ATC-72 of the PEER Tall Buildings Initiative: *Interim Guidelines on Modeling and Acceptance Criteria for Seismic Design and Analysis of Tall Buildings*

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Abstract

The City of Los Angeles, the City and County of San Francisco, and other communities on the West Coast are undergoing a boom in the construction of high-rise buildings that involve a variety of unusual configurations, innovative structural systems, and high performance materials. Various jurisdictions, with the active involvement of peer review committees, are considering performance-based methods to assess the adequacy of these new designs. These parallel efforts create a timely opportunity for collaboration to improve and increase the application of performance-based designs for tall buildings, thereby assuring that new high-rise construction meets intended safety and performance objectives, ensuring safe and usable buildings after future major earthquakes. The Pacific Earthquake Engineering Research Center (PEER) is presently undertaking a multi-year program to develop guidelines to aid the engineering community with the design, analysis and construction of these tall buildings.

The ATC 72 project has been funded by PEER as part of this larger program to develop practical guidance for acceptance criteria and for nonlinear modeling of tall buildings in reinforced concrete and structural steel. Recommendations for selected topics such as stiffness, strength, deformation capacity, hysteretic models, and implementation in software for nonlinear response-history (NLRH) analysis are being developed as part of this effort. Guidance on appropriate parameters to be applied to the use of capacity design, including determining overstrength demands from NLRH analysis and capacity-reduction factors that provide an appropriate overall level of reliability are being addressed. Other issues that affect earthquake response and design, including modeling of podium force transfer are also included. Acceptance criteria address aspects of reliability of safety, capital preservation, re-occupancy, and functionality. Uncertainty assessment is an essential part of this task. The document is presently being finalized and will be completed during 2008. The document is intended to serve as a primary resource for the remaining tasks of the PEER Tall Buildings Initiative that will develop guidelines for the seismic design of tall buildings. In addition to the PEER Guidelines Writing Team, designers of tall buildings, peer reviewers and local jurisdictions will all greatly benefit from the contents of this document.

Introduction

The development of seismic design provisions and construction practice has been based primarily on an understanding of the anticipated behavior of low- to moderate-rise construction. In extrapolating design and detailing provisions for use in high-rise construction, many structural systems have been limited in height or not permitted where combinations of spectral response acceleration parameters, site class, and building occupancy result in Seismic Design Categories D or higher, as defined in ASCE 7-05 *Minimum Design Loads for Buildings and Other Structures*. Recent trends in high-rise residential construction have resulted in a variety of unusual configurations, innovative structural systems, and high performance materials that challenge current design practice. Questions have arisen regarding the applicability of prescriptive code provisions to tall building structural systems, and whether or not these provisions can adequately ensure acceptable performance of this class of structure. Building departments, with active input from peer review committees and advisory groups, have been considering performance-based methods to assess the adequacy of these new designs. Use of alternative performance-based design procedures has led to challenges in the plan check and enforcement process, and use of currently available performance-based analytical methods has led to questions regarding the ability of these methods to reliably predict performance of tall building structural systems. The seismic design of tall buildings, or buildings exceeding 160 feet in height, introduces new challenges that need to be met through consideration of scientific, engineering, and regulatory issues specific to the modeling, analysis, and acceptance criteria appropriate for these unique structural systems. These interim guidelines represent a compilation of the latest information on analytical simulation, system and component behavior, material properties, and recommendations specific to the seismic design of tall building structural systems.

Pacific Earthquake Engineering Research Center Tall Buildings Initiative

The Pacific Earthquake Engineering Research Center (PEER) is leading a multi-year collaborative effort, called the Tall Buildings Initiative, to develop performance-based seismic design guidelines for tall buildings. Guidelines resulting from this initiative are intended to promote consistency in design approaches, facilitate design and review, and help ensure that tall building designs meet safety and performance objectives consistent with the intent of current building codes and the expectations of various stakeholder groups.

