# RESPONSIBILITIES FOR SEISMIC CONSIDERATIONS WITHIN THE DESIGN TEAM 12

## 12.1 RESPONSIBILITIES OF THE STRUCTURAL ENGINEER, ARCHITECT, AND MEP ENGINEER

Seismic considerations should apply to every building system, subsystem, and component, and the performance of each component or system is often interdependent. The traditional organization of the design team and the assignment of responsibilities to the architect, structural engineer, MEP (mechanical, electrical, and plumbing) consultants, and other specialty consultants (e.g., geotechnical engineer, curtain wall consultant, elevator consultant, or security consultant) is critically important to address cross-cutting seismic design issues or problems.

For example, the seismic design and performance of glazing systems, windows, and curtain walls have improved significantly in recent years through the adoption of improved code provisions for these building systems. These improvements can impact both life safety in an earthquake (broken glass can kill or seriously injure) and immediate occupancy following an earthquake (integrity of the building envelope). The trade-offs involve drift limits, curtain wall clearances and design details, and glazing design. In this example, the architect, structural engineer, and curtain wall consultant must work together closely to arrive at the appropriate designs.

## 12.2 DEVELOPING A UNIFIED APPROACH WITHIN THE DESIGN TEAM

The first step in the design process should be the development, with active participation of the owner, of a set of clear performance objectives that address how the building is expected to perform before, during, and following an earthquake. These performance objectives should be based on owner needs and decisions, and should be expanded into detailed performance statements that apply to every subsystem of the building. Throughout the design development, there should be explicit reviews of each element of the design against the performance statements in order to assure that the completed building meets the expectations articulated in the original performance objectives. In addition, the owner should be encouraged to develop and carry out a risk management plan compatible with the performance objectives.

The term "performance objective," discussed in Chapters 2 and 4, should include a statement regarding the seismic performance that is expected of the building, subsystem, or component that is being addressed. Wherever possible, it should include quantifiable performance criteria that can be measured. For example, an objective may be that a subsystem (such as the HVAC system) should be operable following an earthquake of a certain magnitude. The specific criteria related to this may specify how long the system is expected to operate, under what operating conditions, and with what resulting interior environmental conditions.

## 12.3 ENGINEERING SERVICES FOR ADDED VALUE OF RISK MANAGEMENT

The owner should establish a process in which the risk management function and the facilities management function are fully coordinated in the development of a capital improvement and new construction program. The risk manager should balance seismic risk with all other facility-related risks. In order to do so, the risk manager should have an understanding of seismic risks. Once the risk manager gains such an understanding, the risk manager should be educated to prepare a return-on-investment analysis for investments in seismic performance.

RISK CONSIDERATION

The risk manager should balance seismic risk with all other facility-related risks.

The design team has an opportunity to offer the owner a service of educating the risk manager on the details of seismic risk in buildings. This service could be independent of any specific capital improvement or design project, or it can be offered as a pre-design orientation activity that is linked to a design project.

## 12.4 COMMUNICATING SEISMIC CONSIDERATIONS ISSUES TO THE BUILDING OWNER

RISK CONSIDERATION

Issues of building performance should be communicated to a building owner in terms that relate how the building is expected to perform following an earthquake, and the potential impacts that this level of performance may have on the post-earthquake functionality of the building.

Issues of building performance should be communicated to a building owner in terms that relate how the building is expected to perform following an earthquake, and the potential impacts that this level of performance may have on the postearthquake functionality of the building. In order to accomplish this, the design team must learn to communicate using terminology that is familiar to the owner. This can best be accomplished through interaction with the owner's facilities or risk manager.

It is typically more difficult to explain earthquake risk issues to a building owner, since such considerations are probabilistic in nature, and less specific with respect to magnitude, location, or even how often they will occur. The design team must understand the owner's extent of risk aversion or risk tolerance. The more risk neutral the owner is, the simpler the communication is likely to be, in that various outcomes can be multiplied by their respective probabilities and then communicated directly to the owner. This process, however, becomes more complicated with a more risk averse or tolerant owner. The best way this communication can be accomplished is through close interaction and coordination with the owner's risk or facilities manager.

