Graduate Certificate in Design and Analysis of Tall Buildings (Part II)

Seismic Design of High Rise Structures

Acceleration Response Spectrum (ARS) A graphical representation of the maximum acceleration that a set of single-degree-of-freedom (SDOF) systems experiences for a range of natural periods when subjected to a specific ground motion. Related terms: response spectrum, spectral acceleration. Example: Engineers use ARS to select appropriate damping ratios for tall-building dampers. Challenge: Accurately capturing high-frequency content for slender towers.

Adaptive Damping System (ADS) A semi-active device that adjusts its damping characteristics in real time based on measured building response. Related terms: semi-active control, tuned mass damper. Example: An ADS installed in a 60-story office tower modifies its resistance during aftershocks. Challenge: Designing reliable control algorithms that remain functional after power loss.

Base Isolation A seismic protection technique that decouples the superstructure from ground motion by inserting flexible bearings or sliders at the foundation level. Related terms: lead-rubber bearing, friction pendulum bearing. Example: A residential high-rise uses lead-rubber bearings to reduce inter-story drift. Challenge: Maintaining isolation performance under vertical loads and long-duration earthquakes.

Building Code A set of legally enforceable regulations that prescribe minimum design standards for safety, including seismic provisions for tall structures. Related terms: IBC, ASCE 7. Example: The 2024 edition of the International Building Code introduces higher importance factors for skyscrapers. Challenge: Keeping design practices aligned with frequent code updates across jurisdictions.

Capacity Spectrum Method (CSM) A performance-based analysis technique that compares a structure's capacity curve with the demand spectrum to predict damage levels. Related terms: pushover analysis, target displacement. Example: A 45-story tower's capacity curve is plotted against the site-specific spectrum to verify that the expected drift stays within the Immediate Occupancy limit. Challenge: Generating accurate capacity curves for irregular plan-shape buildings.

Characteristic Period (Tc) The fundamental period of a building, often estimated from height, stiffness, and mass distribution. Related terms: fundamental mode, modal period. Example: For a 300-m tower, Tc may be approximated as 2.5 s using empirical formulas. Challenge: Capturing the effect of torsional coupling on the true fundamental period.

Co-efficient of Damping (ζ) A dimensionless parameter representing the ratio of actual damping to critical damping in a dynamic system. Related terms: viscous damping, structural damping. Example: Typical concrete frames exhibit $\zeta \approx 0.05$, while steel frames may have $\zeta \approx 0.02$. Challenge: Accounting for increased damping due to supplemental devices like viscous dampers.

Concrete Core Wall A reinforced concrete shear wall that runs the full height of a building, providing both lateral stiffness and vertical load-carrying capacity. Related terms: shear wall, core tube. Example: The central core of a 70-story tower contains eight 1.5-m-wide walls. Challenge: Designing openings for elevators without compromising shear capacity.

Dynamic Amplification Factor (DAF) The ratio of the maximum dynamic response to the corresponding static response for a given load case. Related terms: response modification factor, modal amplification. Example: A stiffened frame may exhibit a DAF of 1.8 under a near-fault pulse. Challenge: Predicting DAF accurately for irregular structures with multiple dominant modes.

Effective Height (He) The height at which the equivalent static force is assumed to act in simplified seismic analysis methods. Related terms: equivalent static analysis, seismic weight distribution. Example: For a uniformly distributed mass, He ≈ 0.5 H, where H is total building height. Challenge: Adjusting He for buildings with significant mass concentration near the top.

Elastic Design Spectrum A set of spectral accelerations derived under the assumption that the structure remains elastic throughout the earthquake. Related terms: elastic response spectrum, design ground motion. Example: The elastic spectrum is used to size moment frames for a 55-story office building. Challenge: Ensuring that elastic demands do not exceed material yield limits for tall, flexible structures.

End-Bearing A type of base isolation device that separates the building from ground motion by allowing horizontal translation while transmitting vertical loads. Related terms: lead-rubber bearing, sliding bearing. Example: A 40-story residential tower uses end-bearing isolators to achieve a 20-cm isolation gap. Challenge: Controlling pounding between the isolated building and adjacent structures.

