Graduate Certificate in Design and Analysis of Tall Buildings

Seismic Design of Tall Structures

Acceleration Response Spectrum – A plot of maximum accelerations of a single-degree-of-freedom system versus its natural period. Related terms: spectral acceleration, period, damping ratio. Engineers use it to select design earthquakes and to size seismic-resistant members. Challenge: selecting an appropriate site-specific spectrum versus code spectrum.

Adiabatic Damping – Energy dissipation due to internal material hysteresis in the absence of external damping devices. Related terms: material damping, hysteretic damping. In tall buildings, concrete and steel provide modest adiabatic damping that must be accounted for in dynamic analysis. Challenge: quantifying non-linear hysteresis for complex geometries.

Advanced Strong Motion (ASM) Database – A curated collection of recorded ground motions with metadata on site conditions and fault mechanisms. Related terms: ground-motion selection, scaling, intensity measures. Used for realistic seismic input in performance-based design. Challenge: ensuring the database reflects the target region's seismicity.

Alfa-Beta-Gamma (ABG) Method – A simplified procedure to estimate in-elastic displacement demand using three coefficients (α, β, γ). Related terms: displacement coefficient, response modification factor. Provides quick checks for tall structures where full non-linear analysis is impractical. Challenge: calibrating coefficients for high-rise systems.

Amplitude Modulation – Variation of the envelope of a ground-motion time history, often due to basin effects or directivity. Related terms: long-period content, pulse-like motion. Influences the peak drift of tall buildings. Challenge: capturing modulation accurately in synthetic motions.

Analysis Period – The range of natural periods over which a structure's dynamic response is evaluated, typically from 0.1 s to 5 s for skyscrapers. Related terms: period range, modal analysis. Determines the resolution of the response spectrum. Challenge: extending the period range for very tall, flexible towers.

Aspect Ratio – Ratio of a building's height to its plan dimension. Related terms: slenderness, height-to-width ratio. High aspect ratios increase seismic demand due to larger story drifts. Challenge: controlling drift while maintaining architectural intent.

Base Isolation – A seismic protection system that decouples the superstructure from ground motion using flexible bearings or sliders. Related terms: isolation bearings, lead-rubber bearing, friction pendulum. Reduces acceleration transmitted to the building, beneficial for tall structures with sensitive equipment. Challenge: designing isolation devices for large axial loads and ensuring long-term durability.

Base Shear – Total horizontal force at the foundation level resulting from seismic loading. Related terms: lateral load distribution, shear wall, moment frame. Calculated from modal analysis or equivalent static methods. Challenge: accurately allocating shear among different lateral-force resisting systems.

Beam-Column Joint – The connection between vertical columns and horizontal beams, critical for seismic performance. Related terms: moment connection, shear connection, plastic hinge. Must be detailed to allow expected plastic rotation without premature failure. Challenge: achieving ductility while limiting joint drift.

Benioff–Muller Scaling – A method for adjusting recorded ground motions to a target intensity level using the Benioff–Muller relationship. Related terms: scaling factor, magnitude-distance scaling. Helps match the seismic hazard level required for design. Challenge: preserving the frequency content after scaling.

Building Code Spectra – Code-prescribed response spectra based on seismic zone, soil class, and importance factor. Related terms: ASCE 7, Eurocode 8, IBC. Serve as the baseline for elastic design of tall structures. Challenge: reconciling code spectra with site-specific hazard analyses.

Building Information Modeling (BIM) for Seismic Design – Integration of seismic analysis results into a BIM environment for coordination and clash detection. Related terms: parametric modeling, 3-D visualization. Enables rapid updates of structural modifications. Challenge: maintaining consistency between analysis models and BIM geometry.

Buried Foundation – A deep foundation system such as a mat or piled raft placed below the ground surface to improve seismic performance. Related terms: raft foundation, pile group, soil-structure interaction. Reduces pounding risk with adjacent structures. Challenge: accounting for soil non-linearity in dynamic analyses.

