The Other 80 Percent: Strategies for Delegating Design of Nonstructural Systems

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Abstract

The design of nonstructural systems is often delegated by the Structural Engineer of Record to a third-party engineer. This is despite evidence that the seismic performance of nonstructural systems is as consequential to loss of life, repair cost, and downtime as the seismic performance of the structure itself.

This paper provides strategies for the Structural Engineer of Record to implement in managing the delegated design of nonstructural systems to achieve nonstructural performance consistent with the overarching performance objectives of the building.

Introduction

Structural Engineers take responsibility for the seismic performance of structures, spending months and sometimes years analyzing and detailing structural systems to meet defined target performance objectives. How can the same level of performance be achieved in the nonstructural systems when responsibility for their seismic design is delegated to others?

Nonstructural systems, such as cladding, interior partitions, suspended ceilings, mechanical, electrical and plumbing equipment, utility distribution systems, specialty components, and contents can comprise 80% or more of the building's value. Poor seismic performance of these elements can cause injury, block egress, impact life safety systems, disrupt operations, delay reoccupancy and result in substantial property loss. Past earthquakes have demonstrated that damage to nonstructural systems can render undamaged structures unusable. [OSHPD, 1996; FEMA, 2015]

Despite their importance to building function, it is often most efficient and in the project's best-interest for selected nonstructural systems to be designed by someone other than the Structural Engineer of Record (SEOR). This paper presents strategies that the Structural Engineer of Record can implement to effectively delegate a nonstructural design to others. It also identifies the roles and responsibilities of the SEOR, including:

1. Identifying which nonstructural systems to delegate;
2. Aligning performance objectives for each nonstructural system with the overarching performance objectives for the building;
3. Verifying the compatibility of proposed structural and nonstructural systems;
4. Creating performance specifications that communicate detailed design requirements for each nonstructural system;
5. Coordinating with the Specialty Structural Engineer to review the basis of design for the nonstructural system;
6. Reviewing and tracking submittals; and
7. Providing Structural Observation during construction.

Although design of nonstructural systems may be delegated, their design is critical to the seismic performance of a building and requires the focused attention of the SEOR. In addition to appropriate technical criteria, clear communication and proper management of delegated designs is needed to achieve nonstructural performance that meets the goals and expectations established for the project.

Delegated Design

"Delegated design" refers to any structural design performed by an engineer other than the SEOR. This engineer is sometimes referred to as the "Component Engineer of Record" or the "Delegated Engineer". For the purposes of this paper, this engineer is referred to as the "Specialty Structural Engineer" (SSE).

A delegated design may be submitted as part of the permit submittal. For example, the design of a fire protection system may be performed by an SSE and submitted for permit along with the balance of the construction documents. Oftentimes, a delegated design is prepared during construction. In this case, the delegated design is handled as a "deferred submittal", i.e. a submittal that follows issuance of the initial building permit.

Selecting Nonstructural Systems to Delegate

The SEOR's job of managing and coordinating delegated designs begins at the start of any project. In order to determine the SEOR's scope of services and related fee, decisions on what to delegate are ideally made at project commencement. These decisions may require the input of the owner, architect, contractor, MEP consultants, and the SEOR. What systems to delegate depends on a number of factors including the experience and expertise of the SEOR, the complexity of the nonstructural system, the project performance objectives, the project delivery method, and existing relationships between design-build teams and specialty engineers.

Nonstructural systems that are commonly delegated include exterior cladding, stairs, interior partitions, suspended ceilings, MEP equipment, utility distribution systems, and specialty components.

Structural systems, such as temporary and permanent shoring, precast elements, and connection design, can also be delegated. This paper focuses on nonstructural systems, but many of the concepts are similar for delegating design of structural systems or components.