RISK CONSIDERATION

The design team must understand the owner's extent of risk aversion or risk tolerance.

As the member of the design team who initiates the design concept and develops it through design development and the preparation of construction documentation, the architect should play a key role in the seismic design process. To ensure that consideration of seismic issues occurs with the right degree of priority, and at the right time in the design process, the architect should have a clear conceptual understanding of seismic design issues that impact the design.

The structural engineer's role is to provide the structural design for a building. While the structural engineer must play the major role in providing an earthquake-resistant design, the overall design responsibility is shared between the architect and engineer, because of architectural decisions that may impact the effectiveness of the engineer's design solution and hence the building's seismic performance. The use of performance-based design can reinforce the importance of the recommendation that the architect and structural engineer work together from the inception of a design project, and to discuss seismic issues before and during the conceptual design stage. Many of the critical architectural decisions occur at the conceptual design stage, at which point the building configuration is set and issues such as the nature of the structure and structural materials and architectural finishes are identified.

The concept of structural engineers participating with architects during the early conceptual design phase of a project is not new, yet it is often confined to a cursory conversation or does not occur at all, for a variety of economic, cultural, and professional reasons. Developmental projects often require a partial design in order to procure project financing; at this point, the owner typically attempts to minimize up-front costs and the architect will not involve, or only peripherally involve, structural consultants. Some architects see the structural engineer as providing a purely service role in enabling the architect to achieve the forms and spaces that are desired. In a successful project, the architect and structural engineer typically collaborate on layout and design issues from the inception of the project, in order to ensure that the architectural and structural objectives are achieved.

DESIGN CONSIDERATION

In a successful project, the architect and structural engineer typically collaborate on layout and design issues from the inception of the project.

As the servicing needs of contemporary buildings continue to increase, the impact of the MEP (mechanical, electrical, and plumbing systems) consultant's work on seismic design becomes increasingly important. An example of this is the need for penetrations or blockouts in the structure to accommodate ductwork, piping, and equipment, which requires early design consideration. These penetrations are fundamental to the integration of the structural and mechanical system, and their size and location should be carefully worked out between the architect, structural, and mechanical engineers. There are many instance of damage to buildings in earthquakes caused by structural member penetrations that have not been adequately coordinated with the structural design.

DESIGN CONSIDERATION

There are many instance of damage to buildings in earthquakes caused by structural member penetrations that have not been adequately coordinated with the structural design.

Protecting against nonstructural damage requires clear allocation of roles and responsibilities. An important question is: Is the structural design of mechanical equipment supports the responsibility of the equipment vendor, the mechanical engineer, or the structural engineer? Similarly, is the design of the connections for precast concrete cladding the responsibility of the precast element vendor or the building structural engineer? And, is the layout and design of bracing for ductwork the responsibility of the mechanical contractor or the building structural engineer? If these responsibilities are not called out at the outset of the job, the result will be disputes, extra costs, and potentially serious omissions.

DESIGN CONSIDERATION

Protecting against nonstructural damage requires clear allocation of roles and responsibilities.

### Design-Build and Fast-Track Projects

Large projects are often "fast-tracked" to some degree, with the construction contract separated into a number of bid packages that may be sole-source negotiated or competitively bid. The objective here is to speed the project's overall completion, but the process can substantially complicate coordination of tasks. Among the reasons for this are the following.

- The complete design team may not be in existence before the preparation of construction documents has begun. This arrangement can create problems when decisions early in the project determine design approaches and delegate responsibility to entities who are not yet under contract, or who have had no input into such early decisions.

