CHAPTER 6 — SHORING COMPONENT DESIGN CONSIDERATIONS

The shoring component of the SMSE wall system must be compatible with the MSE wall component. This is primarily a geometric concern, but global stability considerations may also govern the design, and may even require adjustment of either the shoring component or the MSE component to provide for an effective wall system design. This chapter provides an overview of design considerations regarding shoring walls for SMSE wall systems, with an emphasis on soil nailing.

The design methodology presented in this report is based on soil nail walls as the shoring component, because soil nailing is a common shoring method for sites where SMSE wall systems are applicable. Soil nail walls also have an advantage with respect to global stability in that they reinforce the soil behind the shoring wall in much the same way that MSE reinforcements do for the MSE mass. As a result, soil nail walls are advantageous as the shoring method for use with SMSE systems. However similar construction considerations apply if other shoring systems are selected, and these guidelines are a useful starting point for design of SMSE systems with other shoring methods.

Where soil nailing is selected as the shoring wall component, design methodology should generally follow that outlined in *Geotechnical Engineering Circular No. 7 – Soil Nail Walls.*[26] The wall designer is referred to this resource, and other available information on soil nail technology, for understanding, evaluating, and designing the shoring portion of the SMSE wall system when a soil nail wall is anticipated.

6.1 COMMON TYPES OF SHORING WALLS

Several shoring techniques are available for SMSE wall systems, including:

- Soil pile and lagging wall with or without tie-backs[33] – Soldier pile and lagging walls are constructed by driving/drilling piles through the proposed excavation depth, and lagging is placed in between the piles as the soil is excavated in stages downward. This wall system may not be feasible for construction in hard ground conditions, where obstructions exist, or where noise and vibrations must be limited. Tie-backs may be utilized to avoid overstress of cantilevered soldier piles.

- Sheet-pile wall with or without tie-backs[34] – Sheet-pile walls are constructed in one phase where interlocking sheet-piles are driven to the final design elevation (below the proposed excavation). This wall type has similar limitations to the soldier pile and lagging wall, discussed above. As with soldier piles, tie-backs may be used to avoid overstress due to large cantilever lengths.

- Soil nail wall[26,32] – Soil nail walls are constructed using top-down techniques and involve installation of closely-spaced steel bars drilled and grouted in place to reinforce and strengthen the existing ground behind the excavation. Soil nail walls allow more construction flexibility than certain other shoring systems with regard to construction in heterogeneous soil/rock conditions, overhead access, reduced right-of-way requirements (i.e., soil nails are typically shorter in length than tie-back anchors), and reduction of embedment depth.

- Tangent or secant pile wall[(29)] – Tangent or secant pile walls are constructed by installing one or more rows of closely spaced (tangent or slightly overlapping) steel reinforced drilled caissons along the wall alignment, with required embedment. This wall type may be constructed where sensitivity to vibration renders sheet-pile or soldier beam construction not feasible, or where the shoring wall component cannot extend laterally behind the wall (i.e., in the case of tie-backs or soil nails).

6.2 SOIL NAIL WALL DESIGN FOR SMSE WALLS

Soil nails function as a reinforcing system working in association with the strength of the soil to form a coherent gravity mass capable of resisting lateral forces. The soil nail system is very flexible in its application, and any number of variations can be devised to meet specific project requirements. However, a typical soil nail wall application for an SMSE wall system would consist of:

- Soil Nails –Corrosion-protected (permanent) rigid steel bars centered in drilled holes and grouted over their entire length. Typical drill hole diameters are 125 to 200 millimeters (mm). The steel bars are capable of carrying tensile and shear stresses, as well as bending moments.

- Facing – A relatively thin (100 mm to 150 mm) permanent reinforced shotcrete facing is applied to the excavation face and connected to the soil nail heads after the nails are installed. For SMSE wall system applications, construction of a single facing layer is adequate, though corrosion protection of the nail heads, bearing plates and reinforcing elements is required for long-term sustainability of the structure. The shotcrete is placed in the appropriate thickness and reinforced with either a wire mesh (with waler and bearing bars) or mats of tied reinforcing bars according to nail head strength requirements.

- Drainage – Strips of drainage fabric extending vertically behind the facing connected to weepholes, consisting of 5 cm (plus or minus) diameter polyvinyl chloride (PVC) pipe extending through the shotcrete facing, are used for wall drainage. The drainage fabric should begin a minimum of 150 mm below the top of the excavation to prevent surface water infiltration behind the wall.

- Sequencing – For shoring applications, the soil nails are installed in a lift-by-lift sequence as the excavation progresses. A lift of soil is excavated (generally limited to 1.8 m in height), holes are drilled at a nominal declination (i.e., 15 degrees) at each soil nail location, nails are installed and grouted in-place, wall reinforcing steel and drainage provisions are installed, shotcrete is placed on the face of the excavation, and immediately thereafter (while the shotcrete is wet) bearing plates are placed and hand-tightened.