Major collaborators on the PEER Tall Buildings Initiative include (in alphabetical order):
Applied Technology Council (ATC),
California Geological Survey,
Charles Pankow Foundation,
Department of Building Inspection, City & County of San Francisco (SFDBI),
Federal Emergency Management Agency (FEMA),
Los Angeles Tall Buildings Structural Design Council (LATBSDC),
Los Angeles Department of Building and Safety (LADBS),
Building Seismic Safety Council (BSSC) of the National Institute of Building Sciences (NIBS),
National Science Foundation (NSF),
Pacific Earthquake Engineering Research Center (PEER) (Lead Organization),
Southern California Earthquake Center (SCEC),
Structural Engineers Association of California (SEAOC),
Structural Engineers Association of Northern California (SEAONC), and
United States Geological Survey (USGS).

The Tall Buildings Initiative includes consideration of performance objectives, ground motion selection and scaling, modeling, acceptance criteria, and soil-foundation-structure interaction issues specific to the design of tall buildings. Guideline development activities are organized around the following tasks:

- Task 1 - Establish and Operate the Tall Buildings Project Advisory Committee (T-PAC)
- Task 2 - Develop consensus on performance objectives
- Task 3 - Assessment of ground motion selection and scaling procedures
- Task 4 - Synthetically generated ground motions
- Task 5 - Review and validation of synthetically generated ground motions
- Task 6 - Guidelines on selection and modification of ground motions for design
- Task 7 - Guidelines on modeling and acceptance values
- Task 8 - Input ground motions for tall buildings with subterranean levels
- Task 9 - Presentations at conferences, workshops, seminars
- Task 10 - Development of a design framework and publication of design guidelines

These interim guidelines represent the outcome of work on Task 7. It is anticipated that future work within the PEER Tall Buildings Initiative (PEER TBI) will review and refine these interim guidelines as the overall program progresses.

Issues In Tall Building Design

The following scientific, engineering, and regulatory issues specific to tall building design have been identified as part of the PEER Tall Buildings Initiative. These issues form the basis of the major technical development areas to be addressed by the overall Tall Buildings Initiative.

Building concepts and materials. Functional requirements for tall residential buildings have led to new building configurations and systems that do not meet the prescriptive definitions and requirements of current building codes. These include efficient framing systems with reduced redundancy as compared with more conventional buildings. High-strength materials and specialized products are also being proposed to help meet the unique challenges introduced by these structural systems.

Performance objectives and hazard considerations. High occupancy levels, associated safety considerations, and interest in re-occupancy following an earthquake have led to a reconsideration of performance objectives and ground

shaking hazards. As a minimum, a building must be safe for rare (low probability, long-return period) ground shaking demands, and must remain safe for significant aftershocks. However, there is increasing concern that serviceability for more frequent events should be considered as well. For very long vibration periods characteristic of tall buildings, special treatment of design ground motions is needed to ensure that these motions are representative in their damage potential, including consideration of duration and long-period energy content, so that designs based on them will safely represent
18 the anticipated effects of future earthquakes. While equivalence to building code minimum performance requirements is likely to be the basic objective, there is no consensus on how to translate that performance objective into specific engineering demands and capacity checks in a performance-based procedure.

Ground motion time histories. The selection, scaling and spectral modification of ground motion time histories to represent a design response spectrum has a large impact on the results of nonlinear analyses. Earthquakes that dominate the seismic hazard in San Francisco, especially at sites near the San Andreas Fault, are for larger magnitudes and closer distances than are available in existing databases of strong motion recordings. This indicates a need to establish rational procedures for time history selection, scaling and modification. Validated seismological methods can be used to generate ground motion time histories that incorporate near-fault rupture directivity effects and basin effects to appropriately represent the duration and long period energy content of these large design events.

Modeling, simulation, and acceptance criteria. Current codes, although legally applicable to tall buildings, are based on, and emphasize design requirements for, low- to moderate-rise construction. As such, they fall short in conveying specific modeling, analysis, and acceptance criteria for very tall buildings because the dynamic and mechanical aspects of response that control the behavior of tall buildings are different from those of shorter buildings. Specialized engineering procedures, consensus-based and backed by research and experience, are needed. Criteria should appropriately address aspects of reliability of safety, capital preservation, re-occupancy, and functionality.