- Communication among designers during fast-track projects is usually more difficult because the development of separate bidding packages means that the design process is fragmented, rather than one which undergoes continuous evolution. At any stage during design development and contract document preparation stages of a project, a complete set of drawings of the project may not exist.
- Because of demands in the project schedule, the design and fabrication, or preparation of shop drawings, many items are not always thoroughly reviewed by the architect or engineer, and in some cases may not even be submitted to the local building department.

Design-build and fast-track construction can be very efficient for simple projects and for design teams that have a track record in working together, but for more complex projects and for design teams that have not previously worked together, both the design and construction phases of a project will need special attention. The assignment of roles and responsibilities is critical if the performance objectives are to be adequately defined and for integrated seismic design and construction to be achieved.

DESIGN CONSIDERATION

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## *Checklists to Facilitate the Design and Construction Process*

A useful aid for the development of performance objectives and the coordination of the design and construction process within the design team is the use of checklists. These may be maintained by hand for smaller jobs, or computerized for larger or more complicated ones. Checklists can highlight key seismic design issues that require consideration and resolution, and can serve to ensure that all issues are adequately dealt with. The checklists discussed below are suggested as models that may be modified to suit the nature of the design team and the construction delivery process.

Figure 12-1 provides a seismic performance checklist, intended to focus the building owner and the design team on issues related to seismic performance expectations. The checklist presents a set of questions that are used to help the client focus on available seismic performance alternatives, leading to a recorded statement of the client's expectations of seismic performance goals that, hopefully, are in line with available

## SEISMIC EXPECTATIONS

A. Earthquake Performance of Structure

| | Damage | | | |
|---|---|---|---|---|
| **Seismic Shaking Hazard Level** | No Life Threat, Collapse | Repairable Damage: Evacuation | Repairable Damage: no Evacuation | No Significant Damage |
| Low | | | | |
| Moderate | | | | |
| High | | | | |

B. Earthquake Performance of Nonstructural Components

| | Damage | | | |
|---|---|---|---|---|
| **Seismic Shaking Hazard Level** | No Life Threat, Collapse | Repairable Damage: Evacuation | Repairable Damage: no Evacuation | No Significant Damage |
| Low | | | | |
| Moderate | | | | |
| High | | | | |

C. Function Continuance: Structural/Nonstructural

| | Time to Reoccupy | | | |
|---|---|---|---|---|
| **Seismic Shaking Hazard Level** | 6 Months + | To 3 Months | To 2 weeks | Immediate |
| Low | | | | |
| Moderate | | | | |
| High | | | | |

Notes:

| Seismic Shaking Hazard Level | Spectral Acceleration (short period or 0.2 sec) | Spectral Acceleration (long period or 1.0 sec) |
|---|---|---|
| Low | <0.167 g | <0.067 g |
| Moderate | ≥0.167 g and <0.50 g | ≥0.067 g and <0.2 g |
| High | ≥0.50 g | ≥0.20 g |

Figure 12-1 Checklist for seismic expectations. (adapted from Elssesser, 1992))

resources. Agreement on such goals and expectations forms the beginning of a performance-based design procedure and can limit future "surprises" due to unanticipated earthquake damage. The checklist statements can become a part of the project's building program, in a manner similar to statements about acoustical or thermal performance, and can serve as the basis for the use of more formal performance-based design procedures during the design.

Figure 12-2 provides a checklist intended to facilitate a discussion between the architect and the structural engineer on the importance of various building siting, layout, and design issues. The checklist identifies a number of issues that should be discussed and resolved by the architect and structural engineer at the early stages of a new project. The checklist should be used when a conceptual design has been prepared and transmitted to the structural engineer. The checklist is intended primarily to provoke a discussion, and is not intended to be filled in and used as a document of record. Most of the items in the checklist will need varying levels of discussion; the checklist is only intended to identify the existence of a potential problem and indicate the importance and priority, or significance, of the problem.

Figure 12-2 also ensures that all significant issues are covered, and that the architect and structural engineer have reached mutual understanding on the resolution of problems. This is the point at which the structural engineer should explain any issues that are not clear. Similarly, if planning or other constraints appear to have resulted in a questionable seismic configuration or a building with other undesirable seismic characteristics, the use of this checklist will ensure the identification of these characteristics fairly early in the design process, and should open the way to their resolution.

