distribution of the observed seismicity, the general characteristics of the seismic motions and their attenuations with respect to the epicentral distance, as well as on neotectonic information. It is indicated in annex Nº 1 the provinces that correspond in each zone.

SEISMIC ZONES

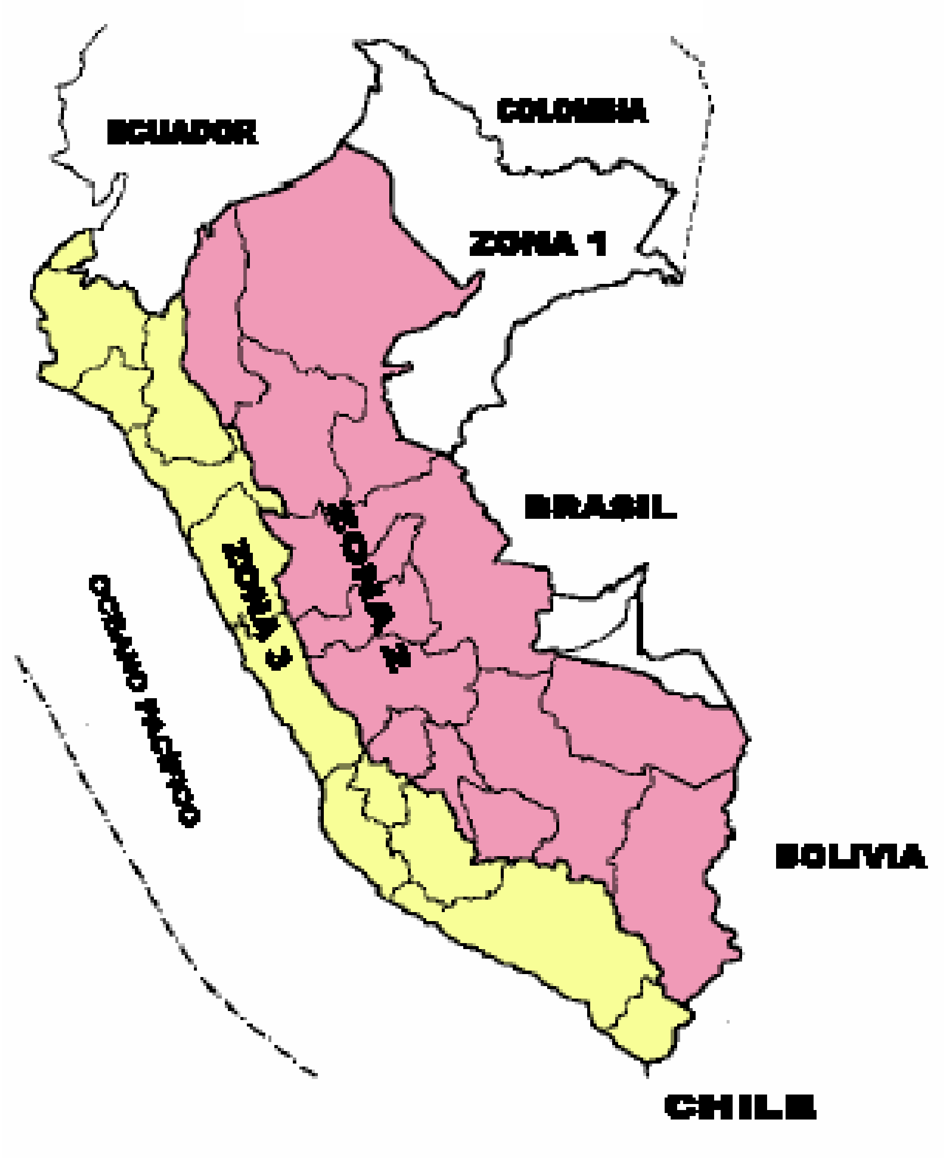

Figure Nº 1

A value Z is assigned to each zone as indicated in Table Nº 1. This value is taken as the maximum ground acceleration with a probability of 10% to be exceeded in 50 years.

