SECTION 03740

STRUCTURAL ANALYSIS & DESIGN STANDARDS

PART 1 – GENERAL

1.1 SUMMARY:

A. This section defines the following:

1. Structural submittal requirements
2. Wind and snow loading design criteria
3. Vibration design criteria for new campus buildings and additions
4. Vibration control on mechanical equipment

1.2 SUBMITTAL REQUIREMENTS:

A. During Schematic Design, the design engineer shall submit:

Code and Loadings:

1. Governing Building Code used for design
2. Dead and Live Loads used for design
3. Lateral Wind Loads and Seismic Loads used for design

Structural System:
Provide a comparative description of feasible structural systems for the building, i.e., consider wood, steel, concrete, masonry. Give a description of the type of construction proposed and reasons therefore, including the structural framing system. The structural design need only be carried only to the point where the total framing systems are determined and a realistic cost estimate can be made.

Foundation Design:
Describe the type of foundation proposed and define the basis for selection. Include bearing capacity, anticipated settlement, alternatives considered, and other pertinent design factors. Also include the depth of excavation, disposition of excavated material, whether in-place foundation material will be compacted, whether imported fill is required, whether compacted backfill will be utilized as foundation, and the frost penetration. State ground water level and method of waterproofing. State needs for drainage or vapor barrier. Describe pertinent corrosion control methods. Refer to the Soils Report included in the supplements.
Vibratory Design:
The structural design engineer shall submit a summary report of the vibration criteria that will be used in the structural design of the building.

B. Design Development documents shall include:

Structural drawings and specifications, including:

1. General Notes and design Criteria used in design
2. Foundation plan
3. Framing Plans
4. Representative detailing
5. Project specifications

Foundation and framing plans shall include the following:

1. Foundation type, depths and sizes
2. Relationship of walls and floor slab to foundation system
3. Overall dimensions
4. Column spacing and representative sizes
5. Framing layout and representative sizes
6. Representative detailing of foundations, floor framing and roof framing

C. Construction Documents shall include:

Final structural construction documents, including:

1. Final structural drawings
2. Final structural specifications
3. All drawings and specifications shall be complete and represent coordination by the Architect with all disciplines. Evidence of this coordination shall be provided by the Architect at the Final Design review.

Final structural calculations:
1. Provide final structural calculations of either the complete structure or representative portions of the structure as stipulated by the Department of Facilities Management at the start of the project.

2. All calculations shall be bound and indexed.

3. All calculations shall include design loadings, member geometry, boundary conditions, analysis assumptions, and governing codes and specifications used by the computer software.

4. Structural vibration criteria and analysis shall be included in the calculations submitted demonstrating compliance with UCB vibrational criteria.

5. Include special calculations demonstrating adequacy of existing structures, where applicable, to account for new functional loads or new criteria.

1.3 WIND AND SNOW LOADING DESIGN CRITERIA

A. Wind Speed: The University of Colorado at Boulder campus is designated a special wind region by ASCE 7-05. A design three second wind velocity of 110 MPH shall be used for buildings within the City of Boulder, including Main Campus, East Campus, Williams Village and South Campus. For all other areas, including the Mountain Research Station, refer to provisions set forth by Boulder County or other governing authority.

B. Exposure Factor: The design engineer shall use Figure C6-8 and Figure C6-9 of ASCE 7-05 to determine the appropriate exposure factor for a building.

C. Topography Factors: The design engineer shall consider wind speed-up effects at isolated hills, ridges, and escarpments per ASCE 7-05, Section 6.5.7. The design engineer shall state the Kzt factor on the construction drawings.

D. Air Density: In calculating velocity pressures using Eq. 6-15 in ASCE 7-05, the numerical constant, 0.00256, may be reduced to account for site specific air density. Any reduction shall comply with ASCE 7, Section C6.5.10, but in no case shall the reduction in the numerical constant exceed fifteen percent (15.0%).

E. Deflection: The design engineer shall follow the deflection requirements as stated in the Brick Industry Association document Technical Note 28B, Revision B. For sandstone masonry veneer and brick masonry veneer backed by steel studs, the design engineer shall calculate deflection using the unreduced wind pressure of the 50-year wind event and maintain deflections under 1/600 (Reference BIA Technical Note 28B).

F. Snow loading: The design engineer shall follow all provisions of ASCE 7-05. For buildings within the City of Boulder, including Main Campus, East Campus,
Williams Village and South Campus, a ground snow load of 30 PSF shall be used, with a minimum roof snow load of 30 PSF. For all other areas, including the Mountain Research Station, refer to provisions set forth by ASCE 7-05.