Input ground motions for tall buildings with subterranean levels. It is common practice to configure tall buildings with several levels below grade. Interaction between the soil, foundation, and structure is expected to significantly affect the character and intensity of the motion that is input to the superstructure. The issue is to define the input ground motions for tall buildings with subterranean levels considering this interaction.

Instrumentation. Tall building instrumentation can serve multiple purposes, including rapid occupancy evaluation following an earthquake, confirmation that building performance has met design expectations, and basic research leading to improved design criteria and analytical methods. Guidelines are needed for building instrumentation plans, and for data utilization following an earthquake.

Task 7 - Guidelines on seismic/structural design, including modeling and acceptance values

The following paragraphs summarize the description of the scope of Task 7 of the Peer TBI.

Develop practical guidance for acceptance criteria and for nonlinear modeling of tall buildings in reinforced concrete (priority) and steel. Recommendations, methodology, and findings will be documented in a final report. Include recommendations for selected topics such as stiffness, strength, deformation capacity, hysteretic models, and implementation in software for nonlinear response-history (NLRH) analysis. An additional potential topic is to provide guidance on appropriate parameters to be applied to the use of capacity design, including determining overstrength demands from NLRH analysis and capacity-reduction factors that provide an appropriate overall level of reliability.

Work with experienced consultants to ensure focus on key components and systems that affect earthquake response and design, including modeling of podium force transfer. As appropriate, conduct analyses to validate procedures.

Criteria should appropriately address aspects of reliability of safety, capital preservation, re-occupancy, and functionality. Uncertainty assessment is an essential part of this task.

A group of practicing engineers and researchers was assembled to prepare the ATC 72-1 report on modeling and analysis criteria. This group includes the following:

Gregory Deierlein	Stanford University
Helmut Krawinkler	Stanford University
Joseph. Maffei	Rutherford and Chekene, Consulting Engineers
Mehran Pourzanjani	Saiful/Bouquet, Structural Engineers
John Wallace	University of California at Los Angeles
Jon Heintz	Applied Technology Council
James Malley	Degenkolb Engineers (Technical Director)

Workshop On Tall Buildings Seismic Design And Analysis Issues

PEER Task 7 is focused on the technical development area of modeling, simulation, and acceptance criteria. A *Workshop on Tall Building Seismic Design and Analysis Issues* was conducted in January 2007, as an integral part of this work. The purpose of this workshop was to identify design and modeling issues of critical importance to various tall building stakeholder groups involved in the design, permitting, and construction of tall buildings, and to establish priorities for issues that should be addressed by the PEER Task 7 work. The outcome of this workshop is recorded in a companion report, ATC-72 *Proceedings of Workshop on Tall Building Seismic Design and Analysis Issues* (ATC, 2007). This report includes a prioritized list of the most important tall building modeling and acceptance criteria issues needing resolution, based on the opinions of practitioners, regulators, and researchers in attendance. This list became the basis for the items to be addressed in the ATC-72-1 project.

Document Content And Organization

Based on the results and recommendations of the workshop, the Task 7 team and the PEER TBI Management Committee worked to establish the items to be addressed in the Task 7 report. These interim guidelines contain the latest available research and information supporting recommendations on analytical modeling and acceptance criteria for the seismic design of tall building structural systems. Chapter 1 provides background information and the context of the overall PEER Tall Buildings Initiative. Chapters 2 through 5 present the primary technical information in the document. Chapter 2 (H. Krawinkler and G. Deierlein, primary authors) provides guidance on general modeling issues including nonlinear modeling, deterioration, P-delta effects, damping, expected properties, and uncertainty. Chapter 3 (H. Krawinkler and G. Deierlein, primary authors) provides recommendations for characterizing nonlinear properties of specific steel and reinforced concrete frame components including beams, columns, joints, and axially loaded steel braces. Chapter 4 (J. Wallace primary author) provides general and specific guidance on modeling of reinforced concrete wall systems and components including planar and core walls, coupling beams, and slab-column frames. Chapter 5 (J. Maffei) provides guidance on design of diaphragms, collectors, and podium system components including backstay effects and capacity design considerations. Chapter 6 identifies important modeling issues not addressed by these interim guidelines, and includes recommendations for additional study. The following briefly summarizes the contents of each of these chapters, beginning with the chapter table of contents.