Capacity Spectrum Method (CSM) – A performance-based analysis technique that plots the structure’s capacity curve against the demand spectrum to find the performance point. Related terms: pushover analysis, demand-capacity ratio. Widely used for tall building seismic assessment. Challenge: developing accurate capacity curves for complex structural systems.

Center of Mass (CM) – The point through which the total weight of the building acts. Related terms: center of stiffness, eccentricity. Misalignment between CM and center of stiffness induces torsional response. Challenge: designing floor plans that align CM and stiffness centers.

Center of Stiffness (CoS) – The point representing the distribution of lateral stiffness. Related terms: torsional vibration, eccentricity. The distance between CM and CoS creates torsional irregularities. Challenge: minimizing eccentricity through symmetric structural layout.

Coefficient of Variation (COV) – Statistical measure of dispersion used in ground-motion selection to assess variability. Related terms: standard deviation, mean, uncertainty. Low COV indicates reliable spectral matching. Challenge: balancing COV with the need for diverse motion shapes.

Combined Load Cases – Simultaneous consideration of seismic, wind, and gravity loads in analysis. Related terms: load combination, design load case. Tall buildings often experience concurrent lateral actions. Challenge: ensuring that interaction effects are captured without excessive conservatism.

Composite Action – The interaction between concrete and steel components that enhances stiffness and strength. Related terms: steel-concrete composite floor, shear connector. In tall structures, composite cores improve seismic performance. Challenge: modeling slip and non-linear behavior accurately.

Concentric Loading – Axial load applied through the centroid of a column without eccentricity. Related terms: axial compression, P-Δ effect. Simplifies analysis but rarely represents real conditions in irregular towers. Challenge: incorporating eccentricities due to drift.

Conservative Design – An approach that intentionally overestimates demands or underestimates capacities to ensure safety. Related terms: safety factor, factor of safety. May lead to uneconomical designs for tall buildings. Challenge: balancing safety with cost efficiency.

Correlation Length – A parameter describing the spatial continuity of ground-motion intensity across a site. related terms: spatial variability, site-specific hazard. Important for multi-tower campuses where simultaneous shaking is considered. Challenge: obtaining reliable correlation data.

Core Wall – A vertical shear wall or tube that houses elevators and stairwells, providing primary lateral resistance. Related terms: tube system, outriggers, moment frame. Core walls dominate the seismic stiffness of most skyscrapers. Challenge: detailing core–outlet connections to avoid premature failure.

Critical Damping Ratio – The amount of damping that results in the fastest return to equilibrium without oscillation. Related terms: hysteretic damping, viscous damping. Used as a reference for defining system damping in spectral analysis. Challenge: distinguishing between critical and actual damping in non-linear structures.

Cross-Sectional Area – The area of a structural member perpendicular to its length, influencing axial capacity. Related terms: slenderness ratio, buckling. Larger areas increase seismic load-bearing capacity. Challenge: optimizing area for weight and material cost.

Current Seismic Code (e.g., IBC 2021) – The latest edition of a building code governing seismic design requirements. Related terms: code adoption, amendment, jurisdiction. Provides the minimum standards for tall building design. Challenge: interpreting code provisions that are written for low-rise structures.

Damaged-State Model – A representation of a structure's performance levels (e.g., immediate occupancy, life safety) based on damage measures. Related terms: fragility curve, performance level. Used in probabilistic seismic risk assessments for tall buildings. Challenge: calibrating damage thresholds for complex systems.

Dynamic Amplification Factor (DAF) – Ratio of the peak response of a structure to the static response under the same load. Related terms: modal amplification, resonance. Tall, flexible towers experience high DAF values. Challenge: accurately predicting DAF for multi-modal systems.

Dynamic Analysis – Numerical simulation of a structure's response to time-varying loads, such as earthquakes. Related terms: linear time history, non-linear time history, response spectrum analysis. Provides detailed insight into drift, acceleration, and internal forces. Challenge: high computational cost for full building models.

