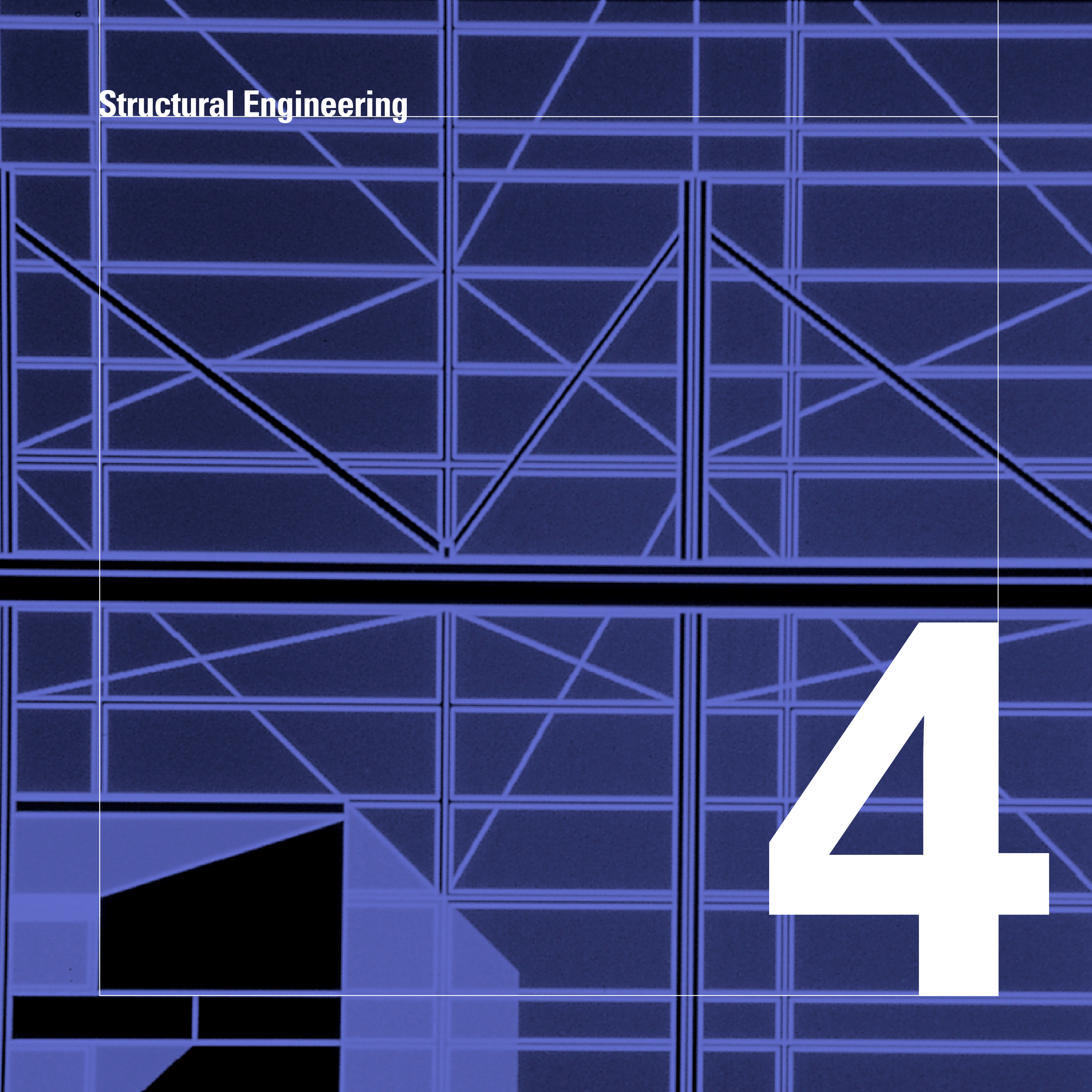
# Structural Engineering



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# 4.1 General Approach

Three characteristics distinguish GSA buildings from buildings built for the private sector: longer life span, changing occupancies, and the use of a life cycle cost approach to determine overall project cost.