G. Frost line depth: For buildings within the City of Boulder, including Main Campus, East Campus, Williams Village and South Campus, a frost line depth of 32 inches shall be used. For all other areas, including the Mountain Research Station, refer to provisions set forth by Boulder County or other governing authority.

1.4 VIBRATION DESIGN CRITERIA FOR BUILDINGS

A. In order to minimize building construction costs associated with increased vibration control, laboratory areas and areas of sensitive equipment shall be designed to be located at-grade or below in the proposed building or addition.

B. Facilities Management may require that a vibration consultant be employed to analyze both overall building structure and specific placement and isolation of machinery and equipment with moving parts. The structural engineer, mechanical engineer, electrical engineer, and the architect will be required to coordinate their work with this consultant and to follow Facilities Management direction based upon the recommendations of the vibration consultant.

C. Vibration analysis shall conform to industry standards, such as American Institute of Steel Construction’s Design Guide 11.

D. General office spaces shall be designed to meet a recommended floor vibration velocity limit of 400 micrometers per second (Residential Day Criterion Curve, see Figures 1 & 2).

E. Classrooms and computer lab spaces shall be designed to meet a recommended floor vibration velocity limit of 200 micrometers per second (Residential Day Criterion Curve, see Figure 1).

F. General laboratory/research areas, where optical microscopes or other similarly sensitive equipment will be operated, shall be designed to meet a recommended floor vibration velocity limit of 50 micrometers per second (VC-A Criterion Curve). Figure 2 shall be used as a basis for vibration velocity limits when the sensitive equipment manufacturer’s recommendations are not available.

G. Precision instrument spaces shall be designed according to the sensitive equipment manufacturer’s recommendations. These areas should be designed considering the effects of adjacent equipment, other sources of vibration, and operations. The use of a consultant specializing in vibration analysis and control is required for both new construction and renovations.

H. Subject to the Department of Facilities Management, the above criteria may be
relaxed on a case-by-case basis provided the relaxed velocity limit will not affect
the current and future utility of the space.

I. All vibration criteria used in design shall be provided on the associated drawings.

1.5 VIBRATION CONTROL ON MECHANICAL EQUIPMENT

A. Provide vibration isolation devices for limiting transmittance of vibration from
vibration-producing equipment to the structure on which it is supported or
attached. The type of vibration isolation device is a function of building uses, size
of mechanical equipment, and the frequency at which the equipment operates. The
mechanical engineer or a vibration consultant shall consider these factors when
designing the vibration isolation system.

B. Provide the types of vibration isolation devices as recommended by the respective
mechanical equipment manufacturers or vibration consultant, to isolate vibrations
for each particular piece of equipment. Include a schedule of equipment (i.e.
pumps and fans) to be isolated listing the required isolation devices in the
Construction Documents.
FIGURE 1: Taken from Colin Gordon’s *Generic Vibration Criteria for Vibration-Sensitive Equipment*
Table 1: Application and interpretation of the generic vibration criterion (VC) curves (as shown in Figure 1)

<table>
<thead>
<tr>
<th>Criterion Curve (see Figure 1)</th>
<th>Max Level (1) micrometers/seconds&lt;sup&gt;1/2&lt;/sup&gt;</th>
<th>Detail Size (2) microns</th>
<th>Description of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshop (ISO)</td>
<td>800</td>
<td>N/A</td>
<td>Distinctly feaetable vibration. Appropriate to workshops and non-sensitive areas.</td>
</tr>
<tr>
<td>Office (ISO)</td>
<td>400</td>
<td>N/A</td>
<td>Feaetable vibration. Appropriate to offices and non-sensitive areas.</td>
</tr>
<tr>
<td>Residential Day (ISO)</td>
<td>200</td>
<td>75</td>
<td>Barely feaetable vibration. Appropriate to sleep areas in most instances. Probably adequate for computer equipment, probe test equipment and low-power (to 20X) microscopes.</td>
</tr>
<tr>
<td>Op. Theatre (ISO)</td>
<td>100</td>
<td>23</td>
<td>Vibration not feaetable. Suitable for sensitive sleep areas. Suitable in most instances for microscopes to 100X and for other equipment of low sensitivity.</td>
</tr>
<tr>
<td>VC-A</td>
<td>50</td>
<td>8</td>
<td>Adequate in most instances for optical microscopes to 400X, microbalances, optical balances, proximity and projection aligners, etc.</td>
</tr>
<tr>
<td>VC-B</td>
<td>25</td>
<td>3</td>
<td>An appropriate standard for optical microscopes to 1000X, inspection and lithography equipment (including steppers) to 3 micron line widths.</td>
</tr>
<tr>
<td>VC-C</td>
<td>12.5</td>
<td>1</td>
<td>A good standard for most lithography and inspection equipment to 1 micron detail size.</td>
</tr>
<tr>
<td>VC-D</td>
<td>6</td>
<td>0.3</td>
<td>Suitable in most instances for the most demanding equipment including electron microscopes (TEMs and SEMs) and E-Beam systems, operating to the limits of their capability.</td>
</tr>
<tr>
<td>VC-E</td>
<td>3</td>
<td>0.1</td>
<td>A difficult criterion to achieve in most instances. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems and other systems requiring extraordinary dynamic stability.</td>
</tr>
</tbody>
</table>