TABLE Nº 1 **ZONE FACTORS**	
ZONE	Z
3	0.4
2	0.3
1	0.15

2.2 Local Conditions

2.2.1 Seismic Microzonification and Site Studies

a. Seismic Microzonification

They are multidisciplinary studies that investigate the seismic effects and associated phenomena like soil liquefactions, slides, tsunamis and others on the area of interest. These studies give information on the possible modifications of the seismic actions due to local conditions and other natural phenomena, as well as limitations and demands that result from the studies and are considered for the design and building of structures and other projects.

The achievement of the microzonification studies must be done as requisites for the following cases:

- City expansion areas.
- Industrial complexes or similar.
- Reconstruction of urban areas destroyed by earthquakes and associated phenomena.

The results from the microzonification studies will be approved by the competent authority, asking for complementary information or justifications in cases where is considered necessary.

b. Site Studies

They are similar to the microzonification studies but not necessarily as broad as them. These studies are restricted to the project zone and give information on the possible modifications of the seismic actions and other natural phenomena due to the local conditions. Their purpose is the determination of the design parameters.

Lower design parameters as indicated in this Code cannot be considered.

2.2.2 Geotechnical Conditions

For effects of this Code, the soil shapes are classified taking into account the ground mechanic properties, the thickness of the stratum, the fundamental vibration period and the propagation velocity of the shear waves. There are four kinds of soils:

a) Shape $\mathbf{S_1}$ type: Rock or very rigid soils.

To this type correspond rock soils and very rigid soils with shear wave propagation velocities similar to those defined for a rock, and where the fundamental period for low amplitude vibrations do not exceed 0.25s, including the cases where is founded on:

- Whole Rocks or partially altered, with a nonconfined compressive resistance higher or equal to 500 kPa (5 kg/cm^2).
- Dense sandy gravel
- Stratum of no more than 20 m of very rigid cohesive material, with a shear resistance in undrained conditions higher than 100 kPa (1 kg/cm^2), over rock or other material with shear wave velocity similar to a rock.
- Stratum of no more than 20 m of dense sand with N > 30, over rock or other material with a shear wave velocity similar to a rock.

b) Shape $\mathbf{S_2}$ type: Intermediate soils.

These are classified as soils with intermediate characteristics between shapes $\mathbf{S_1}$ and $\mathbf{S_3}$.

c) Shape $\mathbf{S_3}$ type: Flexible soils or stratums with great thickness.

This type corresponds to flexible soils or stratums with great thickness where the fundamental period, for low amplitude vibrations, is higher than 0.6s, including those cases where the ground stratum thickness exceeds the following values:

Cohesive Soils	Typical Shear Resistance in undrained condition (kPa)	Stratum Thickness(m) (*)
Soft	< 25	20
Moderately compact	25 - 50	25
Compact	50 - 100	40
Very compact	100 - 200	60

Granular Soils	Typical **N** values in Standard Penetration Tests (SPT)	Stratum Thickness (m)(*)
Loose	4 - 10	40
Moderately dense	10 - 30	45
Dense	Bigger than 30	100

(*) Soil with shear wave velocity lower than a rock.

d) Shape $\mathbf{S_4}$ Type: Exceptional Conditions.

This type corresponds to exceptionally flexible soils and sites where the geological and/or topographical conditions re particularly unfavorable.

The soil type that best describes the local conditions is to be considered, also using the corresponding values of $\mathbf{T_p}$ and the ground amplification factor **S**, given in Table Nº2.

In sites where the ground properties are less known, the values corresponding to shape **S_3** type can be used. It will be necessary to consider a shape **S_4** type, just when geotechnical studies determine so.

Table Nº2
Soil Parameters

Type	**Description**	T_p (s)	S
S_1	Rock or very rigid soils	0.4	1.0
S_2	Intermediate Soils	0.6	1.2
S_3	Flexible Soils or stratum with great thickness	0.9	1.4
S_4	Exceptional conditions	*	*

(*) The values for T_p and S for this case will be established by a specialist, but in neither case they will be lower than those specified for the shape **S_3** type.