Chapter 2 - General Modeling Issues

Chapter 2 of the document begins with a summary of the types of nonlinear element models that an engineer can employ in the design and analysis of tall buildings, which are noted in Figure 1. These include the most simple model using nonlinear hinges, more complicated fiber based models, and the most complex being the continuum model. The report highlights the benefits and drawback of each approach and how they might be implemented in a building structural model. In most applications of structural design, the inelastic hinge model will suffice.

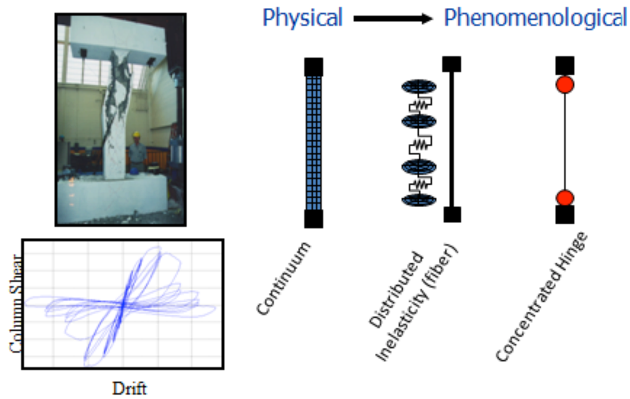

Figure 1 – Comparison of nonlinear modeling approaches

The discussion of deterioration in Section 2.2 highlights the importance of considering this effect as the structural response approaches collapse. Various approaches to modeling deterioration for various structural elements are discussed, and the sensitivity of the structural response of when the deformation exceeds the capping point and negative slopes to the overall structural stiffness are reached are presented. The discussion of structural damping in Section 2.4 is a very important element of the document, since it addresses an area where there is still a great deal of ongoing discussion and controversy. The typical assumption of using 5 per cent viscous damping that has been almost universally employed for elastic analyses implicitly recognizes hysteretic behavior in both the structural and nonstructural elements. How to properly incorporate viscous damping when the inelastic response directly incorporates the hysteretic behavior of the structure is addressed, based on an exhaustive survey of literature results and the response of tall instrumented buildings subjected to wind loading. The final section of Chapter 2 deals with the need to properly account for all the sources of uncertainty (structural modeling, ground motion, etc.) in the process.

Chapter 3 - Characterizing Properties of Nonlinear Structural Components

3.1. Important Parameters
3.2. Quantification of Properties of Steel Beams and Columns
  3.2.1. General Comments
  3.2.2. Modeling of Steel Beams and Columns
3.3. Quantification of Properties of Steel Beam-Column Joint Panel Zones
  3.3.1. Modeling of Steel Panel Zones
  3.3.2. Acceptance Criteria for Steel Panel Zones
3.4. Quantification of Properties of RC Beams, Columns, and Beam-Column Joints
  3.4.1. General
  3.4.2. Modeling of RC Beams, Columns, and Beam-Column Joints
  3.4.3. Acceptance Criteria for RC Beams, Columns, and Beam-Column Joints
3.5. Quantification of Properties of Axially Loaded Steel Braces
  3.5.1. Modeling of Axially Loaded Steel Braces
  3.5.2. Acceptance Criteria for Axially Loaded Braces

Chapter 3 begins with a discussion of the key structural parameters of interest for nonlinear analysis. Key modeling parameters, which are either specified explicitly (as for concentrated plasticity type models) or modeled implicitly (as for finite element models), are as follows:

