# SECTION 31 50 00
# SUPPORT OF EXCAVATION

## PART 1 - GENERAL

### 1.01 DESCRIPTION

A. This section specifies support for cut-and-cover, open-cut excavation, trench excavation and shafts.

B. Related Work Specified Elsewhere:
   1. Grading, excavating and backfilling: Section 31 23 00
   2. Maintenance, support and restoration of utility facilities: Section 33 01 00.
   3. Concrete reinforcement: Section 03 20 00.
   4. Cast-in-place structural concrete: Section 03 30 00.
   5. Structural steel: Section 05 12 00.

C. Contractor's Options:
   1. System of support to consist of soldier piles and lagging, sheet-piling or slurry-trench concrete walls, secured in place by means of bracing members such as wales, struts, shores and ground anchors. Other methods of support permitted only when approved.

### 1.02 QUALITY ASSURANCE:

A. Codes, Regulations, Reference Standard and Specifications:
   1. Comply with codes and regulations of the jurisdictional authorities.
   2. API: 13A, 13B-1.
   3. ASTM: A36, A709, A722.
   4. EPA.

B. Design Criteria:
   1. Design support of excavation in accordance with design criteria shown and specified. Criteria are the minimum acceptable.
   2. Design component members of system to support temporary decking system, earth and rock pressures, unrelieved hydrostatic pressures, utility loads, applicable traffic and construction loads and other surcharge loads. Use loading combinations shown. Prepare design for staged removal of bracing to suit sequence of concrete placement.
   3. Design support system for nonpenetration of station and entrance surfaces visible to public. Temporary penetration permitted only where location of penetration is eventually to be hidden by elements such as acoustical panels or similar items.
   4. Design sheeting and bracing for sides of excavations for underground structures in a manner permitting safe and expeditious construction of permanent structures, minimizing movement or settlement of the ground and preventing damage to adjacent buildings, structures and utility facilities. Locate and design the bracing system such that it will not interfere with the reinforcement and construction of the permanent structure.
   5. For support systems in which struts are installed between opposite sides of the excavation, design and construct support of both sides to obtain comparable rigidity.

6. Choose location of soldier piles to allow for expected deviations from true line during driving procedure without encroaching on future permanent structures.
7. Approval of Contractor's plans and methods of construction does not relieve the Contractor of the responsibility for adequacy of support.

**1.03 SUBMITTALS:**

Submit the following for approval in accordance with the General Requirements and with the additional requirements as specified for each:

A. Working Drawings:
1. Details, arrangement and method of assembly of proposed system, including construction sequence.
2. Method of preloading and bracing.
3. Elevations and sections showing full excavation depth from top grade to bottom of soldier piles or subgrade, whichever is deeper.
4. Loads for various stages of bracing removal and concrete placement.
5. Anticipated equipment load.
6. Maximum design load to be carried by various members of support system and preloads.
7. Depths below main excavation to which support system will be installed.
8. Methods of resolving difficulties arising from misalignment of soldier piles exposed during excavation and criteria for implementation of those procedures.
9. Methods of controlling and monitoring vibrations caused by driving of soldier piles to prevent damage to structures and utility facilities.
10. If proposed support system includes tieback anchors, show geologic profile or section for which each anchor is intended, design load for full depth of the excavation, maximum design and proof load and criteria proposed for deformations under proof loads.
11. Ground anchors and rock bolts:
    a. Prior to starting work, submit support system tieback and rock bolt details including design calculations, installation and load test procedures, grouting materials, grouting methods and detailed working drawings of the proposed rock bolt system.
    b. Show geologic profile or section for which each ground anchor or rock bolt is intended and design load of ground anchor and rock bolt for full excavation condition.
12. Include design calculations and maximum theoretical deflections of support members.
    a. The maximum allowable deflections of support members are as follows:

| | |
|---|---|
| Soldier beams | 1/2-inch |
| Walers | 1/4-inch |

This does not include the movement of support due to creep in tieback.

