Chapter 4

Project Design and Construction

1. Introduction

Having selected the correct site for the facility, the time has arrived to design a project that will provide a level of safety commensurate with the performance objective chosen. The protection systems must be feasible to build as well as effectively maintained. Poor design at this stage will hinder the remaining stages of the project to such an extent that it may prove difficult, even impossible, to meet the overall performance objective for the intended facility.

The acceptable level of damage to structural and nonstructural components should be directly linked to the time—and expense—needed for recovery, as defined by the client institution for the various hazards and levels of risk. Table 4.1 shows the acceptable levels of damage to the facility's components in terms of the recovery time for different degrees of risk. While recovery times cannot be guaranteed in advance, the matter must be addressed thoroughly, since it will affect the institution's pressing need to predict when it will be able to recommence operations after a natural disaster has struck.

Table 4.1 Acceptable levels of damage to components

	Intensity of the hazard		Acceptable level of damage	
Recovery time	Credible maximum desired	Minimum recommended	Structural components	Nonstructural components
Immediate (hours)			Minor	Minor
Short (weeks)			Minor to moderate	Minor to moderate
Moderate (months)			Moderate	Moderate
Long (more than one year)			Moderate to severe	Severe
Very long (or never)			Severe	Not considered

The design process involves seven clearly differentiated stages:

- Drafting of a medical-architectural design and construction program;
- Selection of a development team for the preliminary project;
- Development of the preliminary project;
- Selection of the design team;
- Development of the actual project;
- Selection of the building contractor;
- Construction.

In order to implement these stages, it is vital for the client institution, which sets the goals and requirements, to act rigorously in the selection of three key teams:

- The institution's representatives who establish the objectives and reqiremens.
- The execution team, which carries out the various tasks required at each stage;
- The reviewing team, whose job is quality assurance in compliance with the project goals and needs of the client institution.

Chapter 5 describes the various professional disciplines needed for the project, and the standards they must meet. A key part of the quality assurance strategy is the role played by the reviewing team in ensuring that the performance objectives are met. The team must establish coordination mechanisms for evaluating the implementation of the project and the application of the agreed-upon protection measures. At each stage of the design process, and for each service to be provided, the team must evaluate whether the protection objectives have been achieved.

2. Stages in the design and construction of the facility

Stage 1: Drafting of a medical-architectural program

The design process has, as its starting point, a medical-architectural program, defined by the institution, which stipulates the services the new facility will provide and the physical space it will require to do so. The program typically specifies all the services to be provided, the functional areas needed, and the desired dimensions in square meters.

Stage 2: Selection of a development team for the preliminary project

This is the time to define the requirements that must be met by the specialists who will develop the preliminary project. The requirements that this group must meet are presented in *Chapter 5*.

Stage 3: Development of the preliminary project

It is on the basis of this program that the preliminary plan will be drafted, which will define how the services and spaces will be handled. This process must include the definition of the physical characteristics of the facility and its operation.

Taking into consideration the hazards the facility may face, it will be necessary to choose protection methods and systems that can meet the challenges posed by these hazards. For instance, in areas of high seismicity, buildings must be regular in their geometric plan and elevation, and systems that do not lead to sharp deviations in the structural system must be selected. In addition, it is desirable at this stage to establish whether there will be constraints on the form and distribution of the facility as a result of the structure's protection systems. For instance, if a seismic base isolation system is used, a discontinuity at the isolation interface will be required not only throughout the entire floor plan but also in the immediate perimeter in order to accommodate any displacements that may occur. This situation demands the use of special designs that must be considered at this stage. Likewise, in high-wind areas, the type of roof covering and façade elements is highly relevant. In flood-prone areas, meanwhile, it may be necessary to employ fills above the level of reference that would normally not be considered[5].

Usually, more than one preliminary plan will be produced for each facility. The selection of the definitive plan, in addition to any functional and aesthetic considerations that may influence the final choice, should be guided by how thoroughly the existing regional and local risks have been taken into account, along with the necessary solutions to secure the protection objective set for the project. Among the variables to be considered in this assessment, in connection with the protection objective chosen, the following may be listed:

- Ways in which the hazard could affect the facilities;
- Ways in which the preliminary project addresses potential effects of the various hazards;
- Location;
- Shape of structure;
- Structural system and form and degree of protection;
- External services and dependencies;
- Contemplated special protection features;
- Overall design considerations;
- Guarantees that the performance objectives will be met.

Since it is during the preliminary planning stage that the requirements of the medical-architectural program will be interpreted, and formal solutions found for the protection challenges it poses, it is essential that the execution team have enough experience to perform this correctly.