GSA generally owns and operates its buildings much longer than private sector owners. Accordingly, a higher level of durability and serviceability is required for all systems. In terms of structural design, this has resulted in more stringent requirements than those stipulated in model building codes; the floor load capacity requirement of this chapter is an example.

During the life span of a typical Federal building, many minor and major alterations are necessary as the missions of Government agencies and departments change. The capability to accommodate alterations must be incorporated into the building from the outset. In some cases structural systems should be designed to provide some leeway for increase in load concentrations in the future. They should also be designed to facilitate future alterations, e.g., the cutting of openings for new vertical elements, such as piping, conduit and ductwork.

Security is an important consideration in structural design. Refer to Chapter 8: *Security Design* for design criteria related to this matter.

### Submission Requirements

Every project will have unique characteristics and requirements for submission and review. The general submission requirements for each phase of project development are described in Appendix A: *Submission Requirements*.

**Martin Luther King Courthouse, Newark, NJ**

## 4.2 Codes and Standards

Model codes and mandatory standards adopted by GSA for the design of all new buildings are discussed in Chapter 1: *General Requirements, Codes and Standards, Building Codes.*

The following FEMA Guidelines shall be incorporated into the structural design for all projects:

- Federal Emergency Management Agency (FEMA) publications:

  *NEHRP* (National Earthquake Hazards Reduction Program) *Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, Part 1: Provisions* (FEMA-302A, with 15 maps) and *Part 2: Commentary* (FEMA-303A).

  *Interim Guidelines: Evaluation, Repair, Modification and Design of Steel Moment Frames (FEMA-267) and Interim Guidelines: Evaluation, Repair, Modification and Design of Welded Steel Moment Frame Structures* (FEMA-267B).

  *NEHRP* (National Earthquake Hazards Reduction Program) *Handbook for the Seismic Evaluation of Buildings–A Pre-standard* (FEMA–310).

  *NEHRP* (National Earthquake Hazards Reduction Program) *Recommended Guidelines for the Seismic Rehabilitation of Buildings, Part 1: Guidelines* (FEMA-273, with the NEHRP maps) and *Part 2: Commentary* (FEMA-274).

- American Society of Civil Engineers: *Minimum Design Loads for Buildings and Other Structures, ASCE 7.*

- *Standards of Seismic Safety for Existing Federally Owned or Leased Buildings and Commentary* (ICSSC RP 4) prepared by the Interagency Committee on Seismic Safety in Construction – Recommended Practice 4.

### Use of Recycled Materials

The EPA Comprehensive Procurement Guidelines indicate the materials that must contain recycled content in the construction of buildings with federally appropriated funds. (Refer to: Chapter 1, *Recycled Materials*; and Chapter 3, *Incorporation of Recycled-Content Materials.*)

Chapter 3, *Incorporation of Recycled-Content Materials* includes a listing of ASTM Specifications for cement and concrete.

Information on specifying and purchasing recycled-content products can be found on the Internet at www.epa.gov/cpg.

National Building Museum, Washington, D.C.

# 4.3 Structural Forces

GSA promotes flexibility in the use of space. Since corridor locations may not be known until after construction begins and are subject to change over time, use an "office" uniform live load of 3.8 kPa (80 pounds per square foot) in lieu of the tabulated uniform live load in the model building codes. Spaces with higher live loads than this should be designed for the code required minimum or the actual live load, whichever is greater. Do not use live load reductions for (1) horizontal framing members, (2) transfer girders supporting columns, and (3) columns or walls supporting the top floor or roof.

Special live load requirements are specified for telecommunications equipment rooms by the FIPS 175: *Federal Building Standards for Telecommunication Pathways and Spaces*.

**Telecommunication Closets:** Use 3.8 kPa (80 pounds per square foot) minimum distributed live load capacity, which exceeds the minimum live load capacity stated in FIPS 175, standard part 7.2.3 of 2.4 kPa (50 pounds per square foot). Verify if any equipment will be used that exceeds this floor load requirement.

