Ground Improvement By Grouting

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***Abstract*- Grout curtains are constructed by means of drilling and injecting grout into one or more rows of holes. Consolidation grout holes typically are relatively shallow (5 to 10 m deep) and are grouted in a single stage. is defined as the injection of fluidized materials into voids of the ground or spaces between the ground and adjacent structures, generally through boreholes and under pressure. In foundation investigation, drill holes were drilled to characterize the foundation condition. Core logging, core recovery percentage, rock quality designation and joint condition (weathering, infillings) and Lugeon test results determined the foundation conditions and need to improve the foundation by grouting. Water pressure test is very important to choose the pressure value from the type of flow observed in calculating the Lugeon value (water pressure value). The results will be very useful in designing foundation improvement by grouting and in the design of effect grout hole and grout pattern design. The most commonly used chemical grout for follow-up treatment of cement-grouted foundations is sodium-silicate. Sodium silicate is among the most economical of varies chemical grouts. The various injection grouting techniques used by grouting contractors for ground improvement and ground modification are permeation, compaction, claquage and jet grouting.**

Keywords- Grouting, Lugeon Test, Water Pressure Test, Permeation, Ground modification

I. INTRODUCTION

Dam foundation grouting is a process by which open geologic defects are sealed to reduce seepage and to strengthen the foundation. The grouting material may be a suspension of solids in water (slurry grout), a pure solution (chemical grout), or a combination of the two. Grout curtains are constructed by means of drilling and injecting grout into one or more rows of holes. Consolidation grout holes typically relatively shallow (5 to 10 m deep) and are grouted in a single stage.

1.1 Definition and Purpose of Grouting

Grouting is defined as the injection of fluidizes materials into voids of the ground or spaces between the ground and adjacent structures, generally through boreholes and under pressure.

Many grouts are designed to set (gel or harden) after injection, either instantly or over a period of time. The main objectives of grouting are to produce a stronger, denser and less permeable soil or rock. There is no doubt that the largest quantities of grout are used in creating more or less impervious curtain below dams in order to reduce water losses, uplift pressure and reduce the potential for hydraulic fracturing under operating conditions. Its successful application requires a great deal of experience, through knowledge of geological conditions, an awareness of equipment capabilities and limitations as shown in Fig. 1.

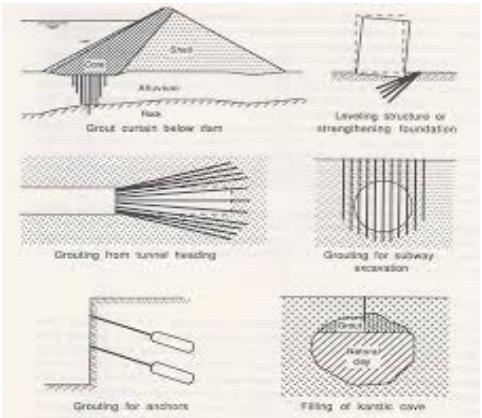

Fig. 1 Typical Application of Grouting

1.1.1. Groutability Test

In foundation investigation, drill holes were drilled to characterize the foundation condition. Core logging, core recovery percentage, rock quality designation and joint condition (weathering, infillings) and Lugeon test results determined the foundation conditions and needs to improve the foundation by grouting. Lugeon values alone do not specify the needs

for grouting the foundation when the joint openings are not enough to inject the cement grout, the grout may not penetrate the joints. Therefore, after performing the Lugeon test, these holes should also be tested. The results will be very useful in designating foundation improvement by grouting and in the design of effect grout hole and grout pattern design.

1.1.2. Categories of Grouting

Grouting techniques are classified according to the method used to introduce the grout into ground as shown in Fig. 2.

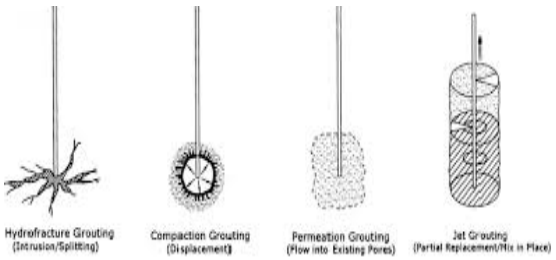

Fig.2 Schematic Representation of Basic Modes of Grouting

(a) Penetration grouting

This grouting describes the process of filling joint or fractures in rock or pore spaces in soil with a grout without disturbing the formation.

(b) Displacement grouting

It is the injection of grout into a formation as to move the formation, it may be controlled as in compaction grouting, uncontrolled as in high pressure soil or rock grouting which leads to splitting of ground called hydro fracture.

(c) Compaction grouting

A very stiff mortar is injected into loose soils, forming grout bulbs which displace and dandify the surrounding ground.

(d) Grouting if voids

Slab jacking or mud jacking is performed where grout is injected under a concrete slab in order to raise it to specific grade. Grout may be simply to fill voids; such as may develop below the joints in a concrete pavement through pumping.

(e) Jet grouting

It is high-speed water jets emanating from a drill cut into alluvial soils as the drill bit is withdrawn, grout is pumped through horizontal nozzles and mixes with or displaces the soil. Jet grouting may be used to form cutoff walls, or form deep foundations similar to ground auger piles.