Equivalent Lateral Force (ELF) A simplified seismic load computed by applying a prescribed horizontal force at each level of the structure based on building weight and seismic coefficients. Related terms: static analysis, seismic coefficient. Example: The ELF for a 30-story tower is calculated using a coefficient of 0.12 g. Challenge: Capturing the effect of higher-mode forces in a single-force representation.

Floor Diaphragm A structural element, usually a concrete slab or steel deck, that transfers lateral forces to vertical resisting members. Related terms: shear transfer, rigid diaphragm. Example: The 12-in-thick concrete floor diaphragm of a skyscraper distributes seismic shear to the central core. Challenge: Ensuring diaphragm continuity across large openings and mechanical shafts.

Fundamental Mode The lowest natural vibration mode of a structure, typically governing the bulk of seismic response for regular tall buildings. Related terms: first mode, mode shape. Example: In a 50-story tower, the fundamental mode accounts for about 80 % of total displacement. Challenge: Recognizing when higher modes become significant due to irregular mass or stiffness distribution.

Geotechnical Site Classification A categorization of soil conditions based on shear-wave velocity, which influences seismic design parameters such as site coefficients. Related terms: NEHRP site class, soil amplification. Example: A downtown high-rise sits on Class B soil, reducing the site coefficient from 1.2 to 1.0. Challenge: Dealing with soft-soil sites (Class D) that amplify long-period ground motions.

Ground Motion Prediction Equation (GMPE) An empirical relationship that estimates expected ground-motion intensity measures (e.g., PGA, Sa) as a function of magnitude, distance, and site conditions. Related terms: attenuation relationship, seismic hazard analysis. Example: Designers use the Boore-Atkinson GMPE to generate site-specific spectra for a coastal megatall building. Challenge: Selecting appropriate GMPEs for regions with limited strong-motion records.

High-Rise Structure A building typically taller than 75 m or exceeding 15 stories, where wind and seismic effects are amplified and dynamic analysis is essential. Related terms: skyscraper, tall building. Example: The 120-story tower qualifies as a high-rise and requires both wind-induced and earthquake-induced response analysis. Challenge: Coordinating wind and seismic design criteria that may conflict on stiffness requirements.

Influence Line A graphical tool that shows how a particular response (e.g., shear, moment) varies as a unit load moves across a structure. Related terms: load distribution, structural analysis. Example: Influence lines help assess the impact of an earthquake-induced impulsive load moving upward through a shear wall. Challenge: Extending influence-line concepts to dynamic, multi-modal loading.

Inter-Story Drift The relative lateral displacement between two consecutive floors, expressed as a percentage of the story height. Related terms: drift ratio, story deformation. Example: Codes often limit drift to 0.004 H for Immediate Occupancy performance. Challenge: Controlling drift in slender towers where drift amplification is pronounced.

Joint Shear Transfer The ability of connections between structural members to transmit shear forces, critical for maintaining diaphragm integrity under seismic loading. Related terms: connection detailing, shear stud. Example: Welded shear studs are used to improve joint shear transfer between steel deck and concrete slab. Challenge: Verifying shear capacity of connections in the presence of large cyclic deformations.

Kinetic Energy Dissipation The process by which a structure absorbs and converts seismic energy into heat, friction, or other forms, reducing the energy transmitted to the superstructure. Related terms: energy dissipation devices, hysteretic damping. Example: Viscous dampers in a tower dissipate kinetic energy during an earthquake, limiting peak accelerations. Challenge: Designing devices that maintain performance over multiple events.

Linear-Elastic Analysis A modeling approach that assumes material behavior remains within the elastic range, simplifying calculations but potentially underestimating damage. Related terms: elastic model, stiffness matrix. Example: Preliminary design of a 40-story frame may use linear-elastic analysis to estimate base shear. Challenge: Transitioning to non-linear analysis for final design of high-rise structures.

Mass Participation Ratio The proportion of the total mass that contributes to a particular vibration mode, indicating the mode's significance in the overall response. Related terms: modal mass, participation factor. Example: The first mode of a 70-story tower has a mass participation of 0.85, while the second mode contributes 0.10. Challenge: Accounting for modes with low participation but high torsional effects.