Performance Objectives

In order to establish the performance objectives for a nonstructural system, the desired objective(s) for the building as a whole must be defined. The building code establishes a de facto set of minimum performance objectives based on building occupancy and seismic hazard. For ordinary buildings the objectives are mainly focused on avoiding serious injury or loss of life following the Design Earthquake and achieving an acceptable margin against collapse in the Maximum Considered Earthquake. For essential services such as hospitals or emergency service centers, the building code establishes minimum requirements intended to maintain essential building functions following the Design Earthquake.

An owner may select enhanced performance objectives that exceed the code minimums. For example, the owner of a research laboratory may select performance objectives that target protection of irreplaceable specimens. A manufacturer may select objectives focused on business recovery or protection of expensive equipment.

With an understanding of the building's overarching performance objectives, the SEOR, in conjunction with the design team, can develop performance objectives for each nonstructural system. For example, if a research laboratory establishes the goal of protecting irreplaceable specimens in a design level earthquake, certain nonstructural systems will need to remain operational, such as power for refrigeration. Damage to other non-essential nonstructural systems may be acceptable.

The process of identifying the appropriate project-specific performance objective for each nonstructural system or component typically requires the collaborative effort of structural, mechanical, electrical, and plumbing design professionals, contractors, architects, and the owner. Some design teams find it useful to document the selected performance objectives and related nonstructural design requirements in a table similar to that shown in Figure 1. The list of systems and equipment can be more granular to account for different performance objectives for different parts of a building. For example, HVAC systems for office spaces need not be designed for the same level of protection as HVAC systems for critical laboratory spaces or manufacturing processes. Note that performance objectives at the MCE_R need not be defined unless damage to the component or system poses a safety risk to large numbers of people or an unacceptable risk to the owner.

Compatibility of Structural and Nonstructural Systems

Once structural and nonstructural performance expectations are established, the structural and nonstructural systems can be selected and checked for their ability to achieve the defined objectives. Demands imposed on nonstructural components are directly dependent on the seismic response of the structure. There are practical limitations to the level of shaking and/or deformation that a nonstructural component is able to withstand and remain functional. The performance of any nonstructural system in a building is therefore highly dependent on the design of the structure.

For example, cladding systems must be designed to accommodate seismic building deformations. When post-earthquake functionality is a desired objective, limits will be placed on the amount of acceptable damage to the cladding following the Design Earthquake. This goes beyond preventing falling hazards and includes the condition of the cladding as it relates to protection from the environment and its damage state. If the selected structural system is particularly flexible, it may not be possible to use certain cladding systems without significant modification, which may add to costs. The SEOR should understand the nature of the cladding system(s) selected for a project near the outset of design. In particular, the SEOR should understand the drift tolerance of the system(s) in order to verify that the structural system and cladding systems will be compatible and that the desired performance objective for the cladding can be achieved.

Performance Objectives – Research Lab w/ Irreplaceable Specimens

		Frequent Earthquake	**Design Earthquake**	**Maximum Considered Earthquake (MCE_R)**
Overarching Performance Objectives	Safety	Prevent minor falling hazards	Prevent minor falling hazards	Prevent significant falling hazards
	Property	No structural damage	Limited/easily repairable structural damage	Prevent major structural damage
	Function	Maintain all building function	Maintain all building functions required to protect specimens	Enable specimens to be retrieved within 72 hours
Performance Objective of Individual Nonstructural System	Cladding System	No damage	No damage that would compromise environmental protection inside the building; No damage that requires removal and replacement of the cladding for repair	Prevent significant falling hazards
	Refrigerators Containing Specimens	Maintain intended function	Maintain intended function	Enable specimens to be retrieved
	Emergency Power Systems	Maintain intended function	Maintain intended function	
	HVAC Systems	Maintain intended function	Maintain intended function	
	Ceilings in Office Areas	Limited damage	Prevent falling hazards	

Figure 1 – Translating Building Performance Objectives into Performance Objectives for Individual Nonstructural Systems

Another example of structural and nonstructural compatibility relates to equipment. Equipment that must be functional after an earthquake is often qualified by shake table testing. Manufacturers provide certification of operability to a specified level of shaking. If the floor accelerations anticipated in a building exceed those for which a particular piece of equipment has been certified, alternate design strategies need to be considered, such as reducing accelerations with base isolation, moving the equipment to a lower floor level, or selecting alternate equipment.

