Section 5:STRUCTURAL DESIGN

5.1 General. This Section provides criteria for the selection, analysis, and design of structural system(s) and materials to be used for military health care facilities. Additional criteria relating to seismic design is provided in Section 6, Seismic Design, of this Military Handbook.

5.2 Design Criteria. Structural design for military health care facilities shall be in accordance with references A through F. Structural material design considerations shall be in accordance with references G through L.

5.3 Design Loadings. Unless otherwise indicated herein, the minimum design loadings for military health care facilities shall be in accordance with ASCE 7-95 (reference AA).

5.3.1 Floor live loads shall be as given in Appendix A. Roof live loads, other than snow loads which are addressed below, shall be in accordance with ASCE 7-95 (reference AA). The live load factors to be used in load combinations must include dead, wind, seismic, etc.

5.3.2 Wind Loads. Determine basic wind speeds from the tables in TI 809-01 (reference A), unless a site-specific study of local records indicates a higher value should be used. The tables are based on a wind speed with a recurrence interval of 50-years, an Exposure C condition (open terrain with scattered obstructions having heights generally less than 30 feet), and a 3-second gust 33-feet above the ground. Using these basic wind speeds, use ASCE 7-95 (reference AA) procedures to determine the design wind pressure loading. Design basic wind speeds will normally be based on "Exposure C" conditions; exceptions are allowed where it can be clearly established that lesser loads associated with "Exposure B" conditions (towns, city outskirts, wooded areas and rolling terrain), or where greater loads associated with a coastal waterfront site, are applicable. Give appropriate consideration to unusual channeling, lifting, or gusting effects from promontory mountain, hill, or valley exposures. Do not use "Exposure A" conditions for permanent military health facilities.

5.3.3 Snow Loads. Determine ground snow loads from the tables in TI 809-01 (reference A), unless a site-specific study of local records indicates a higher value should be used. If a building location is not in the referenced tables, the ground snow load map in ASCE 7-95 (reference AA) may be used. Use ASCE 7-95 procedures to determine the design roof snow loads, including drifting, sliding, etc.

5.3.4 Seismic Loads. Requirements for seismic design are contained at Section 6 of this Military Handbook.

5.3.5 Load Combinations. The basic design loadings shall be considered to act in union in the strength design combinations given in ASCE 7-95 (reference AA). Use the combination or combinations of loadings that produce the greatest overall loading and the most unfavorable effects on the building or its structural components as the basis of design.

5.3.6 Frost Penetration. Determine the minimum design depth of building foundation below finished grade using the tables and procedures in TI 809-01 (reference A).

5.4 Site Conditions & Soils Investigations. Soil Investigation Program. Conduct soil investigations in accordance with TM 5-818-1 (reference R). If arctic or sub-arctic construction conditions are present at the site, the program will address the provisions for building foundations contained in TM 5-852-1 (reference S) and TM 5-852-4 (reference T), respectively.

5.4.1 Seismic Geologic Site Hazards. Seismic geologic site hazards include surface fault rupture, soil liquefaction, soil differential compaction (or settlement), landsliding, and flooding. Use TI 809-04 (reference D) to define requirements for seismic hazard screening.

5.4.2 Site-Specific Seismic Ground Motion Study. Use TI 809-04 (reference D) to determine when a site-specific seismic ground motion study is required, and the required scope of the study. Retain a qualified geotechnical seismic ground motion specialist to conduct these site-specific studies. Complete the study during the early preliminary stage of the soil investigation program so the results will be available during the structural system selection process.

5.5 Additional Design Considerations. Several aspects of structural design typically associated with medical facilities are addressed below. It is essential that structural design considerations enter into the earliest stages of concept planning and design, to assure compatibility with medical function, and the building architectural and equipment features.

5.5.1 Open Area Concept. Provide column-free functional areas as appropriate. Long-span structural construction usually increases functional area openness and flexibility. Although exceptionally long spans or special long span structural techniques are generally more costly (in terms of first cost), designers should give consideration to the life cycle cost benefits provided by the additional flexibility.

5.5.2 Acoustical Design Considerations. Noise attenuation is an important consideration in the structural design of health care facilities. Structural elements can be both transmitters and attenuators of sound, and therefore must be considered into the acoustical design of each project. Refer to Section 23 of this Military Handbook for additional information.

5.5.3 Vibration. The vibration response of the structure requires special consideration. Vibration factors qualify the geometry of the building and affect its lateral load resistance. Designs must consider the vibration potentials of floor and roof framing and floor systems, and the overall structure, to assure adequate isolation and damping of vibrations produced by HVAC equipment, emergency generators, elevator equipment, and other machinery and equipment. In addition to assuring a living environment free from distracting or annoying vibrations, designers must be aware of the requirements of vibration sensitive equipment, such as analytic scales, optical equipment, electronic equipment and X-ray machines.

5.6 Seismic Design Considerations. Building configuration plays an important role in the performance of the structure when subjected to seismic ground motion. For this reason, seismic considerations may require limits on the height and configuration of some structural system types. Optimal seismic resistance and performance is obtained with a symmetrically configured structural framing system. A system with a symmetric and uniformly distributed placement of frames, shear walls, braced frames and wall openings will be more effective and efficient in resisting lateral forces and, more importantly, in reducing horizontal torsional moments. For these reasons, building structural systems with irregular shapes (L, U, T, E, H, or cross), setbacks, or other unusual features will be avoided. If these building layout shapes must be used, the structural system will be divided by expansion (seismic) joints into regular rectangular (plan view) shapes.

5.7 Structural System Type.

5.7.1 Ductile moment-resisting space framing systems are adequate, but the large floor-to-floor heights and long spans necessary in some modern health facilities may make adequate drift control difficult and expensive.