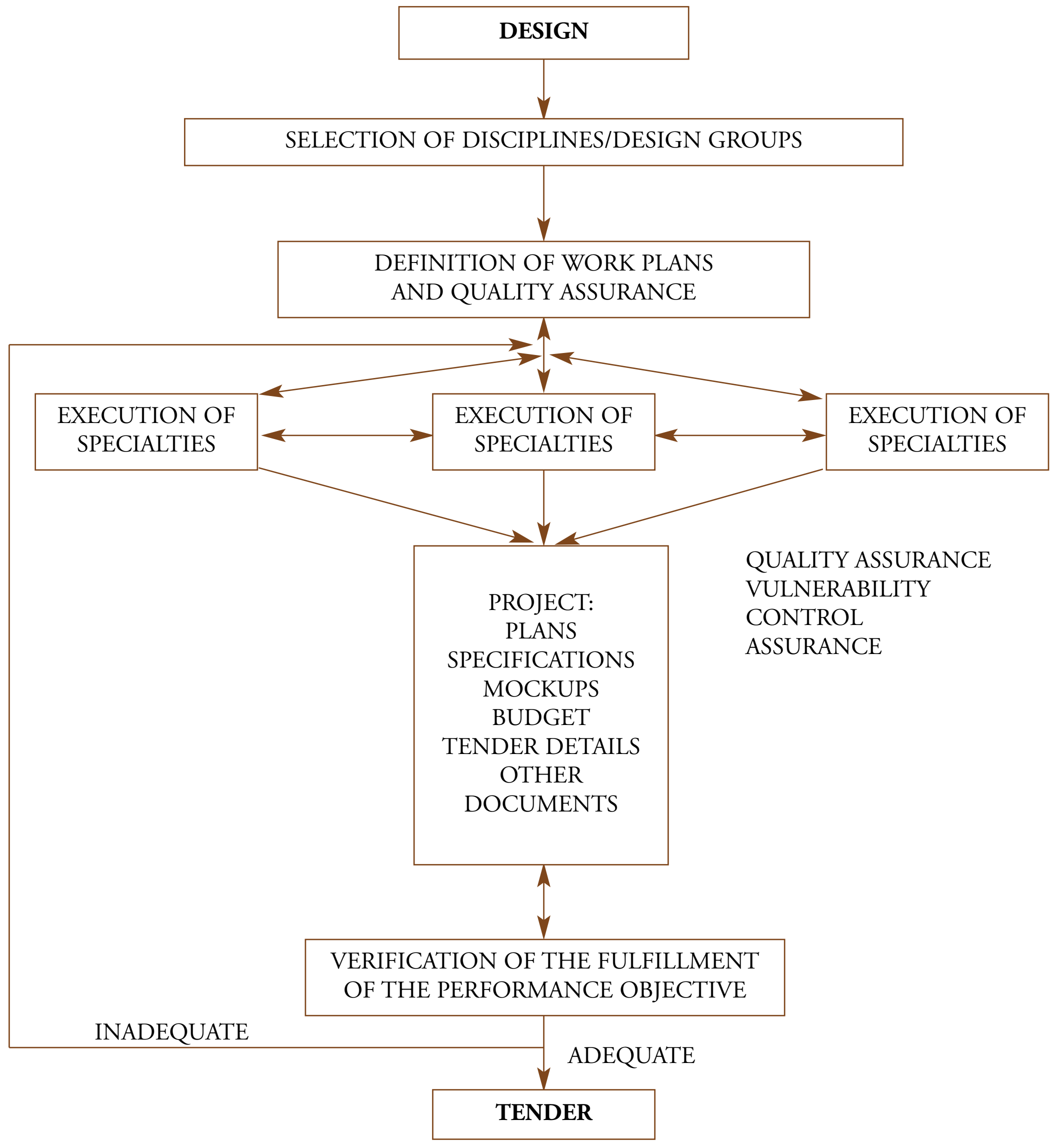
5 *Principles of Natural Disaster Mitigation in Health Facilities* (Pan American Health Organization, 2000), *Disaster Mitigation for Health Facilities: Guidelines for Vulnerability Appraisal and Reduction in the Caribbean* (PAHO, 2000), and *FEMA 55: Coastal Construction Manual* (Federal Emergency Management Agency, 1996), list the basic requirements for each hazard

Stage 4: Selection of the design team

This is the time to define the requirements that must be met by the specialists who will develop the definitive project, and to select the various work groups. The requirements that these groups must meet are presented in *Chapter 5*.

Stage 5: Development of the actual project

The first step in this stage is to carry out the detailed studies needed for the production of the definitive project, which will consist of technical specifications, plans, mockups, and tender documents. The chart below summarizes the necessary steps.