Effective Height – Height at which the seismic force is assumed to act for simplified analysis. Related terms:

equivalent static method, seismic weight distribution. Often taken as 0.5 H for uniform mass distribution. Challenge: selecting an appropriate effective height for irregular mass distributions.

Elastic Design Spectrum – A response spectrum derived under the assumption of linear elastic behavior. Related terms: elastic–inelastic transition, spectral acceleration. Forms the basis for initial lateral force design. Challenge: converting elastic demands to inelastic demands for tall structures.

Elastic–Inelastic Transition – The point where a structure shifts from elastic to plastic behavior under seismic loading. Related terms: yield point, post-yield stiffness. Critical for defining the performance point in capacity spectrum methods. Challenge: capturing the transition accurately in simplified models.

Elastic–Plastic Analysis – A method that allows members to yield while maintaining overall equilibrium. Related terms: plastic hinge, hardening model. Provides more realistic demand estimates than purely elastic analysis. Challenge: determining appropriate hardening rules for high-rise elements.

Elastic Modulus (E) – Material property defining the linear relationship between stress and strain. Related terms: Young's modulus, stiffness. Influences the natural frequencies of tall buildings. Challenge: accounting for reduction of E due to cracking or temperature effects.

Engineering Demand Parameter (EDP) – Quantitative measure of structural response used in performance-based design (e.g., inter-story drift, floor acceleration). Related terms: intensity measure (IM), fragility analysis. Guides the selection of acceptable performance levels. Challenge: selecting EDPs that correlate well with damage.

Equivalent Static Method (ESM) – Simplified design approach that replaces dynamic seismic effects with equivalent static forces. Related terms: base shear, seismic weight. Useful for early-stage design of tall buildings. Challenge: inadequate for structures with significant higher-mode effects.

Exaggerated Mode Shapes – Mode shapes that are amplified due to irregularities such as setbacks or mass concentration. Related terms: mode participation factor, torsional mode. Can cause localized overstress. Challenge: identifying and mitigating exaggerated modes early in design.

Failure Mechanism – The sequence of events leading to structural collapse under seismic loading. Related terms: plastic hinge formation, soft-story collapse. Understanding mechanisms informs detailing and retrofitting strategies. Challenge: predicting complex mechanisms in irregular towers.

Finite Element Model (FEM) – Discretized representation of a structure using elements and nodes for numerical analysis. Related terms: mesh density, convergence study. Enables detailed simulation of material nonlinearity and geometric effects. Challenge: balancing model fidelity with computational resources.

Friction Pendulum Bearing (FPB) – A type of base isolation bearing that uses a sliding surface and a curved friction element to provide restoring force. Related terms: isolation system, period tuning. Offers self-centering capability for tall structures. Challenge: designing FPBs to accommodate large vertical loads.

Floor Diaphragm – Horizontal structural element that distributes lateral forces to vertical resisting members. Related terms: shear wall, outriggers, transfer beam. Critical for ensuring uniform drift distribution.

Challenge: ensuring diaphragm stiffness in high-rise floor plates with large openings.

Force-Based Design – Design philosophy that directly controls internal forces rather than deformations. Related terms: strength design, limit state. Common in seismic design of tall buildings. Challenge: translating force demands into ductile detailing requirements.

Frequency-Domain Analysis – Seismic analysis performed in the spectral domain using Fourier transforms of ground motion. Related terms: spectral density, pseudo-acceleration. Useful for assessing response of linear systems. Challenge: limited applicability for strongly non-linear tall structures.

Fundamental Period (T1) – The period of the first (lowest) natural mode of vibration. Related terms: modal analysis, period elongation. Tall buildings often have T1 between 1 s and 3 s. Challenge: accurately predicting T1 when stiffness is reduced by damage.

