Structural Engineering

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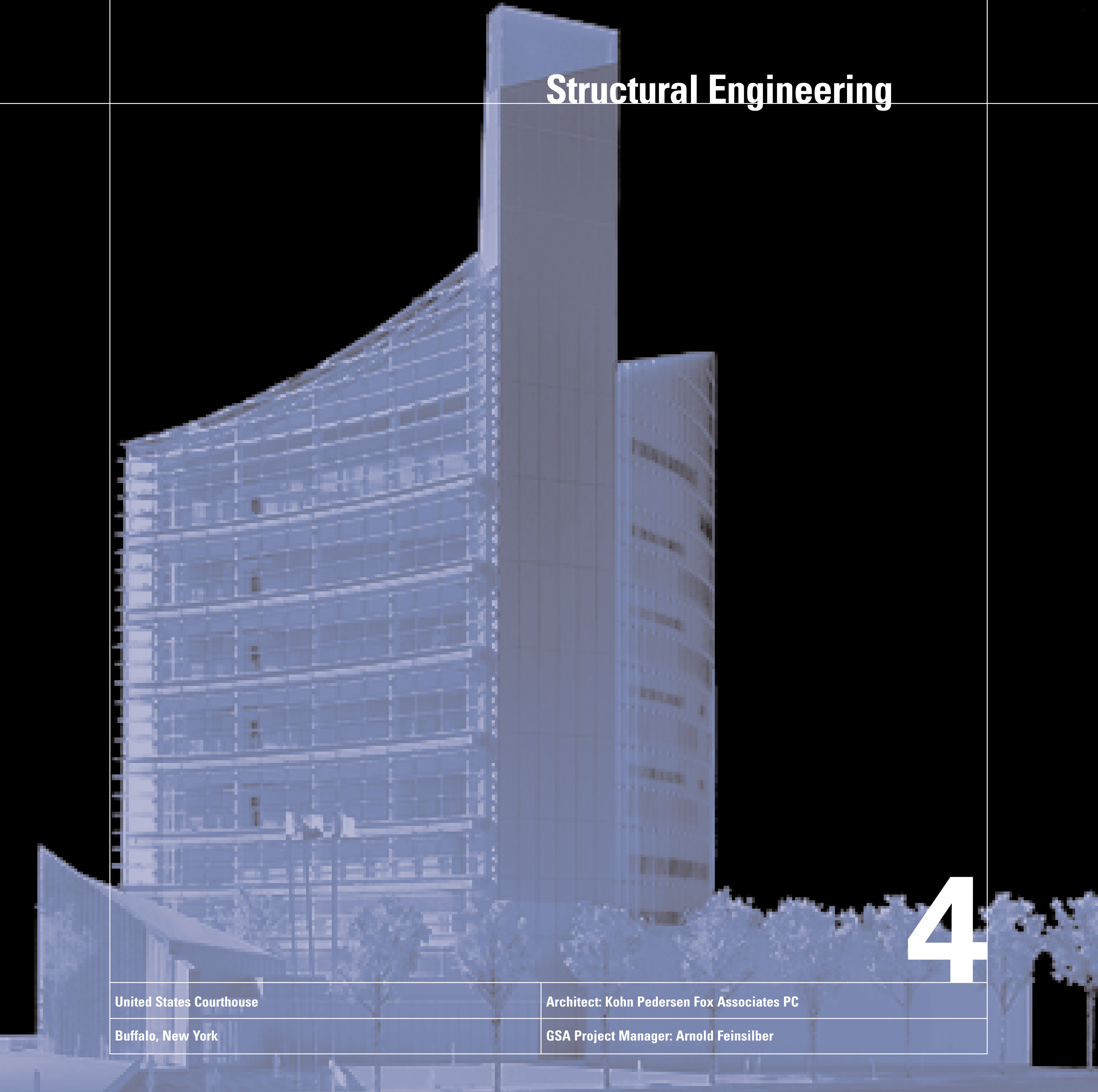

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4.1 General Approach

This chapter provides structural design criteria for buildings and for building systems constructed of concrete, masonry, steel and wood. The design requirements provided herein, or cited by reference, are based on the International Building Code, and industry and FEMA guidelines. Deviation from these criteria, where a valid need exists or an alternative solution is more desirable, may be accepted subject to evaluation and approval by GSA.