Due to the complexity of any health facility in comparison with ordinary buildings, a large number of professionals grouped by discipline as specified in *Chapter 5, Table 5.3* must participate. Each team of specialists will be in charge of developing a specific subproject: the structure, the heating, ventilation and air conditioning (HVAC) system, the various support services, and so on. Coordination is required for all these activities, and therefore clear procedures and protocols must be defined for the generation and sharing of information. Appropriate coordination is the key to the successful completion of this stage.

From the point of view of vulnerability reduction and the fulfillment of the performance objective, the design coordination team must advise each of the specialized work groups on the functional and protection requirements specified for the facility and its services. Each team of specialists will be called on to prepare a document in which it clearly explains how it will achieve these objectives and, most importantly, what their requirements and restrictions will be in relation to the other disciplines.

The design of the project will be the result of the integration of the work of all the participating disciplines on each section of the contemplated facility, so it bears repeating that coordination is indispensable. The safety criteria chosen for each section have to be the same across all disciplines, and the ways in which these criteria will be satisfied must be established in advance by all teams. The protection systems that will be incorporated must then be included in the construction documents outlining the physical details of the system to be built: the technical specifications and the various plans.

When considering the overall safety of the infrastructure in question, it is common to divide its components in two groups: the structure itself, and the nonstructural elements. Generally, the design team in charge of the structure is proficient in two disciplines: structural engineering and architecture. In the design of the nonstructural elements, all disciplines must be equally involved.

Design of the structure

Characteristics of the structural design

The structural system must meet the protection objectives defined for the facility as a whole and the services it will provide. The structural engineering team is chiefly responsible for the safety of the structure. When the performance objectives of the facility and its services call for investment and functional protection, the team must provide a structural system that not only safeguards the structure itself but also the nonstructural elements. Put differently, the structure not only must protect—it must make it feasible to implement procedures for protecting the nonstructural systems. For this reason, the structural system needs to be approved by all the disciplines represented in the project.

At present, non-traditional structural systems provide different levels of safety both for the structural and the nonstructural elements. For instance, in the case of seismic demand, several hospitals have been built successfully employing seismic base isolation systems, which create an interface between the foundations and the structure through the use of rubber or friction-pendulum bearings that simulate an automobile's suspension system. Such systems keep the seismic energy from reaching the structure, through dissipation, reducing significantly the impact of strong ground motion on the structural and nonstructural elements.

The structural system and its components must be designed to withstand the permanent and potential forces that affect a structure, including its dead load (its own weight) as well as its live load (the structure in operation), its seismic load, wind load, snow or ash load, temperature changes, hydrostatic and hydrodynamic soil factors, total and relative settlements of foundations, and so on, all of which are defined and regulated by existing design standards.

In general terms, the design must incorporate structural detailing that can effectively meet the protection objective for each level of risk. It is also important to incorporate in the design any systems that, in case of damage and functional losses, may enable the facility's services to recover within a predefined timeframe. Given the materials that are employed in construction, there will always be some degree of damage. For instance, damage to reinforced concrete buildings may present itself as fissures, cracking, or the partial or total collapse of the material. However, no level of damage is acceptable if it puts the lives of the users or staff at risk. To the fullest extent possible, moreover, situations must be prevented that can cause panic among the staff and the evacuation of the facility when it is technically unnecessary.

Information provided by the structural design team

The structural design team must provide the information required by the other disciplines for the design of the equipment, systems, and other nonstructural components. In return, it must also be informed by the other teams of any issues that may have a bearing on structural design, such as unusually heavy equipment to be installed in higher stories. Among the information that should be provided by the structural team are such data as story drift ratio, forces acting on the points of support, and acceleration at each level.

The project coordination committee must ensure that this information is taken into account by all the other disciplines working on the design of the project.

Safety assessment of the structural system

The specialists in charge of the structural design of the facility must be able to guarantee that the protection criteria set by the client institution will be met.

The design of nonstructural components

Characteristics of the design of nonstructural components

Nonstructural elements are those components that, while not part of the resistant system of the structure, are crucial to the effective operation of the facility. In the case of hospitals, close to 80 percent of the total cost of the facility goes into nonstructural components, among them architectural elements, medical and laboratory equipment, office equipment, electrical and mechanical-industrial equipment, distribution lines, and basic installations (*Table 4.2*).

Table 4.2 Typical nonstructural components that require protection

Architectural	Equipment and furnishings	Basic facilities
Partitions and interiors	Medical equipment	Medical gases
Façades	Industrial equipment	Industrial gas
Suspended ceilings	Office equipment	Electrical distribution
Roofs or decks	Furniture	Telecommunications
Cornices	Contents of furniture	Vacuum
Terraces	Supplies	Drinking water
Chimneys	Clinical files	Industrial water
Plaster	Pharmacy shelves	Air conditioning
Glass windows		Steam
Appendages		General piping
Canopies		
Antennas		

Source: Boroschek, R. and Astroza, M. *Disaster mitigation in health facilities: nonstructural aspects*, Pan American Health Organization, 2000.