- *Pre-Yield Stiffness:* Stiffness prior to yielding is usually characterized by an effective or secant stiffness, which may depend on the type of analysis model and limit state of interest. For example, when evaluating serviceability at low deformation levels, the stiffness represents the early initial stiffness of the member. Alternatively, to assess behavior at large post-yield deformations, it is more appropriate to calibrate the effective stiffness to a secant stiffness evaluated at 60% to 100% of the yield strength.
- *Strength:* Key strength parameters typically relate to the yield strength, the maximum strength, and the residual strength at large deformations. Generally, the yield and maximum strength need to be modeled in all nonlinear analyses. The extent to which residual strength is important depends on whether the analysis shows deformations larger than those at the maximum strength, beyond which degradation occurs. Usually, the basis strength parameters are defined based on the monotonic response, i.e., without considering the reduction in strength due to hysteretic energy dissipation.
- *Deformation Parameters:* The nonlinear response behavior can be characterized by the strength parameters together with the associated yield deformation, capping deformation, post-capping deformation, cyclic hysteretic properties, and cyclic deterioration. The anchor points of the monotonic backbone, or alternatively the modified backbone curve, will depend on how cyclic deterioration is handled in the model.

For all of these parameters, the remainder of this chapter addresses the modeling of elements of steel and reinforced frame structures. Extensive discussions of steel beam, column, brace and joint panel zone elements are taken from past research studies from various sources that have been based on experimental results. A similar detailed discussion is provided for beams, columns and beam-column joints of reinforced concrete frames.

Chapter 4 - Modeling of Planar and Core Wall Systems and Components

Chapter 4 addresses one of the primary issues identified in the project workshop, namely the response and modeling of wall systems. This system has been widely used in many tall structures, and has been especially prevalent in recently designed and constructed buildings used primarily for residential purposes. In many applications, the walls surround the primary vertical transportation and service shafts, creating an integrated group of walls that act as three dimensional core units rather than simple planar walls. Chapter 4 addresses the significant modeling challenges that wall systems face. Use of fiber models for nonlinear analysis is becoming common in structural engineering practice. Fairly complex uniaxial material relations are available for cyclic behavior of concrete and reinforcement to model combined bending and axial load. Shear behavior models are typically based on overall element response and interaction between axial/bending behavior and shear behavior is not considered directly. Indirect treatment of the interaction between shear strength and nonlinear axial/bending deformations is sometimes considered by using a model that reduces shear strength based on the level of displacement ductility imposed. Although data are sparse for walls, use of this model appears appropriate.

For analysis and modeling approaches that require definition of an effective flexural stiffness up to the yield point, test results indicate that use of 0.4 to 0.5 of the gross stiffness is appropriate for axial force levels up to approximately 0.15 Ag f'c. Lower or higher stiffness values could be appropriate for walls with lower strength or higher axial stress. Use of an equivalent elastic shear modulus values between Gc/20 and Gc/10 is recommended based on expected shear stress levels. Use of a higher stiffness value for short walls with modest axial force levels is possible; however, very limited test data exists. Therefore, the potential impact of the variation of wall shear stiffness on analysis results should be considered. Use of more simple uniaxial material models produces in many commercial computer programs show results that are nearly as good as results obtained using fairly sophisticated models. Use of more sophisticated material models for concrete in tension produced modestly better results for walls with T-shaped cross sections. Selection of material and modeling parameters may have a significant impact on model results. Use of modest post-yield slope (3 to 5%) for reinforcement was observed to noticeably improve the correspondence between test and model results. If no post-yield slope is used on the reinforcement material relation, the strain gradient (axial strain along the wall cross section at the yielding region) may be substantially off. Use of an element size approximately equal to the estimated plastic hinge length alleviated this problem.

New provisions for diagonally reinforced coupling beams are included in ACI 318-08 that allow two detailing options, one with transverse reinforcement around the groups of diagonal bars and the other with transverse reinforcement around the entire beam. Test results indicate that the load – displacement response for both options are nearly the same. Effective stiffness values derived from the test results reveal lower values than those obtained using common recommendations and no significant concrete spalling was observed, even for rotations of 8%. Both frame and fiber models, with appropriate hinge and material properties, respectively, are capable of capturing the load – deformation responses measured in the tests. Inclusion of slip/extension springs is required to accurately capture the measured responses (effective stiffness) prior to yield. Plastic rotations and reinforcement tensile strains inferred from the tests substantially exceed the values recommended in FEMA 356 Table 6-18 (rotations).