2.3 Seismic Amplification Factor

According to the site characteristics, the seismic amplification factor (C) is defined by the following expression:

$$C = 2.5 * \left(\frac{Tp}{T} \right) \quad ; \quad C \le 2.5$$

T is the period as defined in the item 4.2.2 or 4.3.2.1

This coefficient is interpreted as the amplification factor of the structural response with respect to the ground acceleration.

3. GENERAL REQUIREMENTS

3.1 General Aspects.

Every building and each of its components will be designed and built to resist the seismic solicitations determined as specified in this Code.

It should be considered the possible effect of the non-structural elements in the structural behavior of the structure. Analysis, reinforcement and anchorage detailing will be done according to this consideration.

For regular structures, the analysis will be done considering that the total seismic force acts independently in two orthogonal directions. For irregular structures, will be supposed that the seismic force occurs in the direction which results most unfavorable for design of each element or component of the study.

The vertical seismic force will be considered to act upon the elements simultaneously with the horizontal seismic force and on the most unfavorable direction for the analysis.

It will not be necessary to consider the effects of earthquake and wind simultaneously.

When only one element of the structure, wall or frame resists a force equal to 30% or more of the total horizontal force in any story, it will be designed for 125% of that force.

3.2 Structural Earthquake-Resistant Conception

It will be considered that the seismic behavior of the structures improves when the following conditions are observed:

- Symmetry, for mass distribution and stiffnesses as well.
- Minimum weight, especially for higher levels.
- Adequate selection and use of construction materials.
- Adequate resistance.
- Continuity in the structure, in plan and elevation.
- Ductility.
- Limited deformation.
- Inclusion of successive resistance lines.
- Consideration of ground local conditions.
- Good constructive practice and strict structural inspection.

3.3 Building Category

Each structure should be classified according to the categories indicated in Table Nº 3. According to the classification, a use and importance coefficient (U) will be used as defined in the following Table.

TABLE Nº 3 BUILDING CATEGORY		
CATEGORY	**DESCRIPTION**	**U FACTOR**
A Essential Facilities	Essential facilities where their function cannot be interrupted immediately after an earthquake, as hospitals, communications centers, firefighter and police headquarters, electric substations, water tanks. Educative centers and buildings that can be used as sheltering after a disaster. Also are included buildings whose collapse can represent an additional risk, as are inflammable or toxic storage containers.	1.5
B Important Facilities	Facilities for meetings as theaters, stadiums, malls, penitentiaries, or for valuable patrimony as museums, libraries and special archives. Also will be considered grain depots and other important storage facilities for supply.	1.3
C Common Facilities	Common facilities that their collapse causes intermediate losses as dwellings, offices, hotels, restaurants, industrial installations or deposits whose failure do not bring additional dangers as fires, pollutant leaks, etc.	1.0
D Minor Facilities	Facilities whose failure cause small losses and normally the probability to cause victims is low as fence walls lower than 1.50m high, temporal depots, small temporal houses and similar constructions.	(*)

(*) For these structures, under the designer criteria, the seismic force analysis can be omitted, but they should provide adequate resistance and stiffness for lateral actions.

3.4 Structural Configuration

The structures should be classified as regulars or irregulars with the purpose to determine the adequate analysis procedure and the appropriate reduction factor values for the seismic force (Table Nº 6).

a. Regular Structures. They have significant horizontal or vertical discontinuities in their configuration resistant to lateral loads.

b. Irregular Structures. Irregular structures are defined when they present one or more characteristics indicated on tables Nº 4 or Nº 5.

TABLA Nº 4 **STRUCTURAL IRREGULARITIES IN HEIGHT**
Stiffness Irregularities – Soft Floor In each direction the sum of the transversal sections of the vertical elements resistant to shear in any story, columns and walls, is lower than 85% of the corresponding sum for the superior story, or is less than 90% of the average sum for the three consecutive stories. It is not applicable to basements. For buildings which have different story heights multiply the values mentioned above by (h_i/h_d), where h_d is the different story height and hi is the typical story height.
Mass Irregularity It is considered that mass irregularity exists when a story mass is higher than 150% of the mass of the adjacent floor. It is not applicable to basements.
Vertical Geometric Irregularity The dimension in plan of the structure resistant to lateral loads is higher than 130% of the corresponding dimension in an adjacent floor. It is not applicable to basements or rooftops.
Discontinuity in Resistant Systems. Out of line in vertical elements, due to orientation change or by a displacement with a higher magnitude than the element dimension.