The impact of damage to the facility's nonstructural components may vary. For instance, damage to medical equipment or to the lifelines that supply medical and support services can actually cause loss of lives or—what often amounts to the same thing—the loss of the functional capacity of the facility. While less dramatic, partial or total damage to certain components, equipment, or systems may entail prohibitive repair and replacement costs.

Secondary effects of the damage to nonstructural components are also important, for instance the fall of debris in hallways or escape routes, fires or explosions, or the rupture of water or sewage pipes. Even relatively minor damage, it should be stressed, can compromise aseptic conditions in the affected areas, putting critical patients at risk. Major damage to systems, components, or equipment containing or involving harmful or hazardous materials may force the evacuation of some parts of the facility, resulting in a loss of operational capacity.

Nonstructural components must incorporate a level of protection that is proportional to the performance objective that has been defined for the medical or support service in question, as well as all other services that are directly or indirectly related to them. Each team of specialists must be responsible for the design of the protection systems required by the components of their competence, and must certify, by following the procedures described in *Annex 4.1, Safety assessment of the nonstructural systems*, that the performance objective defined by the institution has been met.

The project coordination committee must ensure that the subprojects designed by the various disciplines are correctly integrated and compatible with each other, and it should hold regular coordination meetings in which representatives of each team are present. Moreover, the coordination committee will be responsible for ensuring that each work group is provided in timely fashion with the most up-to-date information regarding the work of the other teams and the overall progress of the project.

The protection of nonstructural systems calls for a logical sequence: first, interior safety and the stipulation of requirements for the immediate exterior (characteristics of supports, anchoring, etc.); secondly, the safety of the immediate exterior (furnishings, ceilings, supplies and others); and, finally, the safety of the overall structure. The following table summarizes the main ways to

Table 4.3 Main forms of protection

Nonstructural component to protect	Protection provided by:		
	Structure	Architecture	Furnishings
Architectural	✔		
Industrial equipment	✔		
Medical and laboratory equipment	✔	✔	✔
Distribution systems	✔	✔	

Assessing the safety of nonstructural components

Nonstructural components require protection systems that can guarantee the achievement of the performance objective set for the project. Assessing the degree to which the protection goals for the different disaster scenarios have been met may be done in several ways, most commonly through mathematical modeling or certificates issued by the supplier or manufacturer of the component or system.

In the event that the assessment of the protection systems is done through mathematical analysis or modeling, detailed financial reports must be drafted. The records should include the following information: qualifications of the specialist; the type of system, equipment or component; the performance objective for the components; which service area they will be located in; what standards and codes were applied in the analysis; what type of behavior will determine the response of the system (internal safety, support or anchoring element, resistance to tipping over or sliding, deformation, resistance, level of damage it can sustain, interaction with other elements, dependency on other elements, and so on); description of the system, equipment or component (general description, weight, shape, type of material, support systems, drawings of details, certificates of safety issued by the provider or manufacturer, performance in previous earthquakes or other disasters, description of built-in protection systems, etc.); characteristics of the equipment when operating; bracing and anchoring systems; support elements; load considered in the analysis; description of analysis method; main results of analysis (internal stresses, use factors, deformations, stability, etc.); verification of interaction with other elements; certification of fulfillment of performance objectives; and others.

If the safety assessment is to be done by means of certification by the provider or manufacturer, two methods are acceptable. The first will be certification through analysis, which must be accompanied by all the information mentioned in the previous paragraph. The second method will be certification through testing. In that case, a document should identify the lab where the tests were carried out, the standards used, a description of the procedures employed, the load applied and the results, the requirements for certification (conditions of use and operation, conditions of placement and attachment, etc.), conformity with the standards specified in the contract documents and description of limitations and applicability of the certification.

Annex 4.1 specifies the procedures that must be carried out by each team of specialists to assess the effectiveness of the safety systems to be implemented.

The design stage concludes with the production of the final plans, technical specifications, mock-ups, budgets, and tender documents. At this stage, both the design execution team and the project reviewing team must deliver a document certifying that the protection objective has been met.

Stage 6: Selection of the building contractor

The selection of the contractor who will carry out actual construction of the facility must meet all relevant national legislation and standards. Among the selection criteria, the experience of candidate firms in the building of disaster-resistant health facilities should be considered. *Chapter 5* describes the requirements that must be met by the companies interested in bidding for the contract.