Full-Scale Testing – Experimental validation of components or assemblies at prototype dimensions. Related terms: shake-table test, cyclic loading. Provides data for calibrating analytical models. Challenge: high cost and logistical complexity for full-scale tall-building elements.

Generalized Mass – Effective mass associated with a particular mode of vibration. Related terms: modal mass, participation factor. Determines how much of the seismic energy is absorbed by each mode. Challenge: computing accurate generalized mass for irregular mass distributions.

Geotechnical Earthquake Engineering – Study of soil–structure interaction under seismic loading. Related terms: liquefaction, site response analysis. Influences foundation design of tall towers. Challenge: integrating site-specific soil models with structural dynamics.

Global Drift Ratio – Ratio of total lateral displacement at the top to the building height. Related terms: story drift, inter-story drift. Governs serviceability and occupant comfort. Challenge: meeting stringent drift limits for ultra-tall structures.

Ground Motion Prediction Equation (GMPE) – Empirical relationship that estimates seismic intensity measures from magnitude, distance, and site conditions. Related terms: attenuation relationship, seismic hazard. Used to generate hazard curves for tall building sites. Challenge: selecting appropriate GMPEs for regions with limited data.

Hardening Model – Constitutive model that captures post-yield increase in strength. Related terms: strain hardening, Bauschinger effect. Improves realism of cyclic analysis for steel components. Challenge: calibrating parameters for large-scale steel sections.

Higher-Mode Effects – Contributions of modes beyond the fundamental to overall seismic response. Related terms: modal summation, modal participation factor. Significant for slender towers where higher modes dominate drift at upper levels. Challenge: efficiently incorporating higher-mode effects without excessive computational effort.

Hydraulic Dampers – Viscous devices that dissipate energy through fluid flow. Related terms: tuned mass damper, semi-active control. Often installed at strategic locations in tall buildings to reduce vibration.

Challenge: ensuring reliability under extreme temperature variations.

Impact of Soft-Story – A vertical zone with reduced lateral stiffness, often due to large openings. Related terms: soft-story collapse, seismic retrofit. Soft-stories are major vulnerability points in tall buildings. Challenge: retrofitting with shear walls or outriggers while preserving architectural function.

Inelastic Displacement Ratio (IDR) – Ratio of inelastic displacement demand to elastic displacement demand. Related terms: displacement amplification factor, ductility. Used to convert elastic spectra to inelastic demand for tall structures. Challenge: selecting appropriate IDR values for multi-modal behavior.

Influence Line – Graphical representation of how a response quantity (e.g., shear, moment) varies with load position. Related terms: load path, critical load position. Helpful for assessing seismic load distribution in irregular tall frames. Challenge: extending influence line concepts to dynamic loading.

Initial Stiffness – Linear elastic stiffness of a structural component before yielding. Related terms: tangent stiffness, secant stiffness. Determines natural frequencies and initial modal shapes. Challenge: updating stiffness as damage accumulates during large earthquakes.

Input Motion Scaling – Process of adjusting recorded or synthetic ground motions to match target spectral characteristics. Related terms: scaling factor, spectral matching. Critical for ensuring that analysis reflects the intended design earthquake. Challenge: preserving physical realism while achieving target spectra.

Integrated Design Approach – Coordinated design of architectural, structural, and MEP systems to achieve optimal seismic performance. Related terms: interdisciplinary collaboration, performance objectives. Enables efficient use of space and material. Challenge: managing conflicting requirements among disciplines.

International Building Code (IBC) – Widely adopted code that includes provisions for seismic design of tall buildings. Related terms: ASCE 7, code adoption. Provides baseline requirements for load combinations and detailing. Challenge: interpreting IBC provisions for very tall (>300 m) structures.

Jacketing – Reinforcement of existing structural members by adding a new layer of material, typically concrete or steel. Related terms: retrofit, shear strengthening. Used to increase capacity of columns in seismic retrofits. Challenge: ensuring adequate bond and compatibility with existing material.