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 GSA 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

Codes and mandatory standards adopted by GSA for the design of all new buildings are discussed in Chapter 1.

The following FEMA Guidelines shall be incorporated into the structural design for all projects involving new and existing facilities:

- Federal Emergency Management Agency (FEMA) publications:

  Recommended Seismic Design Criteria for New Steel Moment-Frame Buildings (FEMA 350)

  Recommended Seismic Evaluation and Upgrade Criteria for Existing Welded Steel Moment-Frame Buildings (FEMA 351)

  Recommended Post-earthquake Evaluation and Repair Criteria for Welded Steel Moment-Frame Buildings (FEMA 352)

  Recommended Specifications and Quality Assurance Guidelines for Steel Moment-Frame Construction for Seismic Applications (FEMA 353).

Structural Design of New Buildings

The structural design (including wind, snow and earthquake) of new buildings, structures and portions thereof shall be in full compliance with the latest edition of the International Building Code (IBC). Unless otherwise specified, all new buildings shall be classified as Category II structures according to Table 1604.5 of the International Building Code.

Use of Recycled Materials

Because concrete is one of the most widely used building products, incorporation of recycled materials that do not impact strength may make a substantial contribution to the nation's recycling effort.

The recently completed Seattle Courthouse Steel Plate/Composite Concrete Shear Wall System during construction.

The following is a list of specifications for cement and concrete containing recovered materials:

Cement Specifications:

- ASTM C 595: Standard Specification for Blended Hydraulic Cements.
- ASTM C 150: Standard Specifications for Portland Cement.

Concrete Specifications:

- ASTM C 618, "Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete."
- ASTM C 311, "Standard Methods of Sampling and Testing Fly Ash and Natural Pozzolans for Use as a Mineral Admixture in Portland Cement Concrete."
- ASTM C 989, "Ground Granulated Blast-Furnace Slag for Use in Concrete Mortars."
- American Concrete Institute Standard Practice ACI 226.R1. "Ground Granulated Blast-Furnace Slag as a Cementitious Constituent in 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 Loads

Design loads shall be in accordance with International Building Code (IBC) except as noted:

Flexibility in the Use of Space: Since locations of corridors are not always known until after the completion of construction documents and are subject to change over time, use a uniform live load of 3.8 kPa (80 pounds per square foot) over the entire floor for all elevated slabs unless the tabulated uniform live load required by the International Building Code is higher than 80 psf. This load includes .96 kPa (20 pounds per square foot) of partitions, but excludes heavy loads like the planned use of space saver file systems.

Do not use live load reductions for (1) horizontal framing members, (2) transfer girders supporting columns, and (3) columns or walls supporting the roofs where mechanical equipment can be located. Live load reductions shall be considered in the design of foundation members regardless of the restrictions placed on individual members.

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 EIA/TIA Standard 569, 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 EIA/TIA Standard 569 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

4.4 Structural Considerations

The goals in the selection of load resisting systems are simplicity of the structural framing layout and symmetry in the structural system reaction to design loadings. The selection must consider the need for economy, function, and reliability.

LRFD and ASD. Both Load Resistance Factor Design (LRFD) and Allowable Stress Design (ASD) are acceptable design procedures for GSA buildings. If LRFD is chosen, the design narrative must specifically address floor vibration.

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.

Innovative Methods and Materials. The use of special construction is permitted when necessary, advantageous, and economical. However, specifying new or untried materials or methods of construction should be avoided until the merits of the methods or materials have been established. When the merits are established, new, unusual, or innovative materials, systems or methods may be incorporated into designs when evidence shows that such use is in the best interest of the Government from the standpoint of economy, lower life-cycle costs, and quality of construction. When new and innovative methods and materials are proposed for a specific building, a peer review panel, determined by GSA, shall evaluate the adequacy of the methods, systems and materials proposed by the engineer.