Stage 7: Construction

It is at this stage that the protection objectives set for the facility as a whole must be realized. While the project's specifications and plans developed during the design phase should guide the construction process, in practice it is often necessary to introduce modifications or clarify the meaning of certain requirements. In such situations, any request for modifications presented by the contractor must be meticulously evaluated, and any alteration to the original plans should be approved by the client institution, the design team, and the reviewing team. Modifications to the facility's protection objective must be subjected to careful analysis and documented—thereby ensuring that the facility's real operational capacity within the overall health network has been correctly determined. Quality assurance procedures such as those mentioned in *Chapter 6* must now be rigorously followed in order to ensure that protection goals for the facility are met.

References

General protection standards, codes, and reference material

American Society of Civil Engineers, *ASCE 7-98: Minimum Design Loads for Buildings and Other Structures*.

Applied Technology Council, *ATC 51: U.S.-Italy Collaborative Recommendations for Improving the Seismic Safety of Hospitals in Italy*, California, 2000.

Building Officials Code Administrators International, *International Building Code 2000*.

Building Seismic Safety Council (BSSC), *FEMA 368: NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*, Washington, D.C., 2001.

Building Seismic Safety Council (BSSC), *FEMA 369: NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, Commentary*, Washington, D.C., 2001.

Departments of The Army, The Navy and The Air Force, *NAVY NAVFAC P-355.1: Seismic Design Guidelines for Essential Buildings*, Technical Manual, Washington, D.C., December 1986.

Departments of The Army, The Navy and The Air Force, *NAVY NAVFAC P-355.2: Seismic Design Guidelines for Upgrading Existing Buildings*, Technical Manual, Washington, D.C., September 1988.

Deutsches Institut für Normung, *DIN 4149-1: Buildings in German Earthquake Zones; Design Loads, Dimensioning, Design and Construction of Conventional Buildings*, 1981.

European Committee for Standardization, *Eurocode 8: Design of Structures for Earthquake Resistance. Part 1: General Rules, Seismic Actions and Rules for Buildings*, Brussels, 1998.

Federal Emergency Management Agency, *FEMA 276: Example Applications of the NEHRP Guidelines for the Seismic Rehabilitation of Buildings*, Washington, D.C., April 1999.

Federal Emergency Management Agency, *FEMA 310: Handbook for the Seismic Evaluation of Existing Buildings*, Washington, D.C., 1998.

Federal Emergency Management Agency, *FEMA 356: Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, Washington, D.C., November 2000.

Federal Emergency Management Agency, *FEMA 55: Coastal Construction Manual.*

Federal Emergency Management Agency, *FEMA 74: Reducing the Risk of Nonstructural Earthquake Damage, A Practical Guide*, Washington, D.C., September 1994.

International Standard Organization, *ISO 3010:2001: Basis for Design of Structures -- Seismic Actions on Structures.*

International Standard Organization, *ISO 4354:1997: Wind Actions on Structures.*

Office of Statewide Health Planning and Development (OSHPD), *Building Standard Administrative Code, Part 1, Title 24, C.C.R*, December 2001.

U.S. Army Corps of Engineers, engineering Division, Directorate of Military Programs, *TI 809-4: Seismic Design for Buildings*, Technical Instructions, Washington, D.C., December 1998.

Guidelines, codes and references for the design and analysis for the protection of the structural and nonstructural components

Annex 4.2 lists examples of standards, codes and literature to be considered in the design of the protection systems of structural and non-structural components.

Annex 4.1 Safety assessment of non-structural systems

The procedures that should be developed within each discipline for the assessment of the security of the system, equipment and nonstructural components are: 1) proof of security through analysis and design, 2) certification of security by the provider or manufacturer.

The following table lists in detail the content of the financial report needed to certify the safety of systems, equipment and components in the event that the design team chooses to demonstrate safety through mathematical analysis and modeling.

Safety assessment of systems, equipment and nonstructural components through mathematical analysis[1]
Minimum required financial report[2]
Identity of the specialist
Name of the specialist
Specialty
Classification of the system, equipment or component
Architectural element
Lifeline
Medical or laboratory equipment
Industrial equipment
Isolated electrical or mechanical equipment
Distributed electrical or mechanical equipment
Level of protection under consideration
Protection objective for the overall facility and the area where the system, equipment or component is located
Protection objective for the services supported by the system, equipment or component
Protection objective for the system, equipment or component itself
Standards considered in the analysis
National standards
International standards
Other standards specific to the project
Description of the structure where the system, equipment or component will be located
Geometrical dimensions
Number of stories
Height of stories
Estimated load of the various stories of the building
Background on the dynamic properties of the building
Other essential facts