In both of these examples, it is important for the SEOR to address the structural/nonstructural coordination relatively early in the design process in order to avoid potential significant changes late in design.

For most delegated designs, the design intent is shown on the drawings of the specifying discipline. For example, cladding is shown on the architectural drawings and utility distribution systems are shown on the MEP drawings. The SEOR should review the full drawing set at each design phase to verify that the chosen nonstructural performance objectives are achievable.

Performance Specifications

Once compatibility of the proposed structural and nonstructural systems is verified, the performance objective(s) for the nonstructural systems needs to be translated into design criteria.

The specifications set forth the detailed requirements for the delegated design. The SEOR is typically best qualified to translate the seismic performance objectives into design force and drift requirements. At a minimum, the design criteria include minimum seismic force and drift requirements, minimum qualifications of the SSE, submittal requirements, and a description of testing and inspection requirements. See Figure 2 for sample specifications listing submittal requirements for a delegated design.

For more complicated systems or performance objectives, the design criteria may be more complex. The performance objectives for some systems such as cladding are typically defined at several levels of drift. Testing and Inspection criteria should reflect the desired level of performance. Special prototype testing may be warranted to verify performance.

1.	For all equipment to be anchored or braced, submit a coordinated set of seismic restraint shop drawings for review by the registered design professional in responsible charge of the project prior to installation including: A. Description, layout, and location of items to be anchored or braced with anchorage or brace points noted and dimensioned. Drawings shall show system and equipment layout, spacings, sizes, thicknesses, and types of cold-formed metal framing, fabrication, and fastening and anchorage details, including mechanical fasteners. Show supplemental framing, strapping, bracing, bridging, splices, accessories, connection details, and attachment to adjoining work. B. Numerical value of design gravity and seismic loads shall be identified. C. Details of anchorage or bracing with all members, parts, brackets, shown, together with all connections, connectors, bolts, welds, etc. shall be identified.
2.	For all piping, ductwork and conduit, cable tray, and busway to be braced, include the following with the shop drawing submittal: A. Single-line routing diagrams (plans) on a floor-by-floor basis and riser elevations. B. Type of pipe and pipe contents. C. Structural framing providing vertical and lateral support. D. Maximum spacing of gravity load pipe supports. E. Location of all seismic bracing. F. Numerical value of applied seismic brace loads. G. Numerical value of gravity plus seismic loads on hangers located at seismic brace or anchor locations. H. Details illustrating all support and bracing components, methods of connections, and specific anchors to be used.
3.	Seismic design calculations prepared and sealed by the registered professional engineer responsible for the restraint design.
4.	"Special Seismic Certification" for all required components in accordance with ASCE 7.
6.	Where welding is required for seismic restraint, provide welder certificates and welding procedure specifications in accordance with AWS D1.1 or AWS D1.3.
7.	Written Quality Assurance plan.

Figure 2 – Sample Requirements for a Delegated Design Submittal

In some cases, the performance objective for a system needs to be broken-down into design criteria for each component. For example, a performance objective of continued operation for fire protection systems needs to clarify exactly what components are essential to that system. If a fire alarm control panel is necessary to maintain operations of the fire protection system, the power source for the panel would also be classified as essential. This requires multi-disciplinary input from the extended project team. In order to document consensus design decisions and facilitate compliant delegated designs, it can be useful to create a matrix listing each component and its associated importance factor, seismic certification requirement, and submittal requirements. See example template in Figure 3.