Modal Analysis A technique that decomposes the dynamic response of a structure into its constituent vibration modes, each characterized by a natural frequency, damping, and mode shape. Related terms: eigenvalue problem, mode superposition. Example: Modal analysis of a tall building identifies three dominant modes that dominate seismic response. Challenge: Managing the computational effort for models with thousands of degrees of freedom.

Near-Fault Ground Motion Strong-motion records that exhibit pulse-type characteristics due to rupture directivity, often causing large velocity and displacement demands on tall structures. Related terms: pulse-like motion, directivity effect. Example: A near-fault earthquake imposes a 3-second velocity pulse on a 55-story tower. Challenge: Designing structures to withstand pulse loads without excessive drift.

Non-Linear Time History Analysis (NLTHA) A detailed simulation that subjects a detailed structural model to recorded or synthetic ground motions, capturing material yielding and large deformations. Related terms: dynamic analysis, hysteretic model. Example: NLTHA is performed on a 60-story steel frame using 20 recorded motions to assess performance levels. Challenge: High computational cost and the need for accurate material models.

Performance-Based Design (PBD) A design philosophy that specifies target performance objectives (e.g., Immediate Occupancy, Life Safety) and tailors the structural system to meet those objectives under defined seismic hazards. Related terms: performance levels, damage criteria. Example: A mixed-use high-rise is designed to achieve Immediate Occupancy under a 0.2 g design earthquake. Challenge: Quantifying damage for complex, irregular buildings.

Plastic Hinge A localized region in a structural member where plastic rotation occurs after yielding, allowing redistribution of forces during seismic events. Related terms: hinge formation, inelastic deformation. Example: Plastic hinges are expected to form at beam ends of a moment-resisting frame during strong shaking. Challenge: Controlling hinge length to limit drift and avoid fracture.

Pull-Out Capacity The maximum tensile force that a reinforcement bar can sustain before it detaches from surrounding concrete, critical for seismic detailing. Related terms: bond strength, anchorage. Example: Pull-out tests guide the spacing of vertical bars in shear walls for a 45-story tower. Challenge: Ensuring sufficient pull-out capacity in high-strength concrete mixes.

Quasi-Static Pushover Analysis A simplified non-linear method where a gradually increasing lateral load is applied incrementally to a structural model until target displacement is reached. Related terms: pushover curve, capacity curve. Example: A pushover analysis of a 50-story tower provides an estimate of the base shear capacity. Challenge: Capturing higher-mode effects and torsional response in the pushover framework.

Rayleigh Damping A damping model that combines mass-proportional and stiffness-proportional components to achieve frequency-dependent damping ratios. Related terms: mass proportional damping, stiffness proportional damping. Example: Rayleigh damping coefficients are calibrated to give 5 % damping at the first two modes of a skyscraper. Challenge: Preventing excessive damping at higher frequencies that may affect response predictions.

Seismic Hazard Analysis The process of estimating the probability of various levels of ground shaking at a site, typically using probabilistic or deterministic methods. Related terms: PSHA, deterministic seismic hazard. Example: A probabilistic seismic hazard analysis yields a 0.2 g 10-% in 50-year ground motion for a coastal high-rise. Challenge: Incorporating site-specific uncertainties and future seismicity trends.

Shear Wall A vertical structural element that resists lateral forces primarily through shear action, often constructed of reinforced concrete or steel plates. Related terms: lateral load resisting system, core wall. Example: A series of concrete shear walls surrounds the elevator core of a 55-story tower. Challenge: Designing openings for services while maintaining shear capacity.

Stiffness Matrix A mathematical representation of the relationship between forces and displacements for a structural system, essential for dynamic analyses. Related terms: finite element method, global stiffness. Example: The global stiffness matrix is assembled from element matrices of a high-rise steel frame. Challenge: Managing ill-conditioning in very tall, flexible structures.