13. Include existing utility facilities. After checking their locations by field investigations, revise drawings to show actual locations of facilities, location of excavation supports, interference with proposed work and measures proposed to overcome such interferences.

B. Documentation:
1. Where proposed system of tieback anchors or rock bolts projects beyond vertical projection of property lines shown onto adjoining property, obtain permission of owner in writing.

2. Submit copies of permits with drawings.
3. Calculations:
   a. Design calculations as applicable.
   b. Do not proceed with work prior to approval.

**1.04 JOB CONDITIONS:**

A. Provision for Contingencies:
   1. Monitor performance of components of support system, both vertical and horizontal movement at regular intervals not to exceed three days.
   2. Provide contingency plan or alternative procedures to be implemented if unfavorable performance is evidenced.
   3. Keep on hand materials and equipment necessary to implement contingency plan.

B. Proceed with caution in areas of utility facilities; expose them by hand excavation or other methods acceptable to utility owner.

C. If existing utility facilities interfere with proposed method of support, modify or relocate such facilities with the approval of the appropriate utility owner. If relocation of the utility is not possible, obtain Engineer's approval for field changes to the approved support scheme of the excavation.

D. Do not splice elements of support system unless approved.

**PART 2 - PRODUCTS**

**2.01 MATERIALS:**

A. Steel Sheet Piles: Continuous interlocking type with cross section selected for intended use.

B. Cast-In-Place Structural Concrete: Section 03 30 00, Class 3500 unless otherwise shown.

C. Timber Lagging: Structural grade, minimum allowable flexural stress of 1,100 psi.

D. Concrete Reinforcement: Section 03 20 00.

E. Structural Steel: Section 05 12 00; ASTM A36 or ASTM A709, Grade 36, minimum.

F. NOT USED

G. NOT USED

H. NOT USED

I. NOT USED

J. Bentonite Powder: API 13A.

K. Other Materials: Those best suited for intended use, and as approved.

**2.02 MIXES:**

A. Lean Concrete: Portland cement and mineral or soil aggregate proportioned so that concrete retains its shape during excavation operations.

B. Concrete for Slurry Trench Walls:
   1. Tremie concrete of 3500 psi strength or higher if necessitated by design, with the following additional requirements:
      a. Minimum cement factor: Seven bags per cubic yard.
      b. Water-cement ratio: As necessary for strength and durability.
      c. Sand proportion: As necessary to produce optimum results.
      d. Rounded gravel aggregate: 1-1/2 inch maximum.
      e. Slump: Six inches plus-or-minus one inch.
      f. With water-reducing or fluidizing agents as necessary.
   2. Submit mix design for approval.

C. Bentonite Slurry:
   1. Stable suspension of powdered bentonite, or equal, and natural silts and clays in water.
   2. Density: 64 pcf minimum, 85 pcf maximum.
   3. Marsh funnel flow rate: 40 seconds minimum, 80 seconds maximum viscosity.
   4. Fluid loss: 25-cc maximum in 30 minutes.
   5. pH: 7.0 to 11.0
   6. Shear strength:
      a. By shearometer: 1.4 to 10 N/M.
      b. By fan viscometer: 4.0 to 400 N/M.

## PART 3 - EXECUTION

### 3.01 SHEETING, SHORING AND PILING:

A. Install soldier piles by driving, preboring or other pre-excavation methods. Drive soldier piles only in those areas where shown or approved. Install piles vertically within tolerance of one foot per each 100 feet for full depth of each pile.

B. Where piles are installed by preboring or other pre-excavation methods, take appropriate measures to stabilize excavation to preclude loss of ground.

C. Provide prebored holes for soldier piles adequate to accommodate pile section shown on approved working drawings. Extend hole to necessary depth below top of subgrade.

D. Carry bottom of support system to depth below main excavation, adequate to prevent lateral movement. In areas where additional excavation is required below main excavation subgrade, make provisions to prevent movement of main excavation supports.

