Chapter 11 Ground Improvement

11.1 Overview

Ground improvement is used to address a wide range of geotechnical engineering problems, including, but not limited to, the following:

- Improvement of soft or loose soil to reduce settlement, increase bearing resistance, and/or to improve overall stability for structure and wall foundations and/or for embankments.
- To mitigate liquefiable soils.
- To improve slope stability for landslide mitigation.
- To retain otherwise unstable soils.
- To improve workability and usability of fill materials.
- To accelerate settlement and soil shear strength gain.

Types of ground improvement techniques include the following:

- Vibrocompaction techniques such as stone columns and vibroflotation, and other techniques that use vibratory probes that may or may not include compaction of gravel in the hole created to help densify the soil
- Deep dynamic compaction
- Blast densification
- Geosynthetic reinforcement of embankments
- Wick drains, sand columns, and similar methods that improve the drainage characteristics of the subsoil and thereby help to remove excess pore pressure that can develop under load applied to the soil
- Grout injection techniques and replacement of soil with grout such as compaction grouting, jet grouting, and deep soil mixing
- Lime or cement treatment of soils to improve their shear strength and workability characteristics
- Permeation grouting and ground freezing (temporary applications only)

Each of these methods has limitations regarding their applicability and the degree of improvement that is possible.

Rock mass improvement techniques such as bolting dowelling, shotcreting, etc., are not presented in this chapter, but are addressed in Chapter 12.

11.2 Development of Design Parameters and Other Input Data for Ground Improvement Analysis

In general, the geotechnical investigation conducted to design the cut, fill, structure foundation, retaining wall, etc., that the improved ground is intended to support will be adequate for the design of the soil improvement technique proposed. However, specific soil information may need to be emphasized depending on the ground improvement technique selected.

For example, for vibro-compaction techniques, deep dynamic compaction, and blast densification, detailed soil gradation information is critical to the design of such methods, as minor changes in soil gradation characteristics could affect method feasibility. Furthermore, the in-situ soil testing method used (e.g., SPT testing cone testing, etc.) will need to correspond to the technique specified in the contract to verify performance of the ground improvement technique, as the test data obtained during design will be the baseline to which the improved ground will be compared. Other feasibility issues will need to be addressed if these types of techniques are used. Critical is the impact the vibrations caused by the improvement technique will have on adjacent structures. Investigation of the foundations and soil conditions beneath adjacent structures and utilities may be needed, in addition to precondition surveys of the structures to enable identification of any damage caused by the ground improvement technique, if the risk of damage to adjacent structures and utilities is estimated to be acceptably low.

For wick drains, the ability to penetrate the soil with the wick drain mandrel, in addition to obtaining good rate of settlement information, must be assessed. Good Atterberg limit and water content data should be obtained, as well as any other data that can be useful in assessing the degree of overconsolidation of the soil present, if any.

Grout injection techniques (not including permeation grouting) can be used in a fairly wide range of soils, provided the equipment used to install the grout can penetrate the soil. The key here is to assess the ability of the equipment to penetrate the soil, assign the soil density and the potential for obstructions such as boulders.

Permeation grouting is more limited in its application, and its feasibility is strongly dependent on the ability of the grout to penetrate the soil matrix under pressure. Detailed grain size characterization and permeability assessment must be conducted, as well as the effect ground water may have on these techniques, to evaluate the feasibility of these techniques. An environmental assessment of such techniques may also be needed, especially if there is potential to contaminate groundwater supplies. These techniques are highly specialized and require the approval of the State Geotechnical Engineer before proceeding with a design based on using these techniques.

Similarly, ground freezing is a highly specialized technique that is strongly depending on the soil characteristics and groundwater flow rates present. Again, approval of the State Geotechnical Engineer is required before proceeding with a design based on using this technique.

11.3 Design Requirements

The design requirements provided in FHWA manual No. FHWA-SA-98-086 "Ground Improvement Technical Summaries" (Elias, et al., 2000) shall be followed. In addition, for stone column design, FHWA Report No. FHWA/RD-83/O2C "Design and Construction of Stone Columns" (Barkdale and Bachus, 1983) shall be used, for deep dynamic compaction, FHWA manual No. FHWA-SA-95-037, Geotechnical Engineering Circular No. 1, "Dynamic Compaction" (Lukas, 1995) shall be used, and for wick drain design, FHWA manual FHWA/RD-86/168 "Prefabricated Vertical Drains – A design and Construction Guidelines Manual" (Rixner, et al., 1986) shall be used.

For blast densification, the methodology and general approach described in Kimmerling (1994), and the additional design guidelines provided by Mitchell (1981) should be used. For lime and cement treatment of soils, Alaska DOT/FHWA Report No. FHWA-AK-RD-01-6B "Alaska Soil Stabilization Design Guide" (Hicks, 2002) shall be used for design. Design of geosynthetic base reinforcement and reinforced slopes are addressed in Chapters 9 and 15, respectively.

11.4 References

Barkdale, R. D., and Bachus, R. C., 1983, *Design and Construction of Stone Columns – Vol. 1*, Federal Highway Administration, FHWA/RD-83/02C.

Elias, V., Welsh, J., Warren, J., and Lukas, R., 2000, *Ground Improvement Technical Summaries – Vol. 1 and 2*, Demonstration Project 116, Federal Highway Administration, FHWA-SA-98-086.

Hicks, R. G., 2002, *Alaska Soil Stabilization Design Guide*, Alaska Department of Transportation and Federal Highway Administration Report No. FHWA-AK-RD-01-6B.

Kimmerling, R. E., 1994, *Blast Densification for Mitigation of Dynamic Settlement and Liquefaction*, WSDOT Research Report WA-RD 348.1, 114 pp.

Lukas, R. G., 1995, *Geotechnical Engineering Circular No. 1 – Dynamic Compaction*, Federal Highway Administration, FHWA-SA-95-037.

Mitchell, J. K., 1981, *Soil Improvement: State-of-the-Art Report*, Proceedings of the 10th International Conference on Soil Mechanics and Foundation Engineering, Stockholm, Sweden, pp. 509-565.

Rixner, J. J., Kraemer, S. R., and Smith, A. D., 1986, *Prefabricated Vertical Drains – Vol. 1: Engineering Guidelines*, Federal Highway Administration, FHWA/RD-86/168.