Figure 12-3 provides a list of structural and nonstructural components which are typically included in a building project. It is intended to define the responsibilities within the design team for various aspects of the design, and establishes the scope of work among the major consultants and suppliers. The checklist provides the basis for consultant agreements between the architect, construction manager, and specialist consultants. In most projects, costs and a competitive market tend to limit the time and money available for design. Working within a limited budget and timeframe, current practice is for architects and structural engineers to leave some design tasks to engineers employed by subcontractors and vendors (e.g., the design of precast concrete panels and their connections, prefabricated stairs, and truss assemblies). This

## CHECKLIST TO FACILITATE ARCHITECT/ENGINEER INTERACTION

| Item | Minor Issue | Major Issue | Significant Issue |
|---|---|---|---|
| ***Goals*** | | | |
| Life Safety | | | |
| Damage Control | | | |
| Continued Function | | | |
| ***Site Characteristics*** | | | |
| Near Fault | | | |
| Ground Failure Possibility (landslide, liquefaction) | | | |
| Soft Soil (amplification, long period) | | | |
| ***Building Configuration*** | | | |
| Height | | | |
| Size Effects | | | |
| Architectural Concept | | | |
| Core Location | | | |
| Stair Locations | | | |
| Vertical Discontinuity | | | |
| Soft Story | | | |
| Set Back | | | |
| Offset Resistance Elements | | | |
| Plan Discontinuity | | | |
| Re-entrant Corner | | | |
| Eccentric Mass | | | |
| Adjacency-Pounding Possibility | | | |
| ***Structural System*** | | | |
| Dynamic Resonance | | | |
| Diaphragm Integrity | | | |
| Torsion | | | |
| Redundancy | | | |
| Deformation Compatibility | | | |
| Out-Of-Plane Vibration | | | |
| Unbalanced Resistance | | | |
| Resistance Location | | | |
| Drift/Interstory Effect | | | |
| Strong Column/Weak Beam Condition | | | |
| Structural System | | | |
| Ductility | | | |
| Inelastic Demand Constant or Degrading | | | |
| Damping | | | |
| Energy Dissipation Capacity | | | |
| Yield/Fracture Behavior | | | |
| Special System (e.g., base isolation) | | | |
| Mixed System | | | |
| Repairability | | | |
| ***Nonstructural Components*** | | | |
| Cladding, Glazing | | | |
| Deformation Compatability | | | |
| Mounting System | | | |
| Random Infill | | | |
| Ceiling Attachment | | | |
| Partition Attachment | | | |
| Rigid | | | |
| Floating | | | |
| Replaceable Partitions | | | |
| Stairs | | | |
| Rigid | | | |
| Detached | | | |
| Elevators | | | |
| MEP Equipment | | | |
| Special Equipment | | | |
| Computer/Communications Equipment | | | |

Figure 12-2 Checklist for Architect/Engineer Interaction. (from Elssesser, 1992)

## DESIGN SCOPE-OF-WORK GUIDELINES

Project: ______________________________

| Item | Design | Coordinate | Check | Shop Drawings | Sign/Stamp | Field Review |
|---|---|---|---|---|---|---|
| *Foundation* | | | | | | |
| *Super Structure* Elements and Systems: ___________ | | | | | | |
| ___________ | | | | | | |
| ___________ | | | | | | |
| ___________ | | | | | | |
| ___________ | | | | | | |
| ___________ | | | | | | |
| *Cladding* ___________ | | | | | | |
| ___________ | | | | | | |
| ___________ | | | | | | |
| ___________ | | | | | | |
| *Stairs* | | | | | | |
| *Elevator* | | | | | | |
| *Ceilings* | | | | | | |
| *Equipment* | | | | | | |
| *MEP Systems* | | | | | | |