TABLE Nº 5 STRUCTURAL IRREGULARITIES IN PLAN
Torsional Irregularity It will be considered only in buildings with rigid diaphragms in which the average displacement story exceeds the maximum permissible in 50% according to table Nº 8. In any of the direction of analysis, the maximum relative displacement between two consecutive floors, on a extreme of the building, is higher than 1.3 times the average of this maximum relative displacement with the relative displacement obtained from the opposed extreme.
Incoming Corners The configuration in plan and the resistant system of the structure, have inward corners, whose dimensions in both directions are higher than 20% of the corresponding total dimension in plan.
Diaphragm Discontinuity Diaphragm with abrupt discontinuities or variations in stiffness, including open areas higher than 50% of the rough area of the diaphragm.

3.5 Structural Systems

The structural systems will be classified according to the materials used and the predominant earthquake-resistant system for each direction as indicated in Table Nº 6.

According to the classification do for a structure a reduction factor for the seismic force (R) will be used. The internal seismic forces should be combined with unitary load factors for ultimate resistance design. In the opposite side, the values indicated in table Nº 6 previous multiplication by the corresponding seismic load factor will be used.

TABLE 6 STRUCTURAL SYSTEMS	
Structural System	**Reduction Coefficient R, For regular structures (*) (**)**
Steel Frames. Steel Frames with resistant moment joints **Other steel frames**. Eccentric bracing systems. Cross bracing systems	 9.5 6.5 6.0
Reinforced Concrete Frames. Frames(1) Dual(2) Structural walls(3) Limited ductility walls(4)	 8 7 6 4
Reinforced or Confined Masonry(5)	3
Wood Constructions (allowable stress)	7

(1) At least the 80% of the base shear acts on the columns that fulfilled with the requirements of the Reinforced Concrete Code NTE E.060. In case it has structural walls, these should be designed to resist a fraction of the total seismic force in accordance with its stiffness.

(2) The seismic forces are resisted by a combination of structural walls and frames. Frames must be designed to take at least 25% of the shear force at the base. Structural walls will be designed for the forces obtained in the analysis indicated in item 4.1.2

(3) System where the seismic resistance is hold by structural walls which support at least the 80% of the base shear.

(4) Low height story edification with high density of limited ductility walls.

(5) For allowable stresses design the R values must be 6.

(*) These coefficients will apply only to structures where the vertical and horizontal elements allow energy dissipation maintaining the stability of the structure. It doesn’t apply to invert pendulum type structures.

(**) For irregular structures, the values for R should be taken as ¾ of those indicated in the table. For ground structures refer to the Adobe Code NTE E.080. These types of constructions are not recommended in soils S3 nor are permitted in soils S4.

3.6 Category, Structural System and Regularity in Buildings

According to the category of a building and the zone where it is located, it should be planned observing the regularity characteristics and use the structural system indicated in table Nº 7.

<table>
<tr><th colspan="4">TABLE Nº 7
CATEGORY AND STRUCTURE OF BUILDINGS</th></tr>
<tr><th>Building Category</th><th>Structural Regularity</th><th>Zone</th><th>Structural System</th></tr>
<tr><td rowspan="2">A
(*) (**)</td><td rowspan="2">Regular</td><td>3</td><td>Steel
Reinforced Concrete Walls
Reinforced or Confined Masonry
Dual System</td></tr>
<tr><td>2 and 1</td><td>Steel
Reinforced Concrete Walls
Reinforced or Confined Masonry
Dual System
Wood</td></tr>
<tr><td rowspan="2">B</td><td rowspan="2">Regular or Irregular</td><td>3 and 2</td><td>Steel
Reinforced Concrete Walls
Reinforced or Confined Masonry
Dual System
Wood</td></tr>
<tr><td>1</td><td>Any system.</td></tr>
<tr><td>C</td><td>Regular or Irregular</td><td>3, 2 and 1</td><td>Any system.</td></tr>
</table>

(*) To achieve the objectives indicated in Table Nº 3, the edification will be structured specially to resist severe earthquakes.