Joint Shear Capacity – Maximum shear force a beam-column joint can resist before failure. Related terms: joint reinforcement, plastic hinge length. Governs the development of plastic hinges in tall frames. Challenge: designing joints to achieve desired ductility without excessive congestion.

Jumping Load – Sudden increase in seismic demand due to pulse-like ground motions, often associated with fault directivity. Related terms: velocity pulse, long-period demand. Can cause excessive story drifts in flexible towers. Challenge: identifying and mitigating pulse effects in design.

Kirchhoff's Law (Structural Dynamics) – Principle that the sum of forces and moments in a dynamic system must be zero. Related terms: equilibrium, compatibility. Forms the basis of dynamic equilibrium equations. Challenge: applying the law correctly in non-linear, time-varying systems.

Landau Damping – Energy dissipation due to phase mixing in wave propagation; rarely considered in building seismic analysis. Related terms: modal damping, internal friction. Mentioned for completeness in advanced dynamics texts. Challenge: negligible effect on tall-building seismic response.

Lift-Shaft Interaction – Dynamic coupling between elevator shafts and the surrounding structural core. Related terms: core shear, out-of-plane vibration. Can affect torsional response during earthquakes. Challenge: modeling the interaction without excessive model complexity.

Linear Elastic Analysis – Assumes material behavior remains elastic throughout loading. Related terms: stiffness matrix, modal superposition. Provides initial insight into modal frequencies. Challenge: underestimates demand for tall, flexible structures that will yield.

Linear Period (Tlin) – Natural period of a structure assuming linear elastic behavior. Related terms: effective period, period elongation. Used as a reference for spectral adjustments. Challenge: predicting period elongation due to damage.

Load Path – The route by which seismic forces are transferred from the superstructure to the foundation. Related terms: force redistribution, redundancy. A clear load path ensures robust performance. Challenge: maintaining load path integrity after damage to primary members.

Long-Period Ground Motion – Seismic waves with periods greater than 1 s, often causing large displacements in tall buildings. Related terms: pulse-like motion, near-fault effect. Increases drift demand significantly. Challenge: designing structures to accommodate long-period content without excessive stiffness.

Mass Participation Ratio – Fraction of total mass that participates in a particular mode. Related terms: modal mass, participation factor. Determines the significance of each mode in seismic response. Challenge: high mass participation in higher modes for very tall structures.

Mass Ratio (R) – Ratio of total building mass to the mass of the primary lateral force-resisting system. Related terms: effective mass, mass distribution. Influences dynamic amplification. Challenge: achieving balanced mass distribution to avoid concentration of seismic forces.

Maximum Considered Earthquake (MCE) – The most severe earthquake considered for design, typically with a low probability of exceedance. Related terms: design earthquake, return period. Provides a safety margin for tall building design. Challenge: reconciling MCE with performance-based objectives.

Mean Period (Tm) – Weighted average of the periods of significant modes, often used in code provisions. Related terms: period averaging, seismic coefficient. Provides a single period value for simplified design. Challenge: selecting appropriate weighting factors for irregular structures.

Modal Damping – Damping associated with each mode, often assumed proportional to critical damping. Related terms: Rayleigh damping, viscous damping. Affects modal response amplitudes. Challenge: assigning realistic damping values for higher modes.

Modal Participation Factor (Γ) – Measure of the contribution of a mode to overall displacement or base shear. Related terms: mass participation, mode shape. High participation factors indicate important modes. Challenge: accurately computing Γ for coupled torsional modes.

Modal Superposition – Technique that sums the individual modal responses to obtain total structural response. Related terms: linear analysis, mode coupling. Efficient for linear elastic analysis of tall buildings. Challenge: neglects interaction effects when nonlinearity is significant.

Moment Curvature Relationship – Curve that relates bending moment to curvature, reflecting material and section behavior. Related terms: plastic hinge, ductility. Fundamental for capacity curve development in pushover analysis. Challenge: capturing stiffness degradation with increasing curvature.