Structural Damping The inherent energy-absorbing property of a building’s materials and connections, distinct from added damping devices. Related terms: material damping, hysteretic damping. Example: Concrete structures typically exhibit 2-5 % structural damping. Challenge: Quantifying damping accurately for mixed-material high-rise constructions.

Super-Structure The portion of a building above the foundation, including all floors, walls, and roof that must be designed to resist seismic forces. Related terms: substructure, above-ground portion. Example: The super-structure of a 70-story tower incorporates a composite steel-concrete core. Challenge: Integrating the super-structure’s dynamic behavior with base-isolation devices.

Torsional Irregularity A condition where a building’s mass and stiffness distribution cause significant torsional response under seismic loading. Related terms: torsional mode, plan irregularity. Example: An offset core in a high-rise induces a torsional irregularity that must be accounted for in analysis. Challenge: Mitigating torsion through symmetric layout or supplemental bracing.

Transfer Function In seismic engineering, a function that relates input ground motion to output structural response in the frequency domain. Related terms: frequency response, spectral transfer. Example: The transfer function of a tall building shows amplification peaks near its natural periods. Challenge: Accurately modeling damping to avoid over-prediction of resonant responses.

Uplift Response The vertical displacement of a building’s base or isolated platform caused by seismic forces, especially in base-isolated structures. Related terms: vertical isolation, uplift check. Example: Uplift analysis ensures that the lead-rubber bearings of a 40-story tower do not lose contact during strong shaking. Challenge: Designing restraints that allow uplift without compromising horizontal isolation.

Vertical Load Path The route through which vertical loads (gravity, live loads) are transferred from the super-structure to the foundation, essential for overall stability. Related terms: load transfer, support system. Example: In a composite high-rise, the vertical load path includes steel beams, concrete slabs, and core columns. Challenge: Maintaining the vertical load path integrity after lateral damage.

Wind-Seismic Interaction The combined effect of wind and earthquake loads on a tall building, which may require simultaneous consideration in design. Related terms: combined loading, dynamic interaction. Example: For a coastal megatall, wind-seismic interaction analysis assesses the increase in drift when both loads act together. Challenge: Developing reliable models that capture the non-linear coupling of wind and seismic responses.

Yield Acceleration (Ay) The ground acceleration level at which a structural member first yields, marking the transition from elastic to inelastic behavior. Related terms: elastic limit, yield point. Example: The yield acceleration for a steel moment frame in a 30-story building may be 0.35 g. Challenge: Estimating Ay for complex composite sections with varying material properties.

Zero-Period Ground Motion (ZPGM) A synthetic ground motion characterized by very short dominant periods, often used to evaluate high-frequency response of stiff structures. Related terms: high-frequency content, short-period motion. Example: ZPGM is applied to assess the response of a stiff concrete-core tower. Challenge: Ensuring that the synthetic motion reflects realistic site conditions.

Seismic Design Category (SDC) A classification system that dictates the level of seismic design required based on location, building occupancy, and importance. Related terms: importance factor, site class. Example: A hospital high-rise in a high-seismic zone may be assigned SDC D, requiring stricter design criteria. Challenge: Aligning SDC requirements with performance-based objectives.

Site Coefficient (Fs) A factor applied to the spectral acceleration to account for soil amplification effects, derived from site class and local geology. Related terms: soil amplification, spectral modification. Example: For a Class C site, Fs may be 1.2, increasing the design spectral acceleration. Challenge: Determining accurate Fs values for heterogeneous urban soils.

Story Stiffness The lateral stiffness contributed by a single floor level, influencing the distribution of drift and shear forces across the building. Related terms: shear stiffness, flexural rigidity. Example: In a 45-story tower, lower stories typically have higher stiffness due to larger shear walls. Challenge: Balancing stiffness to avoid concentration of forces in soft stories.

Structural Health Monitoring (SHM) The implementation of sensors and data acquisition systems to continuously assess a building’s condition, especially after seismic events. Related terms: vibration monitoring, damage detection. Example: An SHM system in a skyscraper records acceleration and strain during an earthquake, enabling rapid post-event assessment. Challenge: Ensuring sensor durability and data reliability under extreme loading.