When a portion of a delegated design is shown on the permit drawings to communicate design intent, it is essential to clearly communicate to the SSE whether design of the elements shown on the drawings is in the SEOR's or other design professional's scope or is the responsibility of the SSE. For example, when cold formed steel partition details are shown on architectural drawings but the specifications indicate that cold formed metal framing is a delegated design, it can lead to confusion. It should be made clear whether the drawings indicate minimum design requirements that must be followed or general design intent that may be superseded.

The SEOR should consider what information is needed to provide a complete design that satisfies the performance objective. The SEOR should then verify that this information is provided within the project drawings and specifications. It is critically important that all relevant performance specifications be coordinated for consistency and completeness. This can be easy to overlook with expedited design schedules and multiple bid packages, but it can lead to cost and schedule overruns if not prioritized.

It is helpful for the SEOR to have an understanding of the industry standard for each system being delegated. With this understanding, the SEOR can parse out what additional requirements beyond industry standard need to be specified to reach performance objectives beyond code level design. The SEOR can then also avoid including unachievable design criteria in the project specifications.

Design Criteria – Electrical System Components

		I = 1.5			**I = 1.0**	**Special Seismic Certification**	
Component	Delegated Design?	Contains Hazardous Materials	Serves emergency power system or otherwise required for life-safety purposes	Significant threat to recovery efforts if damaged	All other components	Per ASCE 7-10 Section 13.2.2	Required to meet project performance objectives
Generator							
UPS							
Switchgear serving emergency power							
All other switchgear							
Motor control system							
Conduit and cable tray							
Lighting							
Etc.							

Figure 3 – Sample Matrix for Defining Component Requirements

Coordination Between the SEOR and the SSE

For complex systems, it may be desirable to have a coordination meeting between the SEOR and SSE to review basis of design prior to formal submittal of the delegated design. In some cases, this meeting may require participation by the full design team and contractor.

For deferred submittals, this can take place as a preconstruction meeting. Where the design of the nonstructural system needs to be carefully coordinated with the design of the structure, it is ideal to engage the SSE early in the project and have this meeting during the design phase.

Even with the most carefully crafted specifications, some interpretation may be necessary. A consistent understanding of the basis of design will facilitate future review of the delegated design submittal. It can also reduce the number of resubmittals required, consequently saving time during construction. Additionally, it can help avoid changes to the structure during construction that may be triggered by the SSE's final design. Clear performance objectives and design criteria can reduce disputes between the SEOR and SSE over what constitutes an acceptable design.

Review Process

For most nonstructural delegated designs, the SSE will submit a package including drawings and calculations. The drawings and calculations are stamped and signed by the SSE. If the design is deferred, this will occur during construction.

The SEOR will review each delegated design submittal. The SEOR checks the design to verify it satisfies the design criteria and is consistent with the design intent. The SEOR also checks the structure for loads imposed by the nonstructural system. The SEOR may elect to perform a more detailed review of the submittal based on a wide range of factors including the consequences of improper design, the quality of the documents based on initial review, the complexity of the system and the desired performance objective.

To indicate acceptance, it is common for the SEOR to either provide a review letter or to affix a shop drawing stamp on the drawings or transmittal. This letter or stamp should include language that indicates that the review is limited to the following:

1. Determining general compliance of the design with the design criteria; and

2. Checking the adequacy of the primary structure to resist loads imposed by the system or component.

Sample language for a limited review stamp is shown in Figure 4.

> LIMITED REVIEW
>
> ABC Structural Engineers has reviewed this shop drawing submittal and/or calculations prepared by the Specialty Structural Engineer with the primary intent of determining the system's and/or component's general compliance with the contract documents and the project-specific design criteria. ABC Structural Engineers has reviewed the adequacy of the primary structure to resist loads imposed by the system or component as presented in this submittal. Liability for the structural design of the system and/or components included in this submittal remains fully with the Specialty Structural Engineer responsible for the design. ABC Structural Engineers does not guarantee the correctness or completeness of designs or calculations produced by others.