(Activity: Design, Coordinate, Check, Shop Drawings, Sign/Stamp, Field Review)

Key:

A = Architect

SE = Structural Engineer

MEP = Mechanical, Electrical, Plumbing Consultant

V = Vendor, Subcontractor or Manufacturer of manufactured, assembled or prefabricated components or systems

G = Geotechnical Engineer

___ = Other Specialty Consultant: _______________

___ = Other Specialty Consultant: _______________

Figure 12-3 Checklist for defining project responsibilities. Key professional personnel responsible for various aspects of design should be indicated in the appropriate cell of the check list (adapted from Elsesser, 1992).

checklist can be used to identify where and when these procedures will be used.

Figure 12-4 provides an example that shows how the checklist in Figure 12-3 may be completed for a representative project. This example shows a traditional design and construction process in which the architect plays the key role in design management and project coordination. The assigned responsibilities would vary depending on the nature of the project, the composition of the project team, and the proposed design and construction procedures.

Figure 12-5 provides a list of typical building non-structural components and, similar to Figure 12-2, is intended to delineate the roles and responsibilities of design team members for the design and installation of nonstructural components and systems. In current practice, this area is often unclear and important non-structural protective measures may become the subject of dispute; in some extreme cases, they may be omitted altogether. Both this checklist and that shown in Figure 12-2 are expected to play an important role in establishing the total scope of work for the various project consultants, and in ensuring that important tasks do not fall between the cracks of the various involved design and construction parties.

## 12.5 DESIGN AND CONSTRUCTION QUALITY ASSURANCE

Building codes require that "special inspections" be carried out for specific critical elements of a building during construction. These inspections are intended to assure that a high degree of quality has been achieved in constructing the approved design, and in the manner in which it is intended. As related to seismic design, special inspections typically apply to important construction and fabrication considerations, such as ensuring the use of pre-certified weld procedures and adequate weld quality.

Performance-based seismic design also requires specific performance from nonstructural systems and components in the building. In order to obtain the intended seismic performance in these areas, additional quality assurance activities are needed, above and beyond those typically required by code or employed on normal non-seismic construction projects. The following is a partial list of some nonstructural system components in need of special consideration or inspection.

## DESIGN SCOPE-OF-WORK GUIDELINES

**Project:** Hypothetical*

| Item | Design | Coordinate | Check | Shop Drawings | Sign/Stamp | Field Review |
|---|---|---|---|---|---|---|
| | Activity | | | | | |
| *Foundation* | SE | A | G | SE | SE | A, SE |
| *Super Structure* | | | | | | |
| Elements and Systems: | | | | | | |
| Steel Frame | SE | A | SE | SE | SE | SE |
| Concrete Frame | SE | A | SE | SE | SE | SE |
| Precast or Post-Tensioned Floors | V | SE | SE | SE | V, SE | SE |
| Open Web Joists | V | SE | SE | SE | V, SE | SE |
| *Cladding* | | | | | | |
| Precast, Stone | V | A, SE | SE | SE | V | A, SE |
| Metal | V | A | SE | A | V | A |
| Glass | V | A | A | A | | A |
| | | | | | | |
| *Stairs* | A, SE, V | A | SE | SE | V, SE | A, SE |
| *Elevator* | V | A | SE | A, SE | V | A, SE |
| *Ceilings* | A | A | SE | A | A | A |
| *Equipment* | V | A | SE | A | V, SE | A, SE |
| *MEP Systems* | MEP | A | SE | MEPMEP | MEP | |

*This table represents a hypothetical project and should not be taken as a suggestion for assigning specific responsibilities, which must be uniquely established for each project.