Monte Carlo Simulation – Statistical method that uses random sampling to assess seismic demand variability. Related terms: probabilistic analysis, hazard curve. Provides confidence intervals for response parameters. Challenge: requiring large number of simulations for convergence.

Multistory Building – A structure with several floors, each contributing to overall seismic demand. Related terms: shear wall, frame system. Tall buildings are a subset with significant height. Challenge: controlling inter-story drift across many levels.

Multi-Modal Analysis – Consideration of several vibration modes simultaneously in seismic response prediction. Related terms: higher-mode effects, modal summation. Essential for accurate drift estimation in tall structures. Challenge: computational effort increases with number of modes.

Nonlinear Time History Analysis (NLTHA) – Direct integration of equations of motion using a nonlinear model and recorded or synthetic ground motions. Related terms: incremental dynamic analysis, pushover analysis. Provides realistic demand estimates. Challenge: high computational cost and model sensitivity.

Outrigger System – Structural system that connects the central core to perimeter columns, increasing stiffness and reducing drift. Related terms: belt truss, mega-frame. Common in super-tall skyscrapers. Challenge: designing connections that can develop large plastic rotations.

Peak Ground Acceleration (PGA) – Maximum horizontal acceleration recorded during an earthquake. Related terms: intensity measure, hazard level. Often used as a scaling parameter for ground motions. Challenge: PGA alone does not capture frequency content relevant to tall buildings.

Performance-Based Design (PBD) – Design methodology that targets specific performance levels (e.g., immediate occupancy, collapse prevention). Related terms: target displacement, limit state. Allows tailoring of seismic response for tall structures. Challenge: defining appropriate performance criteria for very high-rise buildings.

Pile-Soil Interaction (PSI) – Dynamic interaction between deep foundations and surrounding soil. Related terms: impedance functions, added mass. Influences seismic response of tall towers with pile foundations. Challenge: modeling non-linear soil behavior under strong shaking.

Plastic Hinge Length (ℓp) – Length over which plastic rotation is assumed to occur at a member end. Related terms: hinge model, curvature ductility. Critical for estimating deformation capacity. Challenge: selecting appropriate ℓp for slender columns versus deep beams.

Pre-Stress Loss – Reduction in pre-stress force due to relaxation, creep, or shrinkage. Related terms: tendon relaxation, concrete creep. Affects initial stiffness of pre-stressed concrete cores in tall buildings. Challenge: accounting for loss in seismic analysis.

Probabilistic Seismic Hazard Analysis (PSHA) – Quantitative assessment of earthquake likelihood and intensity at a site. Related terms: hazard curve, return period. Generates spectra for performance-based design. Challenge: integrating PSHA results with code requirements.

Quasi-Static Analysis – Approximation method that applies static loads incrementally to simulate dynamic effects. Related terms: pushover, incremental dynamic analysis. Useful for identifying weak mechanisms. Challenge: may underestimate demand for structures with significant higher-mode contributions.

Rayleigh Damping – Damping model that combines mass and stiffness proportional terms to achieve desired damping ratios for multiple modes. Related terms: damping matrix, proportional damping. Widely used in dynamic analysis of tall buildings. Challenge: tuning coefficients to avoid unrealistic damping at high frequencies.

Reference Period (Tref) – Period chosen as a reference for scaling or comparison, often the fundamental period of a typical building. Related terms: period scaling, spectral shape. Facilitates comparison across different structures. Challenge: selecting a representative Tref for irregular tall buildings.

Reinforced Concrete Core – Central vertical element composed of concrete walls reinforced with steel, providing primary lateral resistance. Related terms: shear wall, tube system. Dominates the seismic stiffness of many skyscrapers. Challenge: detailing core–outlet connections for ductility.