Figure 4 - Sample Limited Review Stamp

In order to review the design, the SEOR needs to understand the system well enough to determine if the design is reasonable and appropriate for the project. If the system is complex and outside the of the SEOR's expertise, a third-party peer review or consultation may be warranted.

Following review by the SEOR, the design is typically submitted to the building department for review and approval. If the building department has comments on the submittal, the SSE should address the comments and the SEOR should review any revisions.

Construction Administration

Achievement of project performance objectives requires not only appropriate design, but also proper installation. The California Building Code requires "the registered design professional in responsible charge" to prepare a statement of special inspections.

> **1704.3 Statement of special inspections.** Where special inspections or tests are required by Section 1705, the registered design professional in responsible charge shall prepare a statement of special inspections in accordance with Section 1704.3.1 for submittal by the applicant in accordance with Section 1704.2.3.

Figure 5 - 2016 California Building Code Section 1704.3

The SEOR, or a designee, is generally responsible for establishing which special inspections are required by code. The SEOR is responsible for identifying special structural inspection requirements for all systems, regardless of whether they are designed by the SEOR or by an SSE. The SEOR, or designee, is also responsible for identifying any additional quality assurance measures that are deemed appropriate to achieve the performance objectives established for the project. When seismic performance objectives include continuity of operations, inspections, tests and Structural Observations exceeding minimum code requirements will generally be needed to achieve a high level of reliability that the performance will be achieved.

During construction, the SEOR will perform Structural Observation to confirm that the work is in general accordance with the approved plans and design intent. The observation of delegated designs may be waived if measures are in place for the work to be overseen by qualified specialty engineers or inspectors. However, SEORs may elect to observe installations for all components to confirm that they have been installed in an acceptable manner.

The role of the SEOR in the delegated design process from project start to project completion is illustrated in Figure 6.