Stochastic Ground Motion Simulation A method that generates synthetic earthquake records based on statistical properties of observed motions, used for extensive seismic analyses. Related terms: Monte Carlo simulation, random vibration. Example: 100 stochastic simulations are run on a 60-story tower to evaluate probabilistic performance. Challenge: Capturing rare but destructive pulse features in the synthetic set.

Time-Domain Spectral Analysis An approach that computes response spectra directly from time-history simulations, allowing assessment of non-linear behavior over the duration of an earthquake. Related terms: spectral response, non-linear spectra. Example: Time-domain spectral analysis reveals that a high-rise experiences higher spectral accelerations than predicted by linear theory. Challenge: Managing large datasets and extracting meaningful performance metrics.

Vertical Acceleration (Az) The component of ground motion acting in the vertical direction, which can affect the uplift response of base-isolated structures. Related terms: vertical ground motion, uplift analysis. Example: A vertical acceleration of 0.15 g is considered in the design of a 30-story building with friction pendulum bearings. Challenge: Limited code guidance on vertical seismic effects for tall buildings.

Wind Tunnel Testing A physical experiment where scaled models of tall buildings are subjected to controlled wind flows to evaluate aerodynamic forces and vortex shedding. Related terms: aerodynamic loading, gust factor. Example: Wind tunnel data informs the damping requirements for a 80-story tower. Challenge: Replicating simultaneous wind and seismic loading conditions.

Yield Drift Ratio (θy) The drift ratio at which a structural component reaches its yield point, often used as a performance indicator in pushover analysis. Related terms: drift capacity, inelastic deformation. Example: For a reinforced concrete shear wall, θy may be 0.005 H. Challenge: Accurately estimating θy for composite elements with mixed materials.

Zero-Period Damping (ζ0) The damping value applied at infinitely high frequencies in a frequency-dependent damping model, influencing short-period response. Related terms: high-frequency damping, Rayleigh damping. Example: ζ0 is set to 0.02 for a steel-frame tower to limit high-frequency amplification. Challenge: Selecting ζ0 without over-damping realistic mode shapes.

Accelerogram A recorded time history of ground acceleration, used as input for dynamic analyses. Related terms: ground motion record, time-history analysis. Example: The 1995 Kobe earthquake accelerogram is employed in the seismic assessment of a 70-story building. Challenge: Scaling accelerograms to match target hazard levels while preserving frequency content.

Base Shear (Vb) The total horizontal shear force transmitted to the foundation of a structure due to seismic loading, calculated from seismic coefficients and building weight. Related terms: seismic force, lateral load.

Example: For a 40-story tower with total weight W, $V_b = C_s \times W$, where Cs is the seismic coefficient. Challenge: Distributing base shear among columns and walls to avoid overloading.

Critical Damping Ratio (ζ_c) The damping ratio at which a single-degree-of-freedom system transitions from under-damped to over-damped behavior, equal to 1.0. Related terms: damping ratio, critical damping. Example: In modal analysis, ζ_c is used as a reference to compute actual damping values. Challenge: Interpreting ζ_c in complex multi-modal systems.

Dynamic Interaction (DI) The mutual influence between structural components, such as core and perimeter frames, during seismic response, affecting overall stiffness and damping. Related terms: coupled analysis, interaction effects. Example: DI between a concrete core and steel outriggers modifies the fundamental period of a 55-story tower. Challenge: Capturing DI in simplified design models.

Elastic Modulus (E) A material property representing the ratio of stress to strain in the elastic range, critical for estimating stiffness of structural members. Related terms: Young's modulus, material stiffness. Example: Concrete with $E = 30\,\text{GPa}$ and steel with $E = 200\,\text{GPa}$ are used in a composite high-rise. Challenge: Accounting for degradation of E under cyclic loading.

Frequency-Domain Analysis A method that evaluates structural response by solving equations of motion in the frequency domain, often using modal superposition. Related terms: spectral analysis, modal response. Example: Frequency-domain analysis predicts peak accelerations for a 60-story building under a design spectrum. Challenge: Incorporating non-linear behavior, which is inherently time-dependent.