Variation of wall shear stiffness values had only a minor impact of the magnitude of wall shear and moment above the podium levels; however, the required force transfer between the core wall and exterior walls (via the podium level diaphragms) is significantly impacted. Specific recommendations for variation of the shear modulus to address this issue are given in Chapter 5. Elastic modeling above the anticipated yielding region at the base of the wall (or at the podium level) is sometimes used to simplify modeling and to potentially reduce computer run times. However, the results presented indicate that nonlinear elements must be used for the full wall height to capture yielding at upper levels. Based on the limited results presented, minor yielding at upper levels substantially reduced shear and moment magnitudes at levels above the podium. For example, peak reinforcement tensile strains for the case examined were only xx times the yield strain.

In recent years, a fairly significant number of tests have been conducted on post-tensioned slab – column connections and new modeling parameters and acceptance criteria will be published in ASCE-41 Supplement #1. The new recommendations are based on mean values for the test results on conforming connections (e.g., new construction), and allow substantially higher interstory drift (or total rotation) at slab – column connections prior to predicted punching failure.
Use of the “effective slab width model” is recommended to model the coupling between the core wall and the slab – column frame. Based on the case study presented, this coupling reduced the lateral drift only modestly and had almost no impact on the variation of the axial load in the columns. Although this coupling is generally not considered, the potential adverse impacts of coupling between the core wall and the slab-column frame should be considered.

Chapter 5 - Floor Diaphragms, Collectors, and Podium and Backstay Effects

5.1. Common Podium Conditions in Tall Buildings
5.2. Structural Systems, Configurations, Elements, and the Evaluation of Backstay Effects
- 5.2.1. Structural Elements of the Podium
- 5.2.2. Seismic-Force-Resisting Systems
- 5.2.3. Evaluation and Design Considering the Backstay Effect
- 5.2.4. Effect of Structural System Type and Configuration on Backstay Effect

5.3. Additional Effects of Structural Configuration
- 5.3.1. Buildings Without Podium and Backstay Effects
- 5.3.2. Setback or Step-Back Effects

5.4. Multiple Towers on a Common Base
5.5. Buildings on Sloping Sites
5.6. Nonlinear Seismic Response and Capacity Design
- 5.6.1. Capacity Design
- 5.6.2. Capacity Design Using Nonlinear Response-History Analyses
- 5.6.3. Two-Stage Design Process

5.7. Modeling and Design of Structural Elements
- 5.7.1. Bracketing of Stiffness Properties

5.8. Role of Floor Diaphragms, Collectors, and Diaphragm Segments
- 5.8.1. Role of Collectors
- 5.8.2. Design for System Overstrength
- 5.8.3. Collector Eccentricity and Diaphragm Segments

5.9. Rigid, Semi-Rigid, and Flexible Diaphragms
- 5.9.1. Diaphragms with Large Force Transfers
- 5.9.2. Relative Stiffness Between Diaphragm and Vertical Elements
- 5.9.3. Regularity of Configuration of Elements
- 5.9.4. Building Code Requirements
- 5.9.5. Code-Specified Horizontal Irregularities

5.10. Computer Modeling with Semi-Rigid Diaphragm Properties
- 5.10.1. Linear Versus Nonlinear Analysis

5.11. Design of Floor Diaphragms and Collectors
- 5.11.1. Diaphragm In-Plane Shear
- 5.11.2. Strut-and-Tie Models
- 5.11.3. Diaphragm In-Plane Flexure
- 5.11.4. Distribution of Collector Forces
- 5.11.5. Placement of Collectors
- 5.11.6. Using Gravity Slab Reinforcement
- 5.11.7. Excess Capacity
- 5.11.8. Reinforcement Symmetry
- 5.11.9. Design of Diaphragm Segments for Collector Eccentricity and Localized Diaphragm Shear
- 5.11.10. General Procedure for Determining Forces on Collectors and Diaphragm Segments