**Equipment Rooms for Telecommunication Equipment:** Floor loading capacity of telecommunication equipment rooms shall be sufficient to bear both the distributed and concentrated load of installed equipment. The FIPS 175 standard prescribes a minimum live load capacity for distributed loads of 12.0 kPA (250 pounds per square foot) and a minimum concentrated live load of 4.5 kN (1,000 pounds) over the area of greatest stress to be specified.

**Steel bracing in the Milwaukee Courthouse**

## Earthquake Design

The minimum design lateral force shall be determined as follows:

To obtain a more accurate, site-specific ground motion, the latest National Hazard Reduction Program (NEHRP) maps shall be used in lieu of the acceleration and velocity contour maps found in the 1999 BOCA National Building Code, in the 1999 Standard Building Code, and the zonation map found in the 1997 Uniform Building Code. The procedure for determining the design lateral force shall be as follows:

### UBC Procedure

To calculate $C_a$ and $C_v$ the following two formulas shall be used in lieu of using Tables 16-Q and 16-R in the 1997 UBC:

$$C_a = 0.266\ F_a\ S_s$$
$$C_v = 0.666\ F_v\ S_1$$

$S_s$ and $S_1$ shall be taken directly from the NEHRP maps (2500-year return period) for 0.2-second and 1.0-second periods, respectively. $F_a$ and $F_v$ shall be taken from Tables 4.1.2.4a and 4.1.2.4b of FEMA 302, respectively. The Site Class definitions of FEMA 302 are identical to the Soil Profile Types of the 1997 UBC.

The new values of $C_a$ and $C_v$, as calculated above, shall be employed to derive other design seismic forces, as prescribed in the code.

All other provisions of the 1997 UBC shall be followed without additional modification, except as noted herein. Whenever the design seismic force, as calculated via the procedures noted above, is lower than those forces derived by the use of the 1997 UBC without modification, the larger derived seismic force shall govern the design.

### BOCA and SBCCI Procedure

To calculate $A_a$ and $A_v$ the following two formulas shall be used in lieu of using Figure 1610.1.3(2) and Figure 1610.1.3(1) in the 1999 BOCA and Figure 1607.1.5B and Figure 1607.1.5A in the 1999 SBCCI, respectively:

$$A_a = S_s / 2.5$$
$$A_v = S_1$$

$S_s$ and $S_1$ shall be taken directly from the NEHRP maps (2500-year return period) for 0.2-second and 1.0-second periods, respectively.

To calculate $C_s$ the following two formulas shall be used in lieu of the formulas noted in BOCA and SBCCI:

$$C_s = 0.666\ F_v\ A_v / RT$$
$$C_s = 1.666\ F_a\ A_a / R$$

$F_a$ and $F_v$ shall be taken from Tables 4.1.2.4a and 4.1.2.4b of the FEMA 302, respectively. The Site Class for the derivation of $F_a$ and $F_v$ shall be taken from Section 4.1.2.1 and Table 4.1.2.2 of FEMA 302 in lieu of using the S1 through S4 site coefficients noted in these codes.

The new value of $C_s$, as calculated above, shall be employed to derive other design seismic forces, as prescribed in the code.

All other provisions of the 1999 BOCA and 1999 SBCCI shall be followed without additional modification, except as noted herein.

Whenever the design seismic force, as calculated via the procedures noted above, is lower than those forces derived by the use of the 1999 BOCA, or 1999 SBCCI without modification, the larger derived seismic force shall govern the design.

# 4.4 Structural Considerations

**LRFD versus ASD.** Both Load Resistance Factor Design (LRFD) and Allowable Stress Design (ASD) are acceptable design procedures for GSA buildings; however, for larger building structures LRFD is generally recognized as resulting in more economical steel framing and is preferred by GSA.

**Cast-in-Place Systems.** Systems that have fewer limitations in cutting openings during future alterations are preferred over other systems.

**Precast Systems.** Precast floor framing systems should only be used for GSA office buildings when the design can be demonstrated to adapt well to future changes in locations of heavy partitions or equipment. Precast systems may be considered for low-rise structures such as parking garages, industrial buildings, and storage and maintenance facilities.