E. Multiple-Layered Horizontal Bracing:
   1. At locations where top of weathered bedrock is above the subgrade of main excavation, install soldier piles so that tips are at least two feet below top of subgrade.
   2. At locations where top of weathered bedrock is five feet or more below subgrade of main excavation, install soldier piles so that lower tip is at least five feet below bottom of excavation.

3. If weathered bedrock is encountered at elevation between subgrade elevation and five feet below subgrade, install soldier piles so that lower tip is five feet below subgrade or two feet into rock, whichever is higher.

F. After seating soldier piles in pre-excavated holes, encase piles with Class 3500 concrete up to lowest point of excavation adjacent to pile location. Fill remainder of hole with lean concrete, completely encasing pile.

G. Use timber lagging, steel sheeting or precast reinforced concrete members secured in place for sheeting of excavations.

H. Follow excavation closely with placement of sheeting and lagging. Do not allow maximum height of unsheeted or unlagged face of excavation to exceed five feet in rock or predominantly clayey soils and three feet in sandy soils.

I. Do not permit height of unlagged face to exceed 15 inches if water flows from face of excavation or if soil in face moves toward excavation area.

J. Carefully perform excavation for installation of sheeting to minimize formation of voids. Separate sheeting members only to extent necessary to permit packing behind them.

K. Pack behind sheeting as installation progresses to establish tight contact between excavation face and sheeting. Pack openings between sheeting members with straw or other suitable material to allow free drainage of water without loss of soil or sand packing.

L. If unstable material is encountered during excavation, take suitable measures to contain it in place and prevent ground displacement which may cause damage.

M. Maintain sufficient quantity of material on hand for sheeting, shoring, bracing and other operations for protection of work and for use in case of accident or emergency.

N. Support System For Vertical Shafts Which Penetrate Soil/Rock Interface:

1. Soldier piles:

a. If shaft excavation is supported by soldier piles, locate piling at least five feet in a horizontal direction from outer face of shaft wall. Install lower tip of piling at least ten feet below top of unweathered bedrock.

b. Procedure for establishing tip elevations:

1) Make three pilot core borings at equal spacing along soldier pile line. Borings may be washed through overburden, but must be cored through bedrock to a depth of 20 feet into unweathered rock as determined by the Engineer. Advance holes in rock by rotary drilling methods and recover 2-1/8 inch diameter (NX) size rock cores using Series M double-tube core barrel. Drill in conformance to applicable portions of Section 02431. Place cores in wooden boxes as specified in Section 02431 and deliver to storage site as directed.

2) Install soldier piles to obtain tip elevations established by the Engineer's examination of coring results.

3) For shafts where pilot core borings indicate top of unweathered bedrock varies by more than three feet in elevation, set tips of soldier piles at least ten feet below lowest point of top of unweathered bedrock.

4) In drilling soldier pile holes, use equipment capable of penetrating hard igneous and metamorphic rock that has an average unconfined

compressive strength of six to eight kips per square inch and that may reach even greater values in some locations.

2. Ring beams and lagging or liner plate:
   a. If shaft excavation is supported by ring beams or liner plates, install rings or liner plate to at least ten feet below average elevation of top of unweathered bedrock, which will be determined by the Engineer from examination of the rock in the advancing excavation.

**3.02 SLURRY WALLS:**

A. Slurry Trench Equipment:
   1. Use equipment capable of removing from trench foreign materials embedded in soil as well as natural materials, including boulders, where necessary. Arrange equipment to permit free vertical passage of slurry within trench and to prevent development of suction or pressure.
   2. Furnish trench inspection tools adequate to ensure that trench has been excavated to dimensions shown on approved working drawings and that cuttings and foreign material have been removed.
   3. Use slurry mixing equipment capable of producing, with mechanical agitation, a stable suspension of bentonite and water. Transport slurry to panels by temporary pipe line or other approved methods.
   4. Furnish slurry circulation equipment to provide circulation and agitation of the slurry throughout full depth of excavated panels. Do not agitate slurry by air
   5. Use slurry reclaiming equipment which will remove detrimental quantities of excavated material from slurry to ensure use of clean slurry in trenches. Recirculate reclaimed slurry to trenches in a continuous operation regardless of slurry density. Monitor slurry and control its capability of retaining solid particles in suspension.