Response Modification Factor (R) – Code-provided factor that reduces elastic seismic forces based on a structure’s ductility and overstrength. Related terms: importance factor, q factor. Allows designers to account for inelastic behavior. Challenge: applying appropriate R values to complex tall-building systems.

Return Period – Average interval between earthquakes of a given magnitude at a location. Related terms: probability of exceedance, seismic hazard. Used to define design earthquake levels. Challenge: long return periods lead to high uncertainty in hazard estimates.

Rigid Diaphragm Assumption – Simplification that floor plates act as rigid bodies in lateral analysis. Related terms: floor shear, torsional stiffness. Facilitates modal analysis of tall buildings. Challenge: violations due to large openings or irregular mass distribution.

Safety Factor – Ratio of the capacity of a structural element to the applied load. Related terms: factor of safety, reliability index. Provides a margin against uncertainties. Challenge: excessive safety factors can lead to over-design and increased costs.

Scalable Ground Motion – Recorded or synthetic motion that can be adjusted in amplitude while preserving its frequency content. Related terms: scaling, spectral matching. Enables matching to target design spectra. Challenge: maintaining realistic shape after scaling.

Seismic Design Category (SDC) – Classification of structures based on seismic risk, influencing design requirements. Related terms: importance factor, occupancy category. Tall buildings often fall into higher SDCs. Challenge: meeting stricter detailing requirements for high SDCs.

Seismic Hazard Curve – Graph showing the probability of exceeding various intensity measures at a site. Related terms: PSHA, exceedance probability. Provides input for performance-based design. Challenge: interpreting curves for rare, high-intensity events.

Seismic Load Path – The sequence of structural elements through which seismic forces travel from the roof to the foundation. Related terms: lateral force resisting system, redundancy. Ensuring a continuous load path is a key design objective. Challenge: preserving the load path after an element yields.

Seismic Mass – Portion of a building's total mass that contributes to seismic inertia forces. Related terms: effective mass, mass participation. Typically excludes non-structural components with low stiffness. Challenge: accurately estimating seismic mass for buildings with extensive façade systems.

Shear Wall – Vertical element that resists lateral forces primarily through shear. Related terms: concrete core, coupled wall system. Provides stiffness and strength for tall structures. Challenge: detailing wall–floor connections to allow sufficient ductility.

Shear Transfer Length – Length over which shear is transferred from one structural component to another. Related terms: shear lag, load distribution. Important in designing connections between a core and outriggers. Challenge: ensuring adequate transfer without excessive stress concentrations.

Soft-Story Retrofit – Strengthening measures applied to a soft-story level, such as adding shear walls, braces, or outriggers. Related terms: seismic upgrade, capacity increase. Improves lateral stiffness and reduces drift. Challenge: integrating retrofit measures within existing architectural constraints.

Soil-Structure Interaction (SSI) – Interaction effects between a building foundation and the underlying soil during seismic loading. Related terms: impedance functions, foundation rocking. Can modify natural frequencies and damping. Challenge: modeling SSI accurately for very tall, heavy structures.

Structural Damping – Energy dissipation due to internal friction, material hysteresis, and added devices. Related terms: viscous damper, hysteretic damping. Contributes to reducing seismic response. Challenge: quantifying damping for complex, multi-material systems.

Structural Irregularity – Deviation from uniform geometry or stiffness distribution, such as setbacks, mass concentration, or soft stories. Related terms: torsional irregularity, vertical irregularity. Increases seismic demand and design complexity. Challenge: mitigating adverse effects through layout adjustments.

Sub-Structure Modeling – Detailed representation of foundation and soil in a seismic analysis. Related terms: finite element model, impedance functions. Captures interaction effects for tall building foundations. Challenge: balancing model detail with computational efficiency.

Summation of Story Drifts – Accumulation of inter-story drifts from the base to a given level. Related terms: cumulative drift, story drift ratio. Used to evaluate overall deformation demand. Challenge: ensuring sum does not exceed serviceability limits.