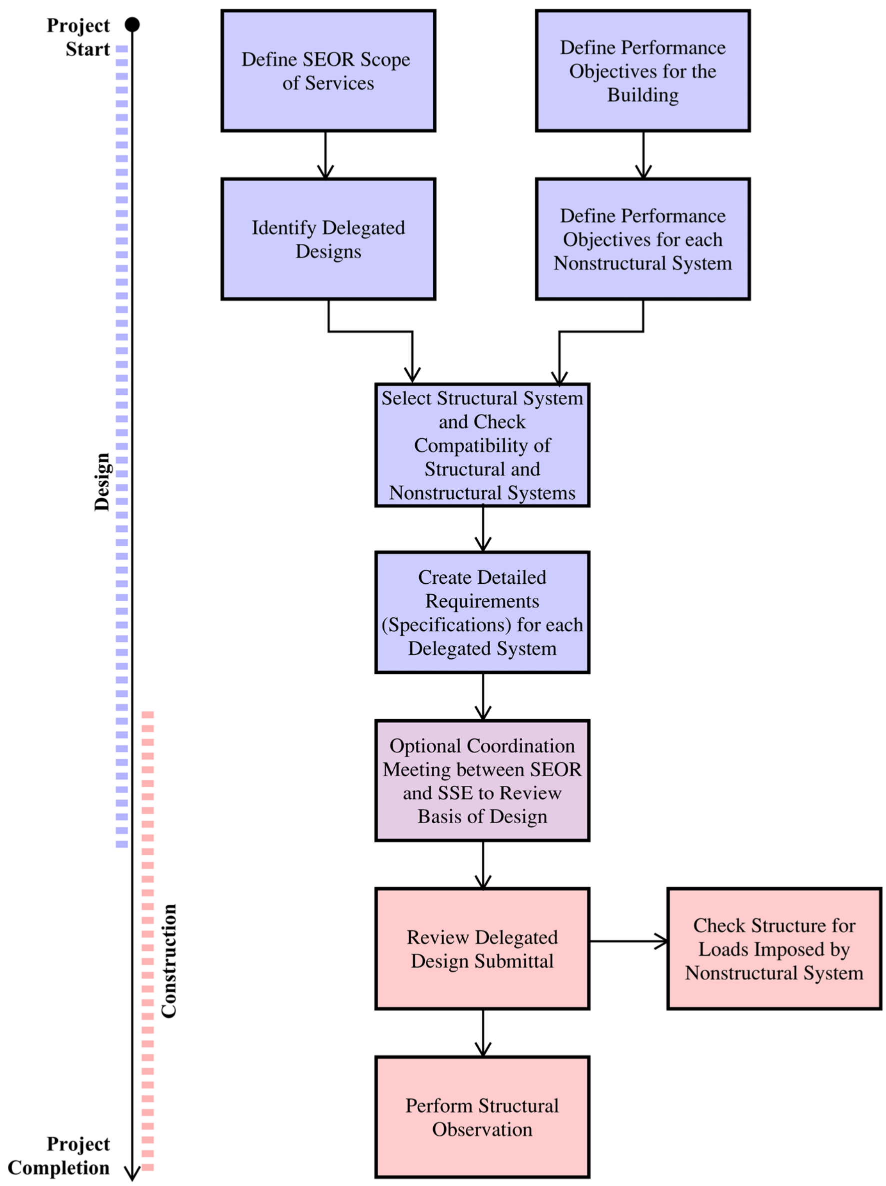

Figure 6 - SEOR’s Role in Delegated Design Process

System-Specific Considerations

Metal Stairs

Stairs are required for life-safety purposes after an earthquake, and are therefore required by code to be designed with a component importance factor of 1.5. The SEOR will need to specify the basis of design including project-specific seismic design criteria and the required interstory drifts. This information is typically included on the structural drawings and/or in the stair specification.

Within the specifications, there should be clarity about the responsibility for design of treads, handrails, and guardrails as well as any secondary stair framing that may be required.

The SSE for the stairs will provide stamped and signed drawings and calculations for the stair design. The submittal should clearly state loading imposed on the structure from the stair to expedite the SEOR's check of the structure. The SEOR will review the submittal for compliance with the design criteria. The SEOR's check should include confirmation that interstory drifts have been appropriately designed for.

Exterior Cladding

Simple and conventional cladding systems are commonly designed by architects and engineers for out-of-plane forces and drifts mandated by building codes. However, many buildings contain multiple cladding systems, with a variety of materials, and a combination of rocking and sliding systems. Most building engineers do not have the expertise to create constructible cladding details that can reliably achieve desired goals for safety, damage protection, and environmental control. Consequently, cladding systems are often delegated to specialty engineers.

For buildings designed for damage control, it is particularly important for the SEOR to provide clear cladding design concepts and performance objectives. From a structural perspective, this may include providing clear direction on the location(s) of sliding joints. It should also include a statement of acceptable performance under multiple loading conditions, which may correspond to frequent earthquakes, the Design Earthquake and the Maximum Considered Earthquake.

One example of cladding performance objectives follows:

1. When subjected to 0.5% interstory drift in any direction: No glass breakage or glass fallout is allowed, all functions remain unimpaired with no visible damage or loss of weather-tightness. No wall components may fall off or disengage.
2. When subjected to 1.0% interstory drift in any direction: Deformation, yielding, or damage to wall elements and framing members is allowed as long as no elements disengage from the specimen. Glass cracking or breakage up to 10% is allowed but glazing shall remain retained completely in framing with no glass fallout. System anchorage may deform, but catastrophic failure or disengagement cannot occur. Sealants may tear, glazing gaskets, and weathering gaskets may disengage.
3. When subjected to 1.5% interstory drift: Deformation or damage of framing members, and/or breakage of glass and metal panels is acceptable. Glass is expected to remain retained in framing. No wall elements become dislodged. System anchorage may deform, but catastrophic failure or disengagement does not occur.