(**) For small rural constructions, like school or medic posts, traditional materials can be used following the recommendations from the corresponding codes for those materials.

3.7 Analysis Procedures

3.7.1 Any structure can be designed using the results from the dynamic analysis referred in item 4.3.

3.7.2 Structures classified as regular according to item 3.4 and of no more than 45m of height and structures of masonry bearing walls of no more than 15m of height, even if they are irregular, could be analyzed through the equivalent static force procedure from item 4.2.

3.8 Lateral Displacements

3.8.1 Permissible Lateral Displacements

The maximum relative story displacement, calculated according to article 4.1.4, should not exceed the fraction of the story height indicated in Table Nº 8.

TABLE Nº 8 LIMITS FOR LATERAL STORY DISPLACEMENTS These limits are not applicable for industrial roofs	
Predominant Material	**(Δ_i / he_i)**
Reinforced Concrete	0.007
Steel	0.010
Masonry	0.005
Wood	0.010

3.8.2 Seismic Separation Joint (s)

Every structure should be separated from other close structures a minimum distance s to avoid contact during an earthquake.

This minimum distance will no be lower than 2/3 of the sum of the maximum displacements of the adjacent blocks, nor lower than:

$s = 3 + 0.004 (h - 500)$ (h and s in centimeters)
$s > 3$ cm.
where h is the height measured from the natural terrain level to the story considered to be evaluate s.

The building will be moved away from the adjacent properties to other lots, or with other facilities, distances no less than 2/3 of the maximum displacement calculated according to paragraph 4.1.4 nor less than s/2.

3.8.3 Building Stability

It will be considered the effect of the eccentricity of the vertical load produced by the lateral displacements of the building, (P-delta effect) as established in item 4.1.5.

Stability to overturning of the structure as a whole should be verified as indicated in item 5.3.1.

4. BUILDING ANALYSIS

4.1 Overview

4.1.1 Seismic Solicitations and Analysis

According to the earthquake-resistant philosophy it is accepted that structures will have inelastic incursions for severe seismic solicitations. Hence it is considered that the seismic solicitations for design are considered as a fraction of the maximum elastic seismic solicitation.

The analysis can be developed using the reduced seismic solicitations along with a model of the elastic behavior for the structure.

4.1.2 Models for Building Analysis

The model for the analysis will consider an adequate spatial distribution of masses and stiffnesses to calculate the most significant aspects of the dynamic behavior of the structure.

For buildings where can be assumed that floor systems work as rigid diaphragms, a lumped-mass model with three degrees of freedom, associated to two orthogonal components for horizontal translation and one component for rotation can be used. For that case the elements deformations must be coordinated through the rigid diaphragm condition, and the distribution of the horizontal forces in plan must be done with the stiffness of the resistant elements in mind.

It should be verified that the diaphragms have enough stiffness and resistance to assure the mentioned distribution, on the contrary, their flexibility for the seismic force distribution should be taken into account.

For stories that do not constitute rigid diaphragms, the resistant elements will be designed for the horizontal forces that directly correspond to them.

4.1.3 Weight of the Structure

The weight (P) will be calculated by adding to the permanent and total load of the structure a percentage of the live load that will be determined as following:

a. For buildings included in categories A and B, 50% of the live load shall be taken.

b. For buildings included in category C, 25% of the live load shall be taken.

c. For depots, 80% of the total weight storaged can be taken.

d. For rooftops and ceilings 25% of the live load can be taken.

e For tank, silos and similar structures 100% of the load they can support shall be considered.

4.1.4 Lateral Displacements

Lateral displacements will be calculated by multiplying by 0.75R the obtained results from the linear elastic analysis using the reduced seismic solicitations. For the calculation of the lateral displacements it will not be considered the minimum values of C/R indicated in item 4.2.3 nor the minimum base shear considered in item 4.3.2.4.

4.1.5 Second Order Effects (P-Delta)

The second order effects must be considered when an increase of more than 10% occurs in internal forces.