B. Field Quality Control:
   1. Make tests on samples of in-place slurry to determine density, viscosity, filtration and sand content in accordance with API 13B-1.
   2. Maintain quality of bentonite slurry compatible with soil characteristics of trench walls.

C. Construction:
   1. Perform preparatory work to discover, protect, maintain, relocate and restore utility facilities and other obstructions in vicinity of slurry walls.
   2. Construct slurry trench walls by displacement of bentonite slurry with tremie concrete.
   3. Construct walls of reinforced concrete or plain concrete embedded with structural steel. Where soldier piles are used in construction of walls, it is permissible to consider piles as reinforcement.
   4. Provide sufficient embedment of walls below subgrade of excavation to prevent loss of ground due to piping under wall or lateral movement of wall.
   5. Use construction methods ensuring that slurry materials employed during trench excavation and placing of tremie concrete are contained and controlled to prevent leakage and spillage of slurry and excavated materials into basements, vaults, utilities and other facilities.
   6. Excavate slurry wall trenches in panels of width and depth shown on approved working drawings with maximum panel length of 18 feet. Reduce panel length when excavating adjacent to facilities sensitive to settlement.

7. Maintain level of slurry in panels no more than five feet below top of trench during excavation operations and until tremie placement is essentially completed.
8. Progress construction with no less than one unexcavated panel and one tremie-filled panel with concrete cured at least 72 hours, between two slurry panels under active excavation.
9. Keep slurry circulated or agitated during drilling and excavating and immediately prior to concreting. Continuously maintain slurry requirements even during nonworking periods and stoppages. If stoppage occurs in the operation causing slurry in panel to remain uncirculated and unagitated for more than 24 hours, backfill panel until operation can be resumed.
10. Place concrete by tremie methods either by gravity flow or by pumping. As soon as possible after placement of concrete is commenced, position bottom of pipe not less than five feet below upper surface of concrete being placed and maintain it in this position throughout operation. Equip tremie pipe with bottom valve or other device to prevent mixing of slurry with concrete inside tremie pipe. Aluminum pipe is prohibited.
11. Inspect trenching in the presence of the Engineer prior to concreting. Ensure that settled cuttings and excavated material have been removed.
12. Start placement of concrete in panels within 12 hours after completion of panel excavation and proceed continuously until concreting is completed.
13. When wales are used, obtain tight bearing between wales and wall and ample bearing area with wedges and dry pack for load transfer.
14. Preload braces at each level to computed maximum compressive force to be encountered at that level. Base calculations of this computed force upon pressure diagrams shown. Take into consideration increased strut loads that may develop because of removal of bracing as structure is built.
15. Accomplish preloading by approved procedures. Transfer load by jacking applied symmetrically to braces without introducing eccentricity.
16. Introduce jacking load into braces immediately after each tier of braces has been installed and before excavation has progressed more than two feet below bottom of bracing tier. Make provision to fix preload into each brace by shim plates, wedges, blocking or other approved device.
17. After concrete invert slab has been placed and attains sufficient strength to receive loads from slurry walls, remove tiers of bracing above invert level, provided the following conditions exist:
    a. Remaining tiers are capable of resisting total load calculated from trapezoidal pressure diagrams shown.
    b. Calculated deflection of the walls between tiers of bracing, assuming forces indicated by the trapezoidal pressure diagrams, does not exceed 1/2 inch.
18. Construct tight joints between adjacent pours of concrete in slurry wall to minimize loss of fines from retained earth. Take necessary care to accomplish this in terms of properly excavating trench and cleaning abutting face of hardened concrete or surfaces of structural members if used. Provide approved method of water stopping.
19. Seal leaks encountered in walls as excavation progresses, if leaks are of sufficient size to permit penetration of fines and loss of ground. Procedures may include grouting outside or through wall.
20. Dispose of unsuitable excavated material and debris.
21. Dispose of slurry waste offsite by means of sealed tanks and in accordance with EPA regulations.