Behavior determining the response of the system, equipment or component
Interior safety
Support element or anchoring
Anchoring
Bracing
Stability (overturning, sliding)
Deformation
Resistance
Highest level of damage tolerated
Interaction with other elements
Dependence on other elements
Other (specify)
Description of the system, equipment or component
General description, function, and dependence on other systems, equipment or components
Weight, distribution of the weight, and location of the center of mass in different conditions of use and operation
Geometrical dimensions
Principal materials and mechanical characteristics
Support systems
With vibration isolation system
Without vibration isolation system
Detail plans or drawings
Interior safety certificate issued by the supplier or manufacturer
Background facts on performance in previous emergencies
Description of built-in protection systems
Systems used for the interior safety of the component
Systems used to increase the safety of the support element
Systems used for anchoring and stabilization
Systems used for damage control
Systems used to prevent interaction with other components
Other systems used to provide safety to the system, equipment or component
Characteristics of the equipment when in operation (evaluate only relevant equipment)
Frequency of operation
Storage capacity
Loads produced during the operation of the equipment
Operational temperature
Operation in corrosive environment
Identification of least favorable actions and load combinations[3]

Bracing characteristics of systems, equipment and components
Description of the structural concept
Angle of the braces
Length of the braces
Profile section of braces
Thickness of the bracing element
Capacity of the material
Elasticity of the material
Distance between braces
Detail plans
Anchorage characteristics of systems, equipment and components
Description of the structural concept
Resistance of the materials
Number of anchoring elements
Diameter of the anchoring elements
Embedded length of the anchoring elements
Plans of the anchoring elements
Characteristics of system, equipment or component support elements
Material
Shape of the elements
Resistance of the materials
Other characteristics of the support elements
Classification of the system, equipment or component
Fundamental period
Rigid equipment or component
High deformability
Limited deformability
Low deformability
Flexible equipment or component
High deformability
Limited deformability
Low deformability
Spatial distribution
Isolated element
Distributed element
Number of points of support
Response
Sensitive to acceleration
Sensitive to deformation
Contents
Hazardous or difficult-to-replace materials
Materials are neither dangerous nor difficult to replace

Interaction with other systems, equipment and components
Not linked
Linked
Dependence on other systems, equipment and components
Independent
Not independent
Other relevant classifications
Method of analysis
Equipment included in structure analysis model
Equipment not included in structure analysis model
Static analysis
Dynamic analysis
Characteristics of (seismic or other) demand
Summary of factors that determine the demand
Return period associated with the expected demand
Damping considered
Factors that may modify the response
Demand as considered in the design
Results
Internal stresses
Utilization factors of bracing elements
Utilization factors of anchoring elements
Estimated deformation
Assessment of the system, equipment or component's bracing or anchoring elements
Stability
Assessment of interaction with other systems, equipment or components
Assessment of potential impacts
Assessment of potential contamination by hazardous or harmful materials
Certification that objectives have been met

Notes: 1 This table applies to architectural elements, industrial equipment, medical and laboratory equipment, lifelines and other components of the services that need to be protected. In the case of each item, the data regarding the equipment or component analyzed should be evaluated individually.

2 The financial report should include all computational processes and the results of the intermediate calculations.

3 In addition to the load generated by the emergency, attention must be paid to the permanent load (the dead load, the live load), the loads caused by equipment ceasing to function, the loads associated with electrical or mechanical failure, the loads derived from the interaction with other equipment or components, and the loads stipulated in the contract.

The following table lists the safety certificates that must be issued by the provider or manufacturer of the standard systems, equipment or components to be employed in the project in case certification is not issued by the professional in charge of designing the project.

Standardized safety assessment of systems, equipment and nonstructural components through certification by the supplier or manufacturer[1]
Analysis-based certification
A financial report must be attached covering the contents specified in Table 5.2, in accordance with the level of detail required by the study. This document will be used for reviewing the safety of the component.
Experimental certification
Identity of accredited laboratory
Standards of reference employed in the tests
Description of test procedures
Demand applied in the tests
Results of the tests
Certification requirements
Conditions of use and operation
Conditions of installation
Other conditions
Date and period of validity of the certificate
Certification of compliance with standards specified in the contract
Description of limitations to, and applicability of, the certification

Notes: 1 This table applies to architectural elements, industrial equipment, medical and laboratory equipment, lifelines and other standard components related to the services that will be protected.