**Pre-tensioning and Post-tensioning.** As with precast floor framing, these systems should only be used when the design can be demonstrated to not impede future flexibility.

**Base Isolation.** Base isolation shall be considered in UBC Earthquake Zones 3 and 4 or equivalent NEHRP seismic zones for two to fourteen story buildings, particularly on rock and firm soil sites which are stable under strong earthquake ground motion. The base isolation system must be cost effective. The effects of the base isolation system on the framing, mechanical, and electrical systems shall be included in the evaluation of cost effectiveness.

**Passive Energy Dissipation Systems.** Passive energy dissipation systems shall be considered in moderate to high-risk seismic zones.

### Progressive Collapse

The structure must be able to sustain local damage without destabilizing the whole structure. The failure of a beam, slab, or column shall not result in failure of the structural system below, above, or in adjacent bays. In the case of column failure, damage in the beams and girders above the column shall be limited to large deflections. Collapse of floors or roof must not be permitted. For additional information refer to the *GSA Security Design Criteria* and the American Society of Civil Engineers: *Minimum Design Loads for Buildings and Other Structures, ASCE 7*.

### Floor Vibration

The floor-framing members shall be designed with a combination of length and minimum stiffness that will not cause vibration beyond the “slightly perceptible” portion of the “Modified Reiher-Meister Scale” or an equivalent vibration perception/acceptance criteria.

### Seismic Instrumentation for Buildings

Seismic instrumentation to measure horizontal and vertical motions of certain floors relative to the ground shall be provided in accordance with the national codes referenced in Chapter 1 and Appendix B of *Seismic Instrumentation of Buildings (with Emphasis on Federal Buildings)*, Special GSA/USBS Project, USGS Project No: 0-7460-68170.