Ground Motion Record Selection The process of choosing appropriate accelerograms that represent the target seismic hazard for use in dynamic analyses. Related terms: record matching, scaling. Example: Seven records are selected based on magnitude, distance, and site class to represent a 0.3 g design event. Challenge: Ensuring the selected set captures the variability of possible ground motions.

Hysteretic Damping Energy dissipation that occurs due to the inelastic deformation of structural components, represented by hysteresis loops in force-displacement space. Related terms: plastic energy, non-linear damping. Example: Reinforced concrete shear walls exhibit hysteretic damping during cyclic loading. Challenge: Modeling hysteresis accurately for mixed-material systems.

Impact Factor (Ip) A factor that accounts for the additional forces generated by sudden changes in ground motion, such as those caused by near-fault pulses. Related terms: pulse effect, velocity pulse. Example: An impact factor of 0.15 g is applied to the design spectrum for a near-fault site. Challenge: Quantifying Ip for regions with limited pulse records.

Joint Flexibility The ability of connections between structural members to rotate or translate under load, influencing overall building stiffness and seismic performance. Related terms: connection detailing, rotation capacity. Example: Semi-rigid moment connections provide controlled joint flexibility in a steel frame. Challenge: Balancing flexibility to allow energy dissipation while preventing excessive drift.

Linear-Elastic Response Spectrum A plot that shows the peak response (acceleration, velocity, displacement) of an SDOF system assuming linear-elastic behavior for a range of periods and damping ratios. Related terms: elastic spectrum, design spectrum. Example: The linear-elastic response spectrum is generated for a 5 % damping level to size a concrete moment frame. Challenge: Adjusting the spectrum for site-specific amplification effects.

Mass Ratio (μ) The proportion of a substructure's mass relative to the total mass of the building, influencing dynamic interaction and vibration characteristics. Related terms: mass distribution, substructure dynamics. Example: The tuned mass damper in a 70-story tower has a mass ratio of 0.02, sufficient to reduce peak acceleration. Challenge: Determining optimal μ for a given performance target.

Modal Participation Factor (Γ) A scalar that quantifies the contribution of a particular mode to the overall response of a structure under a given loading pattern. Related terms: participation coefficient, mode shape. Example: The first mode of a tall building may have $\Gamma = 0.95$, indicating dominant influence. Challenge: Accurately computing Γ for irregular structures where higher modes may be significant.

Non-Structural Component Elements such as partitions, cladding, and mechanical equipment that are not part of the primary load-resisting system but can be vulnerable during earthquakes. Related terms: equipment anchorage, damage mitigation. Example: Seismic restraints are installed on façade panels of a 55-story tower to prevent falling hazards. Challenge: Coordinating non-structural design with overall building movement.

Outrigger System A structural configuration that connects the central core to perimeter columns, increasing lateral stiffness and reducing drift in tall buildings. Related terms: belt truss, mega-frame. Example: Outrigger trusses at the 30th and 45th floors of a skyscraper improve its fundamental period. Challenge: Designing outriggers to accommodate floor-to-floor height variations.

Peak Ground Acceleration (PGA) The maximum horizontal acceleration recorded during an earthquake, often used as a basic indicator of seismic intensity. Related terms: seismic intensity, ground motion. Example: A PGA of 0.35 g is assumed for the design earthquake in a high-seismic zone. Challenge: PGA alone does not capture frequency content critical for tall structures.

Performance Level A predefined target that describes the expected condition of a building after a seismic event, ranging from Immediate Occupancy to Collapse Prevention. Related terms: damage state, performance criteria. Example: A mixed-use high-rise is required to achieve Life Safety under the design earthquake. Challenge: Translating performance levels into quantifiable engineering parameters.

Quake-Resistant Design An overarching approach that incorporates seismic provisions, material selection, and detailing to ensure a building can withstand earthquake forces. Related terms: seismic design, resilience. Example: Quake-resistant design of a 60-story tower includes base isolation, damping devices, and ductile detailing. Challenge: Balancing cost, constructability, and performance objectives.