Annex 4.2

Standards, codes and references specific to protection of structural components and nonstructural components

Protection of Structural Components

Natural hazard	Standards, Codes and References Specific to Design and Analysis
Strong winds	American Society of Civil Engineers, *ASCE 7-98: Minimum Design Loads for Buildings and Other Structures*. Building Officials Code Administrators International, *International Building Code 2000*. Deutsches Institut für Normung, *DIN 4149-1: Buildings in German Earthquake Zones; Design Loads, Dimensioning, Design and Construction of Conventional Buildings*, 1981. European Committee for Standardization, *Eurocode 8: Design of Structures for Earthquake Resistance. Part 1: General Rules, Seismic Actions and Rules for Buildings*, Brussels, 1998. Federal Emergency Management Agency, *FEMA 55: Coastal Construction Manual*. Federal Emergency Management Agency, *FEMA 74: Reducing the Risk of Nonstructural Earthquake Damage, A Practical Guide*, Washington, D.C., September 1994. International Standard Organization, *ISO 4354:1997: Wind Actions on Structures*.
Seismic event	American Society of Civil Engineers, *ASCE 7-98: Minimum Design Loads for Buildings and Other Structures*. Applied Technology Council, *ATC 51: U.S.-Italy Collaborative Recommendations for Improving the Seismic Safety of Hospitals in Italy*, California, 2000. Building Seismic Safety Council (BSSC), *FEMA 368: NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*, Washington, D.C., 2001. Building Seismic Safety Council (BSSC), *FEMA 369: NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, Commentary*, Washington, D.C., 2001. Building Officials Code Administrators International, *International Building Code 2000*. Departments of The Army, The Navy and The Air Force, *NAVY NAVFAC P-355.1: Seismic Design Guidelines for Essential Buildings*, Technical Manual, Washington, D.C., December 1986. Departments of The Army, The Navy and The Air Force, *NAVY NAVFAC P-355.2: Seismic Design Guidelines for Upgrading Existing Buildings*, Technical Manual, Washington, D.C., September 1988. Deutsches Institut für Normung, *DIN 4149-1: Buildings in German Earthquake Zones; Design Loads, Dimensioning, Design and Construction of Conventional Buildings*, 1981. European Committee for Standardization, *Eurocode 8: Design of Structures for Earthquake Resistance. Part 1: General Rules, Seismic Actions and Rules for Buildings*, Brussels, 1998. Federal Emergency Management Agency, *FEMA 74: Reducing the Risk of Nonstructural Earthquake Damage, A Practical Guide*, Washington, D.C., September 1994. Federal Emergency Management Agency, *FEMA 276: Example Applications of the NEHRP Guidelines for the Seismic Rehabilitation of Buildings*, Washington, D.C., April 1999. Federal Emergency Management Agency, *FEMA 310: Handbook for the Seismic Evaluation of Existing Buildings*, Washington, D.C., 1998. Federal Emergency Management Agency, *FEMA 356: Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, Washington, D.C., November 2000. International Standard Organization, *ISO 3010:2001: Basis for Design of Structures -- Seismic Actions on Structures*. Office of Statewide Health Planning and Development (OSHPD), *Building Standard Administrative Code, Part 1, Title 24, C.C.R*, December 2001. U.S. Army Corps of Engineers, engineering Division, Directorate of Military Programs, *TI 809-4: Seismic Design for Buildings*, Technical Instructions, Washington, D.C., December 1998.

Protection of Nonstructural Components

Nonstructural Component	Standards, Codes and References Specific to Design and Analysis	Professional Team Required
Isolated (not distributed) electrical and mechanical equipment Industrial equipment	American Petroleum Intitute, *API 650: Welded Steel Tanks for Oil Storage", Washington, D.C.* Deutsches Institut für Normung, *DIN EN 61587-2: Mechanical Structures for Electronic Equipment - Tests for IEC 60917 and IEC 60297 - Part 2: Seismic Tests for Cabinets and Racks (IEC 61587-2:2000)*, 2001. Ishiyama, Y., *Criteria for Overturning of Rigid Bodies by Sinusoidal and Earthquake Excitations*, Earthquake Engineering and Structural Dynamics, Vol. 10, 1981. Institute of Electrical and Electronic Engineers, *IEEE C 37.81: Guide for Seismic Qualification of Class 1E Metal-Enclosed Power Switchgear Assemblies*, New York, 1989. Institute of Electrical and Electronic Engineers, *IEEE C 37.98: Seismic Testing of Relays*, New York, 1987. Institute of Electrical and Electronic Engineers, *IEEE 344-1987: Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations*, New York, 1987. International Electrotechnical Commission, *IEC 60068-3-3: Environmental Testing – Part 3, Seismic Test Methods for Equipment*, 1991. International Electrotechnical Commission, *IEC 60255-21-3: Electrical relays - Part 21: Vibration, Shock, Bump and Seismic Tests on Measuring Relays and Protection Equipment - Section 3: Seismic Tests*, 1988. International Electrotechnical Commission, *IEC 61166-21-2: High-Voltage Alternating Current Circuit-Breakers - Guide for Seismic Qualification of High-Voltage Alternating Current Circuit-Breakers*, 1993. International Electrotechnical Commission, *IEC/TS 61463: Bushings - Seismic Qualification*, 2000. International Electrotechnical Commission, *IEC 61587-2: Mechanical Structures for Electronic Equipment – Tests for IEC 60917 and IEC 60297 - Part 2: Seismic Tests for Cabinets and Racks.*	Electrical engineer Mechanical engineer Seismic engineer Structural engineer Vulnerability assessment specialist Hospital architect Industrial equipment specialist
Pipes, ducts and electrical conduit systems Fire safety systems	National Fire Protection Association, *NFPA 13: Standard for the Installation of Sprinklers Systems.* Sheet Metal and Air Conditioning Contractors National Association, *Seismic Restraint Manual: Guidelines for Mechanical Systems*, second edition, February 1998. Sheet Metal and Air Conditioning Contractors National Association, *Addendum No.1 To Seismic Restraint Manual: Guidelines for Mechanical Systems*, September 2000 WSP 029, *Aseismatic Design Manual for Underground Steel Water Pipelines*, 1989.	Electrical engineer Mechanical engineer Seismic engineer Structural engineer Vulnerability assessment specialist Fire Protection Specialist
Medical and laboratory equipment Furniture	International Electrotechnical Commission, *IEC 60068-3-3: Environmental Testing - Part 3: Guidance. Seismic Test Methods for Equipment"*, 1991. Ishiyama, Y., *"Criteria for Overturning of Rigid Bodies by Sinusoidal and Earthquake Excitations*, Earthquake Engineering and Structural Dynamics, Vol. 10, 1981.	Hospital architect Medical equipment specialist Seismic engineer Structural engineer Vulnerability assessment specialist Furniture designer