Several criteria should be met for the site soils to be considered appropriate for soil nail construction, including:

- Adequate stand-up time to allow preparation of the wall face (typically 24 to 36 hours) without excessive deformation or sloughing of the near-vertical excavation.
- Acceptable bearing capacity to preclude a bearing failure at the full height of excavation and at each construction phase.
- Sufficient soil strength and stiffness to meet the deformation criteria imposed for the project shoring system.
- The regional water table should occur below the base of the excavation, or should be drawn down beneath the base of the excavation.

If the onsite soil and groundwater conditions do not meet these criteria, alternative shoring systems should be considered, as mentioned previously (i.e., soldier pile, sheet-pile, etc.)

In order to provide long-term support of the excavation for SMSE wall construction, the soil nail shoring component should incorporate provisions for a permanent structure, as follows:

- Provide corrosion protection for soil nails, consisting of epoxy coating or high density polyethylene (HDPE) double corrosion protection, based on the aggressiveness or corrosivity of the onsite soils.(26)
- Install drainage components which are either connected to permanent wall drainage for the MSE wall or with outlets through the face of the MSE wall, preventing build-up of hydrostatic pressures behind the shoring component, discussed in section 3.3.3.
- Construct only one layer of shotcrete facing when the nail heads and bearing plates are protected from corrosion (i.e., encapsulation of nail head in the shotcrete construction facing or application of epoxy coating on exposed steel), or construct two layers of shotcrete facing to provide cover for all steel components.

It is also recommended that the shotcrete facing be left as an "as-shot" or "gun" finish enhancing the shearing resistance between the two walls. *In addition to the above, soil nail reinforcements for SMSE wall system construction should satisfy the following minimum requirements:*

- *Nails should extend to a minimum of 0.7H behind the face of the proposed MSE wall, comparable to an equivalent conventional MSE wall.* (See references 1, 2, and 35.)
- *Nail length, L_z, at any depth (z) should satisfy:*

$$L_Z \geq \frac{FS_{PO} S_h S_v \sigma_h}{Q}$$ **Equation 30.**

where Q is the ultimate nail pullout resistance, FS_{PO} is the factor of safety against nail pullout (equal to 1.35 for permanent shoring construction of non-critical structures and 1.5 for critical structures), S_h and S_v are the horizontal and vertical nail spacing, respectively, and σ_h is the design horizontal pressure for a conventional MSE wall at the nail head location.[26] *The design horizontal pressure is calculated using equations 3 and 4 in chapter 5, but the retained fill unit weight (γ_r) is substituted for the reinforced fill unit weight (γ).*

- *Nail tensile capacity (T_n) at any depth should satisfy:*

$$T_n \geq FS_t S_h S_v \sigma_v$$ **Equation 31.**

where FS_t is the nail tensile capacity factor of safety (equal to 1.8), and σ_v is the design vertical pressure at the nail head location.[26] *The design vertical pressure is calculated using equation 4 in chapter 5, but the retained fill unit weight (γ_r) is substituted for the reinforced fill unit weight (γ).*[26] Design of the soil nail wall shoring system should otherwise be conducted according to procedures outlined in available design guidelines.[26,32]

6.3 SHORING WALL BEHAVIOR

Consideration should be given to the long-term behavior of each of the individual wall components, which may influence project design details. For instance, the shoring wall should be designed for a life of 75 years to be compatible with the MSE wall design life. In this section, the behavior of the shoring wall is discussed, with recommendations to reduce the potential for differential behavior between the soil nail and MSE wall types.

The fundamental mechanics behind soil nailing involves development of tensile forces in the passive reinforcements (or nails) resulting from the restraint provided by the nails and facing to lateral deformation of the structure.[26] Because soil nail walls involve top-down construction, the reinforced zone has a tendency to rotate outward about the toe as lateral support is removed during excavation. This outward rotation is part of the process mobilizing tensile loads within the nails and is expected to be very small, ranging from 0.4 percent of the wall height for fine-grained clay type soils to 0.1 percent or less of the wall height for weathered rock and competent dense soil.[32] As a result, maximum horizontal movements for soil nail walls occur at the top of the wall, decreasing toward the base of the wall. In order to reduce deformations at the top of the wall, use of minimum No. 25 Grade 520 bar for the top row of nails is recommended.

Settlement of the soil nail wall facing also occurs. Settlement is a function of construction rate, nail spacing, excavation lift heights, nail and soil stiffness, global factor of safety, nail inclination, bearing capacity of foundation soils, and magnitude of facing and surcharge loading.[26]

Once the soil nail wall is constructed to its full height, construction of the MSE wall will follow in a bottom-up fashion. The MSE wall component will provide restraint to the shoring wall, impeding additional lateral deflections. Therefore, most of the lateral deformation of the shoring wall is expected to occur during excavation and prior to MSE construction. In contrast, settlement may continue during and beyond the construction of the MSE wall component. With regard to SMSE walls systems, the unique issues are:

- Soil nail wall movement will generally happen before the MSE wall is constructed and is inelastic (i.e., soil and nails have mobilized their strength and will not be pushed “back into place”).

- The MSE mass will provide normal and shear forces to the soil nail facing during construction and long-term.

- The facing and nails need to be able to handle external loading from the MSE mass and transfer it to the soil behind and below the wall, which may be accomplished by ensuring intimate contact between the facing and the cut slope, and possibly incorporating a shotcrete footing for the bottom lift.