Response Modification Factor (R) A coefficient used to reduce elastic seismic forces based on the expected ductility and overstrength of a structural system. Related terms: overstrength factor, ductility. Example: A steel moment-resisting frame may have R = 8, allowing lower design forces. Challenge: Selecting appropriate R values for hybrid systems with mixed materials.

Seismic Isolation Gap The intentional vertical separation introduced by base isolators that allows the super-structure to move independently of ground motion. Related terms: isolation clearance, uplift gap. Example: A 25-mm isolation gap is provided for a 45-story building to accommodate expected uplift. Challenge: Preventing pounding with adjacent structures during large displacements.

Shear Deformation The change in shape of a structural member under shear forces, contributing to overall lateral displacement. Related terms: shear strain, lateral deformation. Example: Shear deformation in concrete walls accounts for 30 % of total drift in a typical high-rise. Challenge: Accurately modeling shear deformation in composite sections.

Stiffness Ratio The ratio of lateral stiffness between two adjacent stories, often used to identify soft-story conditions. Related terms: soft story, story stiffness. Example: If the stiffness ratio between the first and second stories is less than 0.5, a soft-story warning is triggered. Challenge: Designing retrofits for existing soft-story high-rise buildings.

Structural Redundancy The presence of multiple load-path options within a building, providing alternative routes for force transmission if one element fails. Related terms: alternative load path, redundant system. Example: A dual-core design in a skyscraper offers redundancy against column loss. Challenge: Quantifying redundancy benefits in performance-based frameworks.

Super-Structure Damping The damping contributed by the super-structure itself, separate from added devices, influencing overall seismic response. Related terms: structural damping, material damping. Example: The concrete core of a high-rise provides an estimated damping of 3 % of critical. Challenge: Differentiating super-structure damping from that of added dampers in analysis.

Time History Scaling The process of adjusting recorded accelerograms in amplitude (and sometimes duration) to match target spectral characteristics for use in dynamic analysis. Related terms: record scaling, spectral matching. Example: A 1999 Chi-Chi earthquake record is scaled to achieve a target Sa at 1.0 s of 0.45 g. Challenge: Preserving the original record’s frequency content while achieving scaling objectives.

Vertical Stiffness The resistance of a building’s foundation and substructure to vertical loads, influencing uplift behavior and overall stability. Related terms: foundation stiffness, compressive stiffness. Example: High vertical stiffness reduces uplift in a base-isolated tower during strong shaking. Challenge: Balancing vertical and horizontal stiffness to avoid torsional coupling.

Wind Load Factor (γw) A coefficient applied to wind pressures to account for uncertainties and variability in wind loading, similar in concept to seismic load factors. Related terms: wind design, load factor. Example:

$\gamma w = 1.5$ is used in the wind design of a 80-story office tower. Challenge: Coordinating wind load factors with seismic load combinations in mixed-design scenarios.

Yield Force (Fy) The axial or shear force at which a structural component reaches its yield stress, marking the onset of plastic behavior. Related terms: plastic hinge, inelastic response. Example: The yield force for a steel column in a high-rise may be 1,200 kN. Challenge: Accurately determining Fy for composite sections with variable reinforcement ratios.

Zero-Period Response The behavior of a structure at very short periods, where inertia dominates and stiffness effects are minimal, often relevant for stiff cores. Related terms: high-frequency response, inertial amplification. Example: Zero-period response governs the peak shear in a concrete-core tower under short-duration pulses. Challenge: Capturing this response without excessive computational effort.

Seismic Load Combination The set of equations prescribed by building codes that combine seismic forces with other loads (e.g., dead, live, wind) for design. Related terms: load combination, interaction equations. Example: A typical combination is 1.0 DL + 0.5 LL + 1.0 EQ for a high-rise. Challenge: Managing numerous combinations for performance-based design.

Design Ground Motion (DGW) A representative earthquake record or spectrum selected to represent the target seismic hazard level for design purposes. Related terms: target spectrum, hazard level. Example: The DGW for a coastal megatall is a 0.3 g, 5-second period pulse record. Challenge: Ensuring the DGW captures both amplitude and pulse characteristics relevant to