Protection of Nonstructural Components

Nonstructural Component	Standards, Codes and References Specific to Design and Analysis	Professional Team Required
Systems of suspended ceilings Lighting fixtures systems	American Society for Testing and Materials, *ASTM E 580: Standard Practice for Application of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Requiring Moderate Seismic Restraint*, 2000. Ceilings and Interior Systems Construction Association, *Guidelines for Seismic Restraint, Direct Hung Suspended Ceilings Assemblies: Seismic Zones 3-4*, 1991. *"Uniform Building Code Standard 25-2: Metal Suspension Systems for Acoustical Tile and for Lay-in Panel Ceiling"*.	Hospital architect Specialist lighting fixtures Seismic engineer Structural engineer Vulnerability assessment specialist
Elevator/escalator systems	American Society of Mechanical Engineers, *ASME A17.1: Safety Code for Elevators and Escalators*, 2000. Deutsches Institut für Normung, *DIN EN 61587-2: Mechanical Structures for Electronic Equipment - Tests for IEC 60917 and IEC 60297 - Part 2: Seismic Tests for Cabinets and Racks (IEC 61587-2:2000)*, 2001. Japanese Elevator Association, *Guide for Earthquake Resistant Design and Construction of Vertical Transportation*. Standard New Zealand, *NZS 4332:1997: Non Domestic Passenger and Goods Lifts*. 1997.	Elevator/escalator specialist Mechanical engineer Electrical engineer Seismic engineer Structural engineer Vulnerability assessment specialist
Roofing structures	Federal Emergency Management Agency, *Against the Wind*, 1993 Federal Emergency Management Agency, FEMA 361: *Design and Construction Guidance for Community Shelters*, Fist Edition, July 2000	Hospital architect Seismic engineer Structural engineer Vulnerability assessment specialist
Partitions and façade elements	American Architectural Manufacturers Association, Aluminum Curtain Wall Design Guide Manual American Architectural Manufacturers Association, Aluminum Store Front and Entrance Manual American Architectural Manufacturers Association, Design Windloads for Buildings and Boundary Layer Wind Tunnel Testing American Architectural Manufacturers Association, Installation of Aluminum Curtain Walls American Architectural Manufacturers Association, Maximum Allowable Deflection of Framing Systems for Building American Architectural Manufacturers Association, Cladding Components at Design Wind Loads American Architectural Manufacturers Association, Metal Curtain Wall Fasteners American Architectural Manufacturers Association, Metal Curtain Wall Manual American Architectural Manufacturers Association, Rain Penetration Control – Applying Current Knowledge American Architectural Manufacturers Association, Structural Design Guidelines for Aluminum Framed Skylights American Architectural Manufacturers Association, Voluntary Specifications for Hurricane Impact and Cycle Testing of Fenestration Products. Federal Emergency Management Agency, Against the Wind.	Hospital architect Seismic engineer Structural engineer Vulnerability assessment specialist
Doors and windows	American Architectural Manufacturers Association, *Glass and Glazing*. Federal Emergency Management Agency, *Against the Wind"*. International Standard Organization, *"ISO 6612:1980:Windows and Door Height Windows Wind Resistance Tests.*	Hospital architect Structural engineer