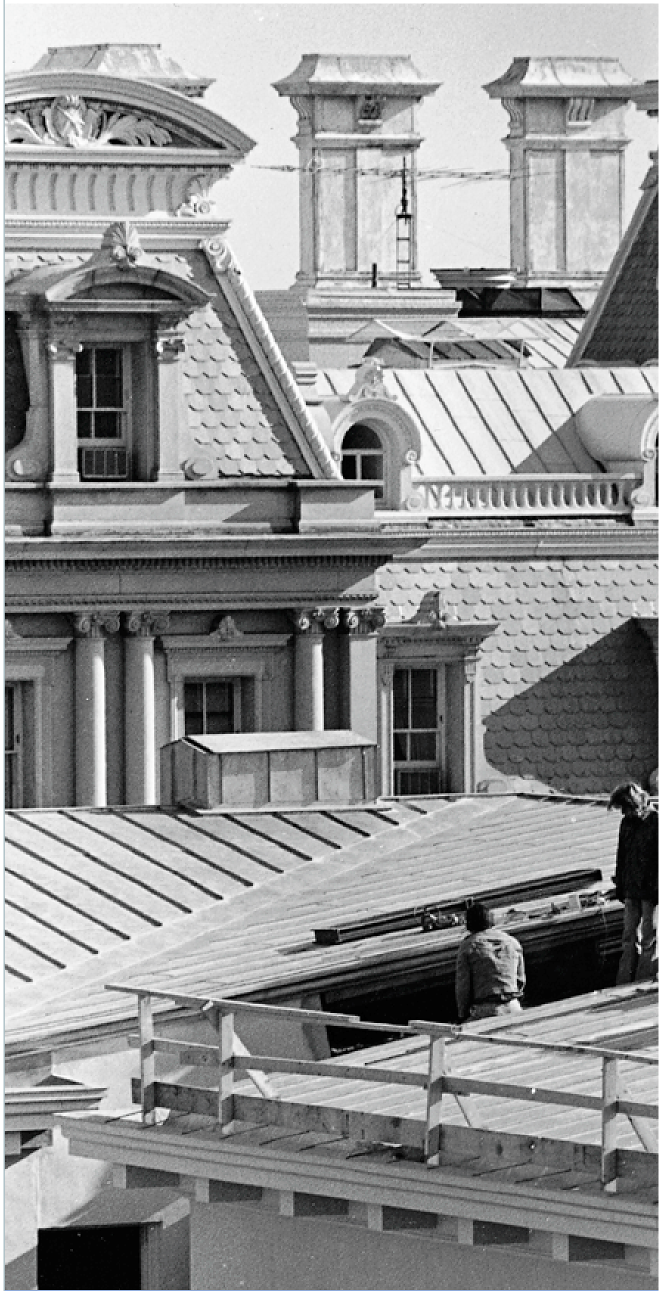
### Geotechnical Considerations

The requirements for the geotechnical engineering investigation and report are listed in Appendix A: *Submission Requirements*.

Footings shall not project beyond property lines.

### Nonstructural Elements

All nonstructural elements, components and equipment located within a building or on the site must be anchored to withstand gravity, wind, seismic, temperature, and other loads as required by the applicable codes.



Workmen on the roof of the Winder Building, Washington, D.C. install a window as part of a renovation project.

# 4.5 Alterations in Existing Buildings and Historic Structures

Alteration requires ingenuity and imagination. It is inherently unsuited to rigid sets of rules, since each case is unique. It is recognized that total compliance with standards may not be possible in every case. Where serious difficulties arise, creative solutions that achieve the intent of the standard are encouraged.

Where a historic structure is to be altered, special documents will be provided by GSA to help guide the design of the alterations. The most important of these is the Building Preservation Plan (BPP) which identifies zones of architectural importance, specific character-defining elements that should be preserved, and standards to be employed. For some buildings a detailed Historic Structures Report is also available. See Chapter 1: *General Requirements*.

### General Design Considerations for Structural Upgrading

**Seismic Performance.** The performance objective of a seismic upgrade is life safety, defined as the safeguarding against partial or total building collapse, obstruction of entrance or egress routes and the prevention of falling hazards in a design basis earthquake.

Not all seismic deficiencies warrant remedial action. Seismic upgrading is an expensive and often disruptive process, and it may be more cost effective to accept a marginally deficient building than to enforce full compliance with current code requirements.

Evaluation and mitigation of existing GSA buildings shall meet the requirements of ICSSC RP 4 (NISTIR 5382), *Standards of Seismic Safety for Existing Federally Owned or Leased Buildings*. with the following modifications:

- Evaluation of existing buildings shall be in accordance with provisions of the Handbook for the Seismic Evaluation of Building–A Prestandard (FEMA 310).
- Seismic rehabilitation of existing buildings shall be in accordance with the provisions of the NEHRP Guidelines for the Seismic Rehabilitation of Buildings and Commentary (FEMA 273 and 274).

**Upgrade Priorities.** It may not be practical to upgrade an entire structure to current requirements at any one time. Whenever upgrading is only partially done, the first priority should be given to items that represent the greatest life safety risk, such as the lateral force-resisting system, unreinforced masonry bearing walls or both.

**Seismic Upgrades for Historic Buildings.** Historic buildings should meet the same life safety objective as other buildings. Decisions made to preserve essential historic features should not result in a lesser seismic performance than that required by ICSSC RP 4. See Chapter 1: *General Requirements, Codes and Standards, Mandatory Design Standards, Conflicts with Historic Preservation*.

**Seismic Strengthening Criteria for Nonstructural Elements.** Where deficiencies in the attachment of elements of structures, nonstructural components and equipment pose a life safety risk, they should be prioritized and those elements with the greatest life safety risk strengthened first to meet current code requirements.

# 4.6 Seismic Requirements for Leased Buildings

### New Construction

New buildings or the construction of an addition to an existing building shall conform to the seismic standards for new construction of the current edition (as of the date of the solicitation) of one of the National Model Building Codes. For more information see the latest edition of GSA's Solicitation for Offers (SFO).

### Existing Buildings

Existing buildings shall meet the seismic requirements of the *Standards of Seismic Safety for Existing Federally Owned or Leased Building and Commentary*, ICSSC RP 4, as modified by the latest edition of GSA's Solicitation for Offers (SFO).