In cases where there are defined damage control objectives for cladding and a high reliability is desired, mockup testing of representative cladding types should be considered.

Utility Distribution Systems

The seismic protection of utility distribution systems is often a delegated design. It is commonly deferred until system subcontractors are under contract and routing of utility systems is confirmed, typically during the construction phase of a project.

Design and implementation of seismic bracing for suspended utilities is prone to construction delays and disputes if responsibility for design is ambiguous, requirements for design are not explicit and/or the scope of systems requiring engineered seismic bracing is not clear. Specifications prepared by mechanical, electrical, plumbing, telecommunications or other engineers must be reviewed by the SEOR for complete and accurate specification of seismic performance criteria. Alternatively, some Structural Engineers elect to create a dedicated specification for delegated nonstructural designs, which is cross-referenced from other specification sections to avoid conflict and inconsistencies.

When the minimum requirements of the code are specified, it is important for the SEOR to be sufficiently familiar with the code requirements to identify what systems require engineered bracing, which require non-engineered sway bracing and which are exempt from bracing requirements.

When higher performance is desired, it must be expressed in a manner that the SSE is able to understand and execute. This may entail bracing more utilities, designing for a higher force, adding more shut-off valves, installing more flexible connections and/or providing other protective measures.

Project requirements should be clearly expressed on the drawings and/or in related performance specifications.

MEP Equipment

Seismic anchorage of MEP equipment is often deferred since specific models of equipment are selected during the construction phase following selection of MEP contractors. A specialty engineer is often retained to design the required seismic anchorage and bracing.

Similar to utility distributions systems, clear and consistent design criteria is needed. Design forces and interstory drifts should be specified by the SEOR. In addition, when required, the need for Special Seismic Certification should be specified. Equipment that must remain operable following the Design Earthquake is defined as a "designated seismic system" and is required by code to be qualified by shake table testing or other acceptable means. For buildings electively designed to higher performance objectives, additional equipment may require Special Seismic Certification. The requirement for Special Seismic Certification should be clearly specified, typically in equipment schedules prepared by the specifying discipline.

The floor/roof accelerations anticipated in a building can exceed those for which a particular piece of equipment has been seismically certified. Response history analyses of buildings in areas of high seismicity can predict extreme levels of shaking, particularly at roof levels. If equipment is not qualified for the anticipated levels of shaking and desired performance, alternate design strategies would need to be considered.

Ceilings and Partitions

Details for ceilings and partitions can be shown by the architect on the permit drawings, or can be delegated as a deferred design. Even when the design of ceilings and partitions is delegated, the architect will need to provide sufficient information on the drawings to specify fire ratings, sound transmission class, size, locations, and finish. It is important to distinguish minimum requirements from concept or suggested details.

When partitions are used as part of the load path for support and seismic protection of equipment or furniture, the delegated designer will need to address this as part of their scope of services. It is important to assign someone to oversee the delegation of responsibility to ensure that all conditions are addressed, since it is easy for oversights to happen. The performance specifications should make clear what the full scope of the delegated design entails.

Conclusion

Past earthquakes have shown that poor seismic performance of nonstructural systems can cause loss of life, trigger the need to repair or replace damaged components, and cause extended downtime. Nonstructural seismic performance can be as critical as the seismic performance of the structure itself.

When delegating design of nonstructural systems, the Structural Engineer of Record still has an opportunity and a responsibility to ensure that the delegated systems achieve a performance objective that correlates to the overarching performance objectives of the building. To do this, the SEOR's involvement in the delegated design process is needed from the start of the project through construction.

The building's performance objectives must be thoughtfully translated into specific performance objectives for each nonstructural system. This often requires input from the entire design team. The SEOR must then translate the performance objectives for each nonstructural system into a set of design criteria that the Specialty Structural Engineer can use to successfully produce the delegated design.

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