Super-Structure – The portion of a building above the foundation, including all floors and roof. Related terms: sub-structure, load path. Primary focus of seismic analysis for tall buildings. Challenge: integrating super-structure behavior with foundation response.

System Ductility – Ability of the overall structural system to undergo inelastic deformation without losing load-carrying capacity. Related terms: ductility factor, energy dissipation. Central to performance-based seismic design. Challenge: achieving high ductility while meeting stiffness and architectural constraints.

Target Displacement – Desired inter-story drift or roof displacement for a specific performance level. Related terms: performance point, damage limit state. Guides selection of seismic inputs and design decisions. Challenge: defining realistic targets for ultra-tall buildings.

Temperature Effects on Seismic Response – Influence of temperature variations on material properties and structural stiffness. Related terms: thermal expansion, creep. Can affect natural frequencies and damping. Challenge: incorporating temperature-dependent material models in dynamic analysis.

Torsional Irregularity – Condition where the center of mass and center of stiffness are significantly offset, causing torsional vibration. Related terms: eccentricity, torsional mode. Increases demand on perimeter columns. Challenge: reducing eccentricity through symmetric layout or adding torsional resisting elements.

Translational Mode – Vibration mode where the structure moves primarily in a single horizontal direction. Related terms: sway mode, modal frequency. Dominant mode for most tall buildings. Challenge: accounting for coupling with torsional modes.

Tri-Axial Seismic Test – Laboratory test that subjects a structural component to simultaneous three-directional shaking. Related terms: shake-table, multi-directional loading. Provides data on interaction effects. Challenge: replicating realistic field conditions.

Uplift Capacity – Ability of a foundation or footing to resist upward forces during seismic events, such as those caused by pounding. Related terms: rocking, foundation uplift. Critical for shallow foundations of tall structures. Challenge: designing foundations that can accommodate uplift without excessive settlement.

Ultimate Strength – Maximum load a structural component can carry before failure. Related terms: yield strength, plastic capacity. Determines the upper bound of seismic demand. Challenge: ensuring ultimate strength is not the governing limit for ductile design.

Uncertainty Quantification – Process of characterizing variability in material properties, loads, and modeling assumptions. Related terms: Monte Carlo simulation, sensitivity analysis. Provides confidence bounds on seismic performance predictions. Challenge: integrating uncertainties without over-conservatism.

Vibration Control Devices – Systems such as tuned mass dampers (TMDs) or active control units that mitigate building vibrations. Related terms: semi-active damper, frequency tuning. Often employed in super-tall skyscrapers to improve occupant comfort and reduce seismic demand. Challenge: ensuring reliability under extreme shaking.

Vertical Irregularity – Variation in stiffness or strength along the height, such as abrupt changes due to setbacks or step-back designs. Related terms: story stiffness, height-dependent period. Can cause localized concentration of forces. Challenge: redistributing stiffness to achieve smoother period progression.

Wind–Seismic Interaction – Simultaneous consideration of wind and earthquake loads, which may be concurrent in certain regions. Related terms: combined load case, dynamic amplification. Tall buildings must be designed for both effects. Challenge: developing analysis procedures that capture interaction without excessive conservatism.

Yield Acceleration (Ay) – Ground acceleration at which a structural system first yields. Related terms: yield displacement, elastic limit. Used to define the elastic–inelastic transition in capacity spectrum methods. Challenge: estimating Ay for multi-modal tall structures.

Yield Displacement (δy) – Lateral displacement at which yielding initiates in the primary lateral force-resisting system. Related terms: ductility, capacity curve. Basis for determining target displacement for performance-based design. Challenge: measuring δy accurately for complex core-outrigger configurations.

Yield Force (Fy) – Lateral force at which the primary resisting system yields. Related terms: yield strength, plastic hinge formation. Central to defining the capacity curve. Challenge: capturing reduction of Fy due to damage accumulation.

Zero-Period Ground Motion – Idealized ground motion with infinitely short period, representing the