5.7.2 Pure shear wall box systems provide excellent seismic resistance but are generally restrictive and inflexible from a planning point of view.

5.7.3 Braced frames, both concentric and eccentric, provide good strength and drift control characteristics. They are more restrictive from a future planning perspective than moment frames, however, since the frames can be strategically placed to lessen the restrictions, they can be significantly less restrictive than shear wall box systems.

5.7.4 Dual bracing systems, combining complete moment-resisting frame system with shear walls, or braced frames have good drift control characteristics. Space frames offer stiffness and tie the building together. Individual space frame members must resist at least 25 percent of the required lateral load. Shear walls or braced frames must resist 100 percent of the lateral load. Resistant frames must resist forces based on their relative stiffness and must satisfy deformation compatibility requirements.

5.8 Seismic Structural System Considerations.

5.8.1 General. All health care facility buildings must have a complete lateral force resisting structural system that provides a continuous and direct load path with members and connections that possess the strength and ductility to transmit seismic forces to the foundation. This structural system shall be capable of withstanding design earthquake ground motions while, (1) remaining within prescribed limits of strength, (2) maintaining deformation limits, and (3) providing adequate energy dissipation capacity.

5.8.2 Innovative Systems. Both base isolation and passive energy dissipation are considered to be innovative seismic force resistant structural systems. Innovative systems shall be considered for major health care facilities in high seismic risk areas, where the design spectral response acceleration at short periods (S_{DS}) is equal to or greater than 0.50. The specific types of base isolation systems that are considered for use in health care facilities must have been researched, tested and proven to be acceptable, based on sound engineering principles and experience. Base isolation materials must be durable, i.e., have minor aging and temperature effects and have reliable, long term performance characteristics Selection considerations shall include a life-cycle cost comparison between a conventional, fixed base system and the base isolation system. If a base isolation system is proposed, it must be submitted to HQUSACE, CEMP-E for approval along with data supporting and justifying the selection.

5.8.2.1 The designs of innovative systems are often specific to the device, which may be a proprietary item. The entire design, including the choice of device and the detailing of the entire structural system, shall be completed by the building designer. The completion of the design of the structural system shall be extended to the construction contractor by the use of a performance specification. If the design becomes proprietary, this shall be immediately reported to the Design Agent's Project manager. Also, the types of tests needed to evaluate the specified performance of these devices are often specific to the type of device. The A-E shall include in design documents the requirements for performance tests that are appropriate for the actual device(s) provided for by the design.

5.8.2.2 Certain nonstructural systems, services, and will be required for the post-earthquake life-safety or operational performance levels of the health care facility, as addressed at Section 6 of this Military Handbook. The structural design of the restraints and anchorages of these important nonstructural elements is an integral part of the structural design of the facility.

STRUCTURAL MILITARY DESIGN CRITERIA AND GUIDANCE

Reference	Military Criteria Document	Document Title
A	TI 809-01	Load Assumptions For Buildings
B	TI 809-02	Structural Design Criteria for Buildings
C	TI 809-03	Structural Design Criteria For Structures Other Than Buildings
D	TI 809-04	Seismic Design For Buildings
E	TI 809-05	Seismic Evaluation and Rehabilitation For Buildings
F	TI 809-06	Masonry Structural Design For Buildings
G	TI 809-07	Design Of Load-bearing Cold-Formed Steel Systems
H	TI 809-26	Welding- Design Procedures And Inspections
I	TI 809-27	Concrete Floor Slabs On Grades Subjected To Heavy Loads
J	TI 809-28	Design And Construction Of Reinforced Ribbed Mat Slabs
K	TI 809-29	Structural Considerations For Metal Roofing
L	TI 809-30	Metal Building Systems
M	TI 809-51	Seismic Screening And Evaluation Procedures For Existing Military Buildings
N	TI 809-52	Commentary On Snow Loads
O	TI 809-53	Selection Considerations For Roofing Systems
P	TM 5-818-1	Soils and Geology Procedures for Foundation Design of Buildings and Other Structures (Except Hydraulic Structures)
Q	TM 5-852-1	Arctic and Sub-arctic Construction General Provisions
R	TM 5-852-4	Arctic and Sub-arctic Construction: Foundations for Structures

STRUCTURAL NON-MILITARY DESIGN CRITERIA AND GUIDANCE

Reference	Non-Military Criteria Document	Document Title
AA	ASCE 7-95	Minimum Design Loads for Buildings and Other Structures
BB	FEMA 302	NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, February 1998
CC	FEMA 273	NEHRP Guidelines for the Seismic Rehabilitation of Buildings, October 1997

STRUCTURAL MATERIALS APPLICABLE CRITERIA

Reference	Materials	Codes or Specifications
BA	Aluminum	The Aluminum Association (AA), "Specifications for Aluminum Structures"
BB	Concrete	American Concrete Institute (ACI), "Building Code Requirements for Structural Concrete"
BC	Masonry	ACI, Building Code Requirements for Masonry Structures
BD	Prestressed Concrete	Prestressed Concrete Institute (PCI), Manuals
BE	Steel	
BF	Steel Joists	Steel Joists Institute (SJI), "Standard Specifications and Load Tables, Open Web Steel Joists and Longspan Steel Joists," and similar publications covering deep longspan steel joists.
BG	Steel, Light Gage	American Iron and Steel Institute (AISI), "Specifications for the Design of Cold-Formed Steel Structural Members"
		Steel Deck Institute, Design Manual and Diaphragm Design Manual
BH	Welding	American Welding Society (AWS) Codes, Standards and Specifications
BI	Wood	American Society of Civil Engineers (ASCE), "Standard for Load Resistance Factor Design (LRFD) for Engineered Wood Construction", ASCE-16