

5 STRUCTURAL ENGINEERING

5.1 Design Criteria

5.1.1 Codes and Standards

The latest edition of the codes, standards, orders, and guides referred to in this section will be followed, with a reference point of August 2008 being the anticipated design completion date. All work will be in accordance with BNL's Implementation Plan for DOE 413.3, "Program and Project Management for the Acquisition of Capital Assets."

5.1.2 DOE Orders

DOE O5480.4 – Environmental Protection, Safety and Health Protection Standards
DOE O413.3A – Program and Project Management for the Acquisition of Capital Assets
DOE O414.1C – Quality Assurance
DOE O420.1B – Facility Safety
DOE O420.2B – Safety of Accelerator Facilities

5.1.3 Codes, Standards, and Guides

Building Code of New York State (NYSBC) – 2002 Edition
American Concrete Institute
Building Code Requirements for Structural Concrete (ACI 318-99)
BNL Standards Based Management System Subject Areas
New York State and Suffolk County Department of Health Codes
American National Standards Institute
ANSI 117.1 Accessible and Useable Buildings and Facilities
AISC Specification for Structural Steel Buildings
SJI Standard Specifications for Long Span Steel Joists (LH Series) and Deep Long Span Steel Joists (DLH Series)
American Society for Testing Materials Standards
Factory Mutual
National Institute of Standards and Technology
Occupational Safety and Health Administration (OSHA)
Underwriters Laboratory
New York State Fire Prevention Code - 2002 Edition
Americans with Disabilities Act Accessibility Guideline (ADAAG)
Leadership in Energy and Environmental Design (LEED) 2.2
LEED for Labs

5.2 Soil Conditions

5.2.1 Subsurface Conditions

The subsurface explorations encountered topsoil lying above a layer of fill overlying a stratified sand deposit that extends to more than 100 ft deep. Topsoil ranging in thickness from 2 to 12 in. was encountered in

borings drilled in landscaped areas. Topsoil was not encountered in borings drilled in paved/developed areas. Each of the borings encountered fill ranging in thickness from 2 to 9 ft. This fill is characterized as silty sand or widely-graded sand. Fill was also detected within the upper 1 to 10 feet in CPT soundings made near existing roadways. Several explorations experienced refusals, indicating buried objects within the fill.

A layer of stratified sand, sand with silt, and sand with gravel was encountered below the fill in all of the borings and CPT soundings. The sand is light brown to brown, with density ranging from medium dense to very dense.

Subsurface explorations were terminated within the sand at maximum depths of about 100 ft. A 1999 report on the stratigraphy and hydrogeologic conditions at the lab prepared by the United States Geologic Survey refers to the sand as the "Upper Glacial Aquifer," and states that the thickness at BNL is about 185 ft. Confining clay units and additional sand and gravel aquifers overlie bedrock, which reportedly occurs at a depth of about 1,500 ft.

The depth to groundwater appears to range from about 21.5 to 36.5 ft below ground surface, depending on the location at the site. This is based on the boring and CPT observations, as well as data collected in 2003 for CFN.

The soil beneath the NSLS-II has an average shear velocity that classifies it as a stiff profile for earthquake design purposes as defined by the New York State Building Code. The corresponding site class is D. The soil is not considered to be susceptible to liquefaction.

It is recommended that foundations be designed as spread footing foundations with slab-on-grade floors. Fill should be removed below footings so they bear directly on the sand deposits, or on a layer of compacted structural fill placed after removal of fill. Maximum allowable bearing pressure is 2.5 tons per square foot on footings at least 3 ft wide.

The site contours indicate that the Experimental Hall floor will range from 9 ft below grade to 4 ft above grade. Floors are well above groundwater levels encountered in the explorations. It is recommended that the slab-on-grade floors bear on a minimum of 6 in. of compacted structural fill placed over the natural sand deposit. The existing fill should be removed below floor slabs due to the tight settlement tolerance. Adequate densification should be accomplished using a heavy roller for both the native sand as well as the structural fill. This will provide a base for the Experimental Hall floor and should yield a low differential settlement when combined with the floor slab design.

Soils beneath the floor slab will settle in response to dead and live loads. It is anticipated that settlement will be complete within about one to two weeks after load application. Settlement resulting from floor slab dead loads and fill required beneath the floor slab is expected to occur during construction, and therefore will not contribute to post-construction settlement. However, the 250 psf live load could cause minor post-construction settlement. GEI calculated that the total and post-construction settlement from the live load to be less than 0.25 inches. Differential settlement will be less than the total settlement.

5.2.2 Laboratory Testing

Geotechnical studies of the proposed NSLS-II building site have been performed which included 21 grain size distribution analyses on soil samples recovered from the test borings.

5.3 Design Loads

5.3.1 Live Loads:

- Laboratories: 125 psf
- Experimental Hall: 250 psf (2000 psf capacity of 15 inch SOG)

- Ring Tunnel: 250 psf (3000 psf capacity of 33 inch SOG)
- Booster Ring 250 psf (2000 psf capacity of 18 inch SOG)
- Tunnel Mezzanine: 250 psf
- Ring Building Access Corridor: 125 psf or wheel loads from fork lift trucks
- Corridors: 100 psf
- Stairs, Lobbies & Viewing Gallery: 100 psf
- Offices: 100 psf (incl. 20 psf for partitions)
- Light Storage Areas: 125 psf
- Mechanical Rooms: 150 psf or actual weight of equipment

5.3.2 Snow Loads:

- Ground snow load P_g : 45 psf
- Snow importance factor I_s : 1.0 (Category I)
- Snow exposure factor C_e : 0.9
- Thermal Factor C_t : 1.0
- Design snow load: 30 psf + drift where applicable

5.3.3 Wind Loads:

- Basic wind speed (3-second gust): 120 mph
- Wind load importance factor I_w : 1.00 (Category I)
- Wind exposure: B

5.3.4 Earthquake Loads:

- Short period acceleration S_s : 0.25g
- 1 second period acceleration S_1 : 0.08g
- Site Class: D
- Seismic Use Group: I
- Seismic Design Category: B
- Seismic Importance Factor I_E : 1.0 (Category I)

5.4 Structural System

5.4.1 Foundation:

Geotechnical investigation reports on the project done during the Conceptual Design Phase (August 30, 2006) and Advanced Conceptual Phase (May 25, 2007) by GEI Consultants recommend the foundation system to be spread footings bearing directly on sand deposits or compacted structural fill after removal of existing fill. The recommended maximum allowable bearing pressure is 2.5 tons per square foot.