**3.03 PRIMARY SUPPORT:**

A. Use wales, struts, tieback anchors and rock anchors as necessary to provide primary support of excavation faces retained by soldier piles, sheeting, sheet piles or concrete slurry walls. For excavation depths greater than eight feet, primary support or supports are required.

B. Provide struts with intermediate bracing as needed to enable them to carry maximum design load without distortion or buckling.

C. Provide diagonal bracing as needed to maintain stability of system.

D. Include web stiffeners, plates or angles as needed to prevent rotation, crippling or buckling of connections and points of bearing between structural steel members. Allow for eccentricities caused by field fabrication and assembly.

E. Install and maintain primary support members in tight contact with each other and with surface being supported.

F. Design primary support members to support maximum loads occurring during excavation or removal stages.

G. Preloading:
   1. Except for ground anchors and slurry wall bracing, preload primary bracing members including struts, shores, wales carrying axial load, and similar members at installation to 50 percent of design load, which for this purpose is maximum load that bracing member will have to carry. Preload tiebacks and slurry walls as specified for those installations.
   2. Use procedures that produce uniform loading of bracing member without appreciable eccentricities or overstressing and distortion of members of wall system.
   3. Make provisions for permanently fixing load in each member using steel shims or wedges welded into place.
   4. Accomplish preloading by jacking support in place against soldier piles or wales.
   5. Do not use wooden wedges to preload bracing member.
   6. Include in preloading system means to determine within five percent amount of preload induced into bracing members.

H. If decking beams are not required or if decking beams are not designed for support of excavation loads, install uppermost tier of bracing at vertical distance of not more than six feet below top of excavation.

I. Install tiers of primary support with no greater vertical distance between them than 16 feet

J. Reduce maximum vertical distance to 12 feet at locations where ground movement and settlement must be minimized to prevent damage, where shown and as directed.

K. Excavate to no more than two feet below point of support about to be placed. Install support and preload immediately after installation and prior to continuing excavation.

**3.04 SUPPORT SYSTEM WITH TIEBACKS:**

A. Install tieback system in accordance with approved working drawings. Install anchorage in soil no closer than a plane extending upward at an angle of 45 degrees to the horizontal from outer limit of lowest depth of excavation.

B. Stress tiebacks to proof loads equal to 140 percent of maximum design load and maintain proof load for 30 minutes prior to reducing to design load. Reject tiebacks which lose more than five percent of proof load during 30-minute period.

C. Apply proof loads in increments of five tons at one-minute intervals and provide means to measure load application within accuracy of plus-or-minus five percent.

D. After reducing tieback load to design load, encase anchors in grout maintaining design load until anchors are fixed in place.

E. In transfer of loads from jacks to support system, use fixation method which will limit load loss to no more than five percent of design load.

F. Provide and maintain convenient access and appropriate means to accomplish these observations.

G. Preliminary And Creep Tests On Tiebacks:

1. Reapply proof loads equal to 140 percent of design load at each level of support in excavation on first installation on each side of excavation at horizontal intervals not exceeding 500 feet and wherever there is significant difference in soil in which tiebacks are installed.
2. As specified for proof loading, apply proof loads in increments of five tons at one-minute intervals. Provide means to measure load applications with an accuracy of plus-or-minus five percent of design load. Maintain proof load for 24 hours prior to reducing it to design load.
3. Make records of axial movement with incremental applications of load as well as amount and time of load fall-off with no pumping of jack or axial movement during 24-hour period that proof load on tieback is maintained. If during 24-hour period axial deformation of tieback system exceeds 0.02 inch or decrease in jack pressure without pumping is more than five percent after correcting for temperature changes during the test period, redesign tieback system to satisfy requirements.