Key:

A = Architect

SE = Structural Engineer

MEP = Mechanical, Electrical, Plumbing Consultant

V = Vendor, Subcontractor or Manufacturer of manufactured, assembled or prefabricated components or systems

G = Geotechnical Engineer

___ = Other Specialty Consultant: _______________

___ = Other Specialty Consultant: _______________

Figure 12-4 Example of completed checklist shown in Figure 12-3. (adapted from Elssesser, 1992)

## NONSTRUCTURAL COMPONENT SEISMIC RESISTANCE RESPONSIBILITY MATRIX

**Who is Responsible for:**

| Type of Nonstructural Component or System | Design | | | | Design Review | | | | | Installation | | | | Observation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Access Floor (raised) | | | | | | | | | | | | | | | | | | |
| Ceilings | | | | | | | | | | | | | | | | | | |
| Suspended T-bar | | | | | | | | | | | | | | | | | | |
| Gypsum Board (hung) | | | | | | | | | | | | | | | | | | |
| Electrical Equipment | | | | | | | | | | | | | | | | | | |
| Busduct / Cable Trays | | | | | | | | | | | | | | | | | | |
| Power Generator | | | | | | | | | | | | | | | | | | |
| Light fixtures | | | | | | | | | | | | | | | | | | |
| Main Service Panel | | | | | | | | | | | | | | | | | | |
| Transformers | | | | | | | | | | | | | | | | | | |
| Elevator | | | | | | | | | | | | | | | | | | |
| Cable guides | | | | | | | | | | | | | | | | | | |
| Escalator | | | | | | | | | | | | | | | | | | |
| Exterior Cladding: | | | | | | | | | | | | | | | | | | |
| EIFS | | | | | | | | | | | | | | | | | | |
| GFRC | | | | | | | | | | | | | | | | | | |
| Metal Panels | | | | | | | | | | | | | | | | | | |
| Precast Concrete | | | | | | | | | | | | | | | | | | |
| Exterior Window Walls | | | | | | | | | | | | | | | | | | |
| Fire Sprinkler System | | | | | | | | | | | | | | | | | | |
| Fluid Tanks | | | | | | | | | | | | | | | | | | |
| Mechanical Equipment | | | | | | | | | | | | | | | | | | |
| Air Handlers | | | | | | | | | | | | | | | | | | |
| Boilers | | | | | | | | | | | | | | | | | | |
| Chillers | | | | | | | | | | | | | | | | | | |
| Cooling Tower | | | | | | | | | | | | | | | | | | |
| Condensers | | | | | | | | | | | | | | | | | | |
| Ductwork / VAV box | | | | | | | | | | | | | | | | | | |
| Fans | | | | | | | | | | | | | | | | | | |
| Furnaces | | | | | | | | | | | | | | | | | | |
| Piping Systems | | | | | | | | | | | | | | | | | | |
| Pumps | | | | | | | | | | | | | | | | | | |
| Interior Partitions | | | | | | | | | | | | | | | | | | |
| Other Equipment | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| Stairs | | | | | | | | | | | | | | | | | | |
| Storage Racks | | | | | | | | | | | | | | | | | | |
| Veneer | | | | | | | | | | | | | | | | | | |
| Brick | | | | | | | | | | | | | | | | | | |
| Stone | | | | | | | | | | | | | | | | | | |
| Water Heater | | | | | | | | | | | | | | | | | | |

Figure 12-5 Checklist for responsibility of nonstructural component design. (from ATC/SEAOC Joint Venture, 1999)

- Inspection of the anchorage and bracing of architectural and mechanical elements.
- Labeling of fenestration products to ensure that they have been provided as specified, and inspection to ensure proper installation.
- Inspection of ceiling and partition attachments.
- Inspection of special equipment.

The report, *ATC-48, Built to Resist Earthquakes: The Path to Quality Seismic Design and Construction* (ATC/SEAOC, 1999), provides comprehensive guidance on issues pertaining to the quality design and construction of wood-frame, concrete, and masonry buildings, and anchorage and bracing of non-structural components.

RESOURCES

**Design and Construction Quality Assurance**

ATC-48, *Built to Resist Earthquakes: The Path to Quality Seismic Design and Construction* (ATC/SEAOC, 1999).