To estimate the importance of the second order effects, for each level the following quotient can be used as an stability indicator:

$$Q = \frac{N_i \, \Delta_i}{V_i \, he_i}$$

the second order effects must be taken into account when $Q > 0.1$

4.1.6 Vertical Seismic Solicitations

These solicitations will be considered for the design of vertical elements, in post or pre-tensed elements and for building cantilevers.

4.2 Static Analysis

4.2.1 Overview

This method represents the seismic solicitations through a system of horizontal forces acting in each story of the building.

It can be used only for buildings without irregularities and low heights as established in item 3.7.2.

4.2.2 Fundamental Period

(a) The fundamental period for each direction will be estimated with the following expression:

$$T = \frac{h_n}{C_T}$$

where:

C_T = 35 for buildings with frames as resistant elements in the considered direction.

C_T = 45 for reinforced concrete buildings with frames, elevator boxes and stairs as earthquake-resistant elements.

C_T = 60 for masonry structures and for all reinforced concrete buildings with fundamentally shear walls as earthquake-resistant elements.

(b) Also a dynamic analysis procedure that considers the stiffness characteristics and mass distribution in the structure can be used. As a simple way for this procedure the following expression can be used:

$$T = 2\pi \sqrt{\frac{\left(\sum_{i=1}^{n} PiDi^2\right)}{\left(g\sum_{i=1}^{n} FiDi\right)}}$$

When the dynamic procedure does not consider the effect of non-structural elements, the fundamental period should be taken as 0.85 of the obtained value with this method.

4.2.3 Seismic-Base Shear

The total shear force acting in the base of the structure, corresponding to the direction considered will be determined through the following expression:

$$V = \frac{ZUSC}{R} P$$

the minimum value for C/R should be considered :

$$C/R \geq 0.1$$

4.2.4 Seismic Force Distribution in Height

If the fundamental period, T, is higher than 0.7s, a fraction of the shear force V, denominated Fa, will be applied as a concentrated force at the top of the structure. This force Fa will be determined through the following expression:

$$Fa = 0.07\,T\,V \leq 0.15V$$

where the period T in the expression above is the same as the one used for the determination of the shear force acting in the base of the structure.

The rest of the shear force, in other words (V – Fa), will be distributed along the different levels, including the last one, according to the following expression:

$$F_i = \frac{P_i h_i}{\sum_{j=1}^{n} P_j h_j} (V - Fa)$$

4.2.5 Torsional Effects

The force acting in each level (Fi) will be assumed to be acting in the mass centre of the level considered, as well as the accidental eccentricity effects as indicated as follows.

For each direction of analysis the accidental eccentricity for each level (e) will be considered as 0.05 times the building dimension in the perpendicular direction to the application of the forces.

In each level, in addition to of the actuating force, an accidental moment denominated Mti will be applied ad it will be calculated as:

$$Mt_i = \pm F_i \; e_i$$

It can be assumed that the most unfavorable conditions can be obtained considering only the accidental eccentricities with the same sign for all stories. Only the increases of the horizontal forces can be considered but not the diminutions.

4.2.6 Vertical Seismic Forces

The vertical seismic force will be considered as a fraction of the weight. For zones 3 and 2 this fraction will be 2/3 Z. For zone 1 it is not necessary to consider this effect.

4.3 Dynamic Analysis

4.3.1 Scope

The dynamic analysis of structures can be accomplished through spectral combination procedures or time-history analysis.

For conventional edifications a spectral combination procedure can be used; and for special edifications a time-history analysis must be used.

4.3.2 Spectral Modal Combination Analysis

4.3.2.1 Modes of Vibration

The natural periods and modes of vibration can be determined by an analysis procedure that considers appropriately the stiffness characteristics and mass distribution for the structure.

4.3.2.2 Spectral Acceleration

For each horizontal direction analyzed an inelastic spectra of pseudo-accelerations defined by the following expression will be used:

$$Sa = \frac{ZUSC}{R} g$$

For the analysis in the vertical direction a design spectra with values equal to 2/3 of the design spectra used for the horizontal directions.

4.3.2.3 Superposition Criterion

Through the superposition criteria indicated, the expected maximum response (r) can be determined for the internal forces in the elements of the structure as well as for the global parameters of the structure as are the shear force in the base, floor shears, overturning moments, total and relative story displacements.