5.4.2 Building Super-Structure:

a) Ring Building:

The overall structure for this building will be in structural steel with curved roof supported by 67'-0" span open web steel joists on columns radially spaced on inner and outer rings @ approximately 21'-0" and 25'-0" spacing respectively. For lateral force resistance, radial steel joists shall be connected to end columns by moment connections and braced frames shall be used circumferentially. The roof deck shall typically be 20 GA – 1 ½" thick steel deck.

Within the Ring Building, there will be the ring tunnel, walls and roof of which shall be constructed in cast-in place concrete. The thickness for walls adjacent to earth berming shall be 20" and the thickness for walls without earth berming shall be 32". The tunnel roof slab shall be 34" thick, designed to provide shielding and support the electrical gear. The tunnel floor slab shall be 33" thick reinforced concrete slab on grade poured in place over compacted sub-grade.

The Experimental Floor shall have 15" thick reinforced concrete slab, poured in place over compacted sub-grade. This slab shall be poured against and tied to the tunnel floor slab with rebar dowels to minimize differential settlement. Isolated from this slab, will be the 8" reinforced concrete access corridor slab, poured over compacted sub-grade near the outer ring and designed for fork lift truck wheel loads.

b) Service Buildings:

These buildings along the inner perimeter of the Ring Building shall be two story structures with concrete exterior walls at the Lower Level supporting the braced steel frames for the Second Floor above. The concrete side walls shall be designed for lateral earth pressure from the berms.

The Second Floor construction shall typically consist of 20 GA – 2" thick composite steel deck with 3" lightweight concrete topping (total slab thickness = 5") supported on framework of steel beams and girders.

The Roof will comprise of structural steel framing supporting 20 GA – 1 ½ " thick steel roof deck.

The First Floor construction shall consist of 6" thick slab on grade reinforced with 6x6 – W2.9 x W2.9 WWF over 6" compacted granular fill and vapor retarder. Vibrating equipment areas will have a structural slab with an air gap between the compacted fill below.

c) Operations Center Building:

This two story building (with alternate third floor) shall have construction similar to the Service Buildings except that the lowest story shall be framed and braced in structural steel too.

d) Lab Office Buildings

These are generally single story structures with Penthouse above the laboratories. The Penthouse floor construction shall comprise of 20 GA – 2" thick composite steel deck with lightweight concrete topping (total slab thickness = 5") supported on framework of steel beams and girders. The roof shall consist of 20 GA - 1 ½ " thick steel roof deck supported on structural steel beams and girders instead of open web steel joists (See sketch SK-6 for typical framing) The use of steel beams/girders will provide better support for the mechanical equipment and systems.

The First Floor construction shall be similar to the Service Buildings.

e) Linac and RF Buildings:

These structures are mainly single story structures with partial mezzanine/ second level floor in the RF Building. Construction of these structures in structural steel is similar to Service Buildings.

f) Access Tunnel:

There will be an Access Tunnel 20' wide and 14' high (clear height) that will go through under the Ring Building for service vehicles. The tunnel retaining walls shall be about 18" thick reinforced concrete walls, also supporting the tunnel roof/experimental floor. This may consist of eight span continuous one way reinforced concrete slabs supported on concrete beams spanning between the tunnel walls.

g) Special Considerations:

The floor slab for the Storage Ring Tunnel, the Experimental Hall and the Booster Tunnel shall be designed to allow minimal differential settlement. Thickness of floor slabs, walls, and tunnel roof are driven by radiation shielding requirements and not gravity loads.

The floor slabs of the Storage Ring Tunnel, Booster and Linac tunnel, and the Experimental Hall shall be structurally continuous with no isolation joints or contraction joints.

5.4.3 Lateral Load Resisting System:

Lateral loads shall be mainly resisted by braced frames wherever possible, otherwise by moment frames where bracing location would become architecturally prohibitive.

5.4.4 Materials

- Concrete (normal weight, unless noted otherwise):
 - Foundation and slab on grade: $f_c = 4000$ psi.
 - Piers, walls, grade beams, slabs and stairs on grade: $f_c = 4000$ psi.
 - Light weight concrete for Second Level/Mezzanine Floors: $f_c = 4000$ psi.
- Reinforcing steel:
 - Deformed: ASTM 615, Grade 60.
 - Welded wire fabric: ASTM A185.
- Structural steel:
 - Wide flanges and tees: ASTM A992, $F_y = 50$ ksi.
 - Channels, angles and plates: ASTM A36, $F_y = 36$ ksi.
 - Steel pipes: ASTM A53, Type E or S, Grade B, $F_y = 35$ ksi.
 - Structural tubes: ASTM A500, Grade B, $F_y = 46$ ksi.
 - Anchor bolts: ASTM F1554, 3/4" dia. min.
 - Bolts: ASTM A325, 7/8" dia. min.
- Steel Joists:
 - Chord and web sections: ASTM A36, $F_y = 36$ ksi ; or ASTM A588 $F_y = 50$ ksi