Notes:

(1) As measured in one-third octave bands of frequency over the frequency range 8 to 100 Hz.

(2) The detail size refers to the line widths for microelectronics fabrication, the particle (cell) size for medical and pharmaceutical research, etc. The values given take into account the observation that the vibration requirements of many items depend upon the detail size of the process.

FIGURE 2: Taken from Colin Gordon's *Generic Vibration Criteria for Vibration-Sensitive Equipment*
1.6 STRUCTURAL REQUIREMENTS REGARDING NEW FLOOR AND WALL PENETRATIONS IN EXISTING BUILDINGS

A. No floor or wall penetrations may be installed without prior review and approval of the Department of Facilities Management.

B. The Department of Facilities Management shall review the proposed new penetrations and assess whether or not further structural evaluation is required by a structural engineer.

C. Prior to installing new floor or wall penetrations, the existing structure shall be scanned with a Pacometer, Ground Penetrating Radar or other suitable method to locate existing reinforcing in the vicinity of the proposed opening. The proposed location of the new penetration shall be superimposed on the reinforcing ‘map’ to determine if the penetration location is acceptable in the proposed location or requires shifting to clear critical reinforcing or structural members.

D. Once determined that a circular penetration size and location is acceptable, it shall be installed by core-drilling.

E. Once determined that a rectangular penetration size and location is acceptable, it shall be installed by core-drilling the four corners, followed by saw-cutting between the corners. Overcutting at the corners should be avoided without exception.

F. Floor slab penetrations through existing concrete slabs-on-grade:

1. These floor penetrations are generally acceptable, unless the slab-on-grade also functions as a concrete “lid” spanning over a below-grade utility tunnel. If a basement level floor penetration is to be installed in a slab ‘lid’ over a utility tunnel, it should be evaluated as if it were a structural slab (see below).

2. Floor penetrations through concrete slabs-on-grade may be placed with significant freedom, although multiple penetrations in close proximity should be avoided.

G. Floor slab penetrations through existing structural concrete flat slabs:

1. All slab reinforcing is considered to be ‘primary’ structural reinforcing. No reinforcing is considered secondary or non-structural. Indiscriminately cutting through the slab reinforcing to install new floor penetrations without prior structural consideration could cause structural failure of the slab and should be avoided without exception.
2. Subject to review by a structural engineer, floor penetrations should be generally located at least 36” from the face of an adjacent building column.

3. Clusters of closely spaced openings should be avoided without exception. New floor penetrations should not exceed 6” in diameter without further review by a structural engineer. Generally, new openings should be spaced at least 36” apart.

4. Enlarging an existing floor slab penetration by reaming a larger diameter hole through the previous hole is generally acceptable, subject to other limitations cited herein. NOVEMBER 2011 UCB STANDARDS 3740-8

5. Existing slab reinforcing should be located and the penetrations should be located to avoid cutting any reinforcing where possible. Where impossible to avoid cutting through the existing reinforcing, no more than one (1) bar should be cut in each of the two primary slab directions without further detailed review by a structural engineer.

H. Floor slab penetrations through existing concrete slabs supported by concrete joists/beams and/or steel beams:

1. Generally, new floor penetrations may be installed through the slab between the joists.

I. Floor slab penetrations through existing concrete waffle slabs:

1. Generally, new floor penetrations may be installed through the slab between the waffle slab joist ribs.

J. Wall penetrations:

1. Wall penetrations require evaluation of the wall construction and lintel design.

2. Lintels shall be installed prior to cutting the wall penetration.

1.7 SEISMIC DESIGN CRITERIA

A. All structural elements on The University of Colorado Boulder campus shall be designed according to ASCE 7-05, seismic class B.

END OF SECTION 03740