The expected maximum response (r) corresponding to the total effect of different modes of vibration used can be determined through the following expression:

$$r = 0.25 \sum_{i=1}^{m} \left| r_i \right| + 0.75 \sqrt{\sum_{i=1}^{m} r_i^2}$$

Alternatively, the maximum response can be estimated through the complete quadratic combination of the values calculated for each mode.

In each direction the modes of vibration considered are those where their effective mass sum is at least 90% of the mass of the structure, but at least the first three predominant modes of vibration in the direction of the analysis should be taken into account.

4.3.2.4 Minimum Shear Force at the Base

For each direction considered in the analysis, the shear force at the base of the building cannot be less than 80% of the calculated value according to item 4.2 for regular structures, nor less than 90% for irregular structures.

If it is necessary to increase the shear force to fulfill the minimum requirements indicated, all other results should be scaled appropriately, except the displacements.

4.3.2.5 Torsional Effects

The uncertainty in the location of the mass centers for each level can be considered through the accidental eccentricity perpendicular to the earthquake direction equal to 0.05 times the dimension of the building in the perpendicular direction to the analysis direction. For each case the most unfavorable sign should be considered.

4.3.3 Time-History Analysis

The time-history analysis can be accomplished by assuming a linear and elastic behavior and no less than five horizontal acceleration registries corresponding to real or artificial earthquakes should be used. These registries should be normalized to get the maximum acceleration that corresponds to the maximum value expected for that site.

For especially important structures the dynamic time-history analysis will be accomplished considering the inelastic behavior of the elements of the structure.

5. Foundations

5.1 Overview

The assumptions done for the supports of the structure will be concordant to the characteristics of the foundation ground.

The design of the foundations will compatible to the obtained force distribution of from the analysis of the structure.

5.2 Bearing Capacity

In every soil mechanics study the effects of earthquakes should be considered for the determination of the bearing capacity of the foundation terrain. In sites where soil liquefaction can occur, a geotechnical research should be done to evaluate this possibility and determine a more adequate solution.

For the calculation of acceptable pressures over the foundation ground under seismic actions, the minimum safety factors indicated in Technical Standard of Buildings E.050 “Soils and Foundations” will be used.

5.3 Overturning Moment

Every structure and its foundation will be designed to resist the overturning moment produced by an earthquake. The safety factor should be higher or equal to 1.5.

5.4 Isolated Footings and Caissons

For isolated footings with or without piles on soils type S3 and S4 and for zones 3 and 2 connection elements will be provided to sustain in tension or compression, a minimum horizontal force equivalent to 10% of the vertical load supported by the footing.

For the case of piles and caissons connection beam should be provided or rotations and strains should be taken into account due to the effect of the horizontal force by designing piles and footings for these solicitations. Piles will have reinforcement in tension equivalent at least 15% of the vertical load they support.

6. NON-STRUCTURAL ELEMENTS, APENDIXES AND EQUIPMENT

6.1 Overview

Non-structural elements are those where their contribution to the stiffness of the system is abject even when they can or cannot be connected to the system resistant to horizontal forces.

In case the non-structural elements are not aisled from the main structural system, these should be designed to resist a seismic force (V) associated to its weight (P) as is following indicated:

$$V = Z\ U\ C_1\ P$$

The values for U correspond to those indicated in chapter 3 and the values for C_1 will be taken from table Nº 9:

TABLE Nº 9 **VALUES OF C_1**	
- Elements that can precipitate outside the building when fail because the direction of the force is perpendicular to its plane. - Elements whose failures involve danger to people or other structures.	1.3
- Walls inside an edification (force direction perpendicular to its plane).	0.9
- Fences	0.6
-Tanks, towers, inscriptions and chimneys connected to a side of the building considering the force coming from any direction.	0.9
- Floors and ceilings that act as diaphragms with the direction of the force in its plane.	0.6

For non-structural elements connected to the main structural system and must go with its deformation, it must be assured that in case of failure, they will not cause personal damages.

The equipment and installation connections inside a building must be responsibility of the corresponding expert. Each expert should assure these equipments and installations will not constitute a risk during an earthquake and, in case he is dealing with essential facilities, he should assure their operability continuance.