5.12. Recommended Stiffness Properties for Modeling of Podium and Backstay Effects
- 5.12.1. Lateral Stiffness for the Passive Resistance of Soil
- 5.12.2. Properties for Other Types of Structural Elements

Another major issue that was identified in the project workshop was the podium effect that is common in many modern tall buildings. The base part of a tall building is often referred to as a podium, which in general terms can apply to any lower part of a structure that is larger or base-like compared to the tower or towers above. See Figure 2. For the purpose of seismic structural design, we can define the podium to consist of those stories at the bottom of a building that contain substantially increased lateral-force resistance compared to the levels above. The podium effect is significant for seismic design because it causes a transfer of lateral forces, typically through one or more floor diaphragms, from lateral-force-resisting elements above the podium into additional elements that exist within the podium. The lateral force resistance in the podium levels and the force transfer through floor diaphragms at these levels helps resist building overturning from seismic forces. This component of overturning resistance is referred to as the backstay effect, based on its analogy to the back span of a cantilever beam. The evaluation of backstay effects involves a comparison of the stiffness of two seismic force paths that each contribute to the overturning resistance of the building. One force path is through the foundation overturning resistance underneath the non-perimeter seismic-force-resisting elements. A second force path — the backstay force path — resists overturning through in-plane forces in the lower floor diaphragms and perimeter walls. Designing for these effects requires careful consideration of element stiffness assumptions, and often a bracketing of assumptions. For tall buildings in high seismic areas, a capacity-design approach and nonlinear response-history analysis are recommended. The chapter discusses podium and backstay effects, gives guidance on the modeling and seismic design of floor diaphragms and collectors, and provides recommendations for element stiffness properties.

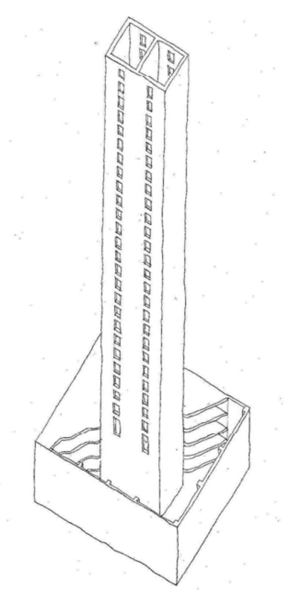

Figure 2 – Example of core wall building with below grade structure that creates podium effect.

Chapter 6 - Recommendations For Additional Study

- 6.1 Important Modeling Issues Not Considered in this Report
  - 6.1.1 Bi-Axial Effects In Columns (Strength, Deformation, Deterioration)
  - 6.1.2 Bi-Axial Effects In Shear Walls (Strength, Deformation, Deterioration)
  - 6.1.3 Soil-Foundation Interface, Including Uplift
  - 6.1.4 Effect of Variation in Axial Force on Columns
  - 6.1.5 Non-Conforming Components
  - 6.1.6 Local Failure Modes and Specific Effects of Detailing
  - 6.1.7 Possibility of Inelastic Deformations Between Analysis Nodes
  - 6.1.8 Effect of Dispersion in Geotechnical Properties
- 6.2 Nonlinear Component Properties Not Addressed in this Report
- 6.3 Other Issues Identified in the Project Workshop but Not Addressed in This Report

The final chapter of the report presents a brief discussion of issues not specifically addressed in the report that may have important effects on structural response. This list is presented to highlight areas where guidelines writers may need to access other sources, and/or where future study may be needed to better understand the structural response of these systems.

Conclusions

The ATC 72-1 report presents a great deal of information and guidance on important issues for the modeling and acceptance of structural elements and systems in tall buildings. The report compiles information from previous research and other investigations to address a number of significant issues that were identified in a large workshop of practicing engineers and researchers. The report, which will be completed during the second half of 2008, will be become a base reference document for the development of guidelines being prepared as part of the PEER Tall Buildings Initiative. These guidelines are scheduled to be completed during the second half of 2009.

References

Applied Technology Council, (ATC, 2007) ATC-72 *Proceedings of Workshop on Tall Building Seismic Design and Analysis Issues*, Redwood City, California.