H. NOT USED

I. NOT USED

**3.05 LAGGING:**

A. Unless otherwise shown or specified, provide timber lagging of three inches minimum thickness where it spans soldier piles placed at distances five to seven feet on centers and for excavation depths up to 25 feet. Increase minimum lagging thickness to four inches for excavation below 25 feet in depth.

B. For other conditions and types of lagging, submit design details for approval.

**3.06 TRENCH EXCAVATION:**

A. Perform sheeting, shoring and bracing for trench excavation for utility facilities and other purposes in accordance with specified safety requirements.

**B.** Provide sheeting, shoring and bracing for trench excavation in subgrade of subway excavation to prevent movement of main excavation support system.

**3.07 SUPPORT OF EXCAVATION AT INTERFACES:**

A. Design, construct, maintain and remove all or parts of support system at limits of the Contract at interface with the Authority's adjacent contracts, as may be necessitated by construction schedules and sequence of operations of respective contracts.

B. In the event excavation is commenced at an interface prior to the commencement of excavation on adjacent contract, design, construct and maintain end support system making provisions as follows:

1. Install near face of cofferdam on line separating contracts. Allow no part of support system to project into the next contract except thickness of supporting wall, e.g. soldier piles and lagging, and tiebacks if approved.
2. Provide support system adequate to support backfill and restoration loads with installation of a reasonable bracing system by adjacent contractor during excavation for his contract.
3. Design and construct support system so that it will be supported against vertical settlement when adjacent contractor removes lower portion of the cofferdam to effect connection of structures at juncture of two contracts.

C. If excavation has commenced on adjacent contract at interface prior to excavation on this Contract, make provisions as follows:

1. Coordinate removal of such portions of cofferdam which have been installed in adjacent contract and support and maintain remainder as necessary to effect juncture of contracts.

**3.08 FIELD QUALITY CONTROL:**

A. Tests:

1. Where system of tiebacks or rock bolts is proposed in conjunction with or in lieu of struts, bracing and shores, undertake approved number of on-site tests to demonstrate adequacy of tiebacks or rock bolts for typical subsurface conditions.
2. Conduct tests and obtain approval prior to use of tieback system for excavation support.
3. The Engineer may furnish and install certain instruments to monitor performance of tieback or rock-bolt system.

B. Remove components of support system which inadvertently penetrate or encroach on permanent structure without endangering stability of support.

C. Welding: In accordance with Section 05 12 00.

**3.09 REMOVAL OF SUPPORTING SYSTEM:**

A. When removing support of excavation system, wholly or in part, do not disturb or damage adjacent buildings, structures, construction or utility facilities. Fill voids immediately with lean concrete or with approved backfill compacted to density specified in Section 02320.

B. During strut removal stages, design soldier piles or slurry walls for increased vertical spacing of supports. For the removal of the first level support immediately above the invert slab, the slab can be considered a support for the soldier piles or slurry walls if it is poured directly against the sheeting and shoring and the invert slab is in place for at least 48 hours and is adequate to safely support the support of excavation, adjacent structures and the works. Leave support immediately above top of intermediate structure element, such as walls, slabs, or other horizontal members, until they are placed and are in place for at least seven days and are

adequate to carry the loads from the support of excavation and other loads imposed on them. Leave support immediately above top of roof slabs of structure in place for at least seven days after placement of roof slab concrete.

C. Remove other supports above roof structure only after backfill has been placed and compacted to required density to within three feet of bottom of support.

D. Except as specified below, remove supporting system to a depth of six feet below surface. Remove supporting systems of intersections of streets and at temporary access ramps to a depth of eight feet.

E. Where top of Authority structure extends into six-foot or eight-foot limit, remove adjacent supporting systems to a depth flush with top of the Authority structure or one-foot below surface, whichever is greater. Increase removal depths where necessary to accomplish work in this Contract.

F. Remove material of supporting system from site immediately.

**END OF SECTION**