Base Isolation. Base isolation shall be considered for buildings located in Regions of High Seismicity 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 shown to be as cost effective as conventional foundation systems. 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 for buildings located in Regions of High Seismicity.

Progressive Collapse

Refer to Chapter 8: *Security Design.*

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 equivalent vibration perception/acceptance criteria. Recommended vibration design criteria for general office will be based on T. M. Murray, "Tips for Avoiding Office Building Floor Vibrations," Modern Steel Construction, March 2001. More stringent vibration considerations may be required for fixed seating areas such as those in the courtrooms or judges' chambers.

Seismic Instrumentation for Buildings

New and existing buildings located in Regions of High Seismicity over six stories in height with an aggregate floor area of 60,000 square feet (5574 m^2) or more, and every building located in Regions of High Seismicity over 10 stories in height regardless of floor area, shall be provided

Base isolator installation at the historic Pioneer Courthouse, Portland, OR

with USGS approved recording accelerographs. USGS developed *guidelines* and a *guide specification* for Federal agencies for the seismic instrumentation of their buildings. The guidelines describe the locations and the types of instruments used for several "typical" buildings. Typical costs were also developed for existing buildings. *The Seismic Instrumentation of Buildings (with Emphasis on Federal Buildings),* Special GSA/USGS project, USGS Project No: 0-7460-68170, can be downloaded as a PDF file at **http://nsmp.wr.usgs.gov/celebi/gsa_report_instrumentation.pdf**.

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 and/or braced to withstand gravity, wind, seismic, temperature, and other loads as required by IBC for new buildings and FEMA 356 for existing buildings.

The W.F. Bennett Federal Building in Salt Lake City is the first federal building to use buckling-restrained brace technology.

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 6 (NISTIR 6762), *Standards of Seismic Safety for Existing Federally Owned and Leased Buildings* with the following modifications:

- Evaluation of existing buildings shall be in accordance with the provision of the ASCE Standard, Seismic Evaluation of Existing Buildings, ASCE/SEI 31). The primary objective of the Standard is to reduce the life-safety risk to occupants of federal buildings and to the general public. **Life-Safety** is the minimum performance objective appropriate for federal buildings.
- Seismic rehabilitation of existing buildings shall be in accordance with the provisions of Prestandard and Commentary for the Seismic Rehabilitation of Buildings (FEMA 356). **Life-Safety** is the minimum acceptable performance level for existing Federal buildings. FEMA 356 further provides for an extended level of performance, Immediate Occupancy, where required to meet the agency's mission. ASCE/SEI 31, ASCE Standard, Seismic Evaluation of Existing Buildings, and FEMA 356, Prestandard and Commentary for the Seismic Rehabilitation of Buildings, provide the basis for defining these performance objectives, evaluation criteria and if necessary, mitigation, are identified.

  If shown by ASCE/SEI 31 evaluation that the desired performance level is not satisfied, the rehabilitation of the building to attain the desired performance level shall substantially satisfy the Basis Safety Objective criteria of FEMA 356, including the use of both the BSE-1 and BSE-2 earthquake criteria.

  It should be noted that the hazard level (ground motion) used in ASCE/SEI 31 to evaluate buildings is based on earthquakes with a 2% probability of exceedance in 50 years (2%/50 years). On the other hand, the hazard level used for a rehabilitation design in FEMA 356 is based on compliance with the Basic Safety Objective (BSO). The BSO requires compliance with both the BSE-2 earthquake (2%/50 years earthquake accelerations) at the Collapse Prevention Performance Level and with the BSE-1 earthquake (the lesser of the accelerations from the 10%/50 years earthquake or 2/3 of the 2%/50 years earthquake) at the Life-Safety Performance Level. The earthquake accelerations associated with the 2/3 of the 2%/50 years earthquake will result in significantly higher seismic design values than those resulting from a 10%/50 years earthquake in some areas of the country.

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 6. See Chapter 1.

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 IBC. For additional 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 and Leased Building and Commentary,* ICSSC RP 6, as modified by the latest edition of GSA's Solicitation for Offers (SFO).

ICSSC RP 6 can be downloaded as a PDF at **http://fire.nist.gov/bfrlpubs/build01/PDF/b01056.pdf**.

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