7. EVALUATION, RETROFITTING AND STRENGHTENING OF STRUCTURES

7.1 Overview

The structures damaged by earthquakes should be evaluated and repaired in such a way that the possible structural defects that cause the failure can be amended and they can recover their resisting capacity toward a new seismic event, according to the Earthquake –Resistant Design Philosophy as described in chapter 1.

When the seismic event occurred, the structure should be evaluated by a civil engineer, who should determine if the actual state of the building makes necessary its reinforcement, repair or demolition. This study must consider the geotechnical characteristics of the site.

The repairing process should be able to give the structure an adequate combination of stiffness, resistance and ductility and should guarantee its good behavior for future events.

The repairing or reinforcement project will include the details, procedures and constructive systems to be followed.

Criteria and processes to repair and reinforced existing buildings not indicated in this code can be used with the approval of the competent authority.

8. INSTRUMENTATION

8.1 Accelerographs

In all seismic zones, each building project with an area equal or bigger than 10,000 m2, have to be instrumented with a triaxial accelerograph.

Triaxial accelerographs have to be provided by the owner with technical specifications Approved by the Geophysical Institute of Peru

8.2 Location

The instruments will be located in a $4m^2$ room on the lowest story of the building taking into account an easy access for their maintenance; and a proper illumination, ventilation, provided of electric energy, and physical safety and will be identify clearly in the architectural drawings.

8.3 Maintenance

The operative maintenance, parts and components, fungible material and instruments services should be provided by the owners of the building under control of the Geophysics Institute of Peru. The responsibility will be held for 10 years.

8.4 Data Availability

The accelerograms registered by the instruments will be processed by the Geophysics Institute of Peru and incorporated to the National Bank of Geophysical Data.

This information is of public domain and will be available to users by request.

8.5 Requirements for the Project Agreement

To obtain the project agreement, and under the responsibility of the competent officer, the owner will present an installation certificate, expedited by the Geophysical Institute of Peru along with a service contract of operative maintenance of the instruments.

ANNEX

ANNEX Nº 1
SEISMIC ZONFICATION

Seismic zones which divide our Peruvian territory are shown in figure Nº 1.

As follows provinces of each zone are indicated:

Zone 1
1. Department of Loreto. Provinces: Mariscal Ramón Castilla, Maynas and Requena.
2. Department of Ucayali. Province: Purús.
3. Department of Madre de Dios. Province: Tahuamanú.

Zone 2
1. Department of Loreto. Provinces: Loreto, Alto Amazonas and Ucayali.
2. Department of Amazonas. All the provinces.
3. Department of San Martín. All the provinces.
4. Department of Huánuco. All the provinces.
5. Department of Ucayali. Provinces: Coronel Portillo, Atalaya and Padre Abad.
6. Department of Pasco. All the provinces.
7. Department of Junín. All the provinces.
8. Department of Huancavelica. Provinces: Acobamba, Angaraes, Churcampa, Tayacaja and Huancavelica.
9. Department of Ayacucho. Provinces: Sucre, Huamanga, Huanta and Vilcashuaman.
10. Department of Apurimac. All the provinces.
11. Department of Cusco. All the provinces.
12. Department of Madre de Dios. Provinces: Tambopata and Manú.
13. Department of Puno. All the provinces.

Zone 3
1. Department of Tumbes. All the provinces.
2. Department of Piura. All the provinces.
3. Department of Cajamarca. All the provinces.
4. Department of Lambayeque. All the provinces.
5. Department of La Libertad. All the provinces.
6. Department of Ancash. All the provinces.
7. Department of Lima. All the provinces.
8. Constitutional Province of Callao.
9. Department of Ica. All the provinces.
10. Department of Huancavelica. Provinces: Castrovirreyna and Huaytará.
11. Department of Ayacucho. Provinces: Cangallo, Huanca Sancos, Lucanas, Víctor Fajardo, Parinacochas and Paucar del Sara Sara.
12. Department of Arequipa. All the provinces.
13. Department of Moquegua. All the provinces.
14. Department of Tacna. All the provinces.