(f) Special grouting applications and techniques, including electro grouting

Electro grouting is used for promotion electro chemical hardening during electro osmosis by adding chemicals such as sodium silicate or calcium chloride.

II. WATER PRESSURE TEST

The water pressure test comprises a series of packer test out at five consecutive water tests, each of 10 minutes' duration as in the case of field permeability test. The first run is as low pressure, the second at medium pressure and the third at peak pressure which is used for the second test and the fifth or final test is run at the same pressure used for the first test. As a general practice, linear extrapolation is used to calculate the permeability in Lugeon unit as follows;

Lugeon Unit= water take in liter per minute per meter of length × 10 bars

(or) Lugeon= $10 \times Q/I \times P$

Where, Q=Liter per minute(l/m)

(amount of Injected Water)

I= Section of test length(m)

P=yield pressure (kg/cm^2)

2.1 Interpretation of Water Pressure Test Results

The interpretation of water pressure test results is done by plotting the discharge verses pressure shown in Figure 3. It is very important to choose the pressure value from the type of flow observed in calculating the Lugeon value. In the case of turbulent flow, the Lugeon value calculated from the highest pressure should be used. In dilation type of flow, the average of 2 low or medium values should be used. For wash out type of flow using the Lugeon value show the highest value and for void filling type of flow take the final water value of the test. In such case the water pressure value is mostly calculated by proportional extrapolation of the absorbed volume. Varying size apertures of fissures

or joints and different flow characteristic between water absorption as a small number of joints with joint aperture. However, the resulting seepage and groutability may be different.

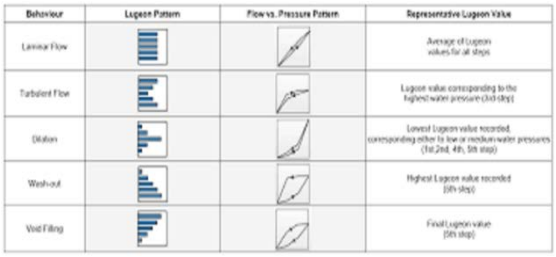

Fig.3. Interpretation of Water Pressure Test Results and Type of Flow

III. SUPPLEMENTARY GROUTING WITH CHEMICALS

Most dam foundation grouting in the United States is accomplished with Portland cement-based grouts. As a matter of economy and long term durability of the grout curtains, this probably is appropriate. The most commonly used chemical grout for follow-up treatment of cement- grouted foundations is sodium- silicate. Sodium silicate is among the most economical of the various chemical grouts. It requires use of a reactant to form a silicic acid gel. Reaction in common use have included calcium chloride, sodium bicarbonate and sodium aluminates.

3.1 Grouting Techniques

The various injection grouting techniques used by grouting contractors for ground improvement and ground modification can be summarized as follow:

3.1.1 Permeation

Grout is injected into the soil at low pressure and fills the voids without significantly changing the soil's structure or volume. Wide varieties of binders are used with this grouting technique. The choice of the binder is dictated mainly by the permeability of the soil.

3.1.2 Compaction Grouting

A highly viscous grout with high internal friction is injected into a campactable soil. The grout acts as a radial, hydraulic jack and physically displaces the soil particles, thus achieving controlled densification.

3.1.3 Claquage

Grout is injected into the soil at a high pressure through a special valve tube, thereby hydrofacturing the soil. The resulting fissures are filled with the grout and the surrounding soil is modified to create a densified mass.

3.1.4 Jet Grouting

This system differs substantially from the other ground improvement or ground modification techniques- it breaks up the soil structure completely and performs deep soil mixing to create a homogeneous soil, which in turn solidifies. The jet grouting techniques can be used regardless of soil, permeability, or grain size distribution. In theory, it is possible to improve most soils, from clay and silts to sand and gravels by jet grouting. Although it is possible to inject any binder, in practice, water- cement are normally used. Where impermeabilization of the soil is required, water-cement-bentonite mixtures are typically used.

3.2 Three Basic Jet Grouting Systems

(a) The "Monofluid" Jet Grouting System

Grouting contractors uses a high- pressure pump to convey the binder through a drill string to a set of nozzles located just above the drill bit. The high velocity, high energy jet breaks up and mixes the soil surrounding the drill string to create a column of stabilized material whose diameter ranges from 40 cm to 120cm.The main equipment required for this jet grouting system is:

-A high pressure, high flow pump (70 MPa, 300L/min);

-A jet grouting drill rig fitted with a special drill string and a suitable timer that accurately controls the step-raising of the drill string;

-An efficient batching plant with sufficient capacity for the required amount of the grouting binder.

Uses- A borehole is drilled to the required depth by rotary or rotary –percussive methods using water, compressive air, bentonite, or a binder as the flushing medium. When the foundation level is reached, the flushing ports are closed and the binder is injected at a

very high pressure (20MPa to 60 MPa) through the nozzles and into the soil. Simultaneously, the drill string is rotated and slowly withdrawn. Rotation speeds range between 10 and 30 rpm and the withdrawal rates vary between 20 and 50 cm/min.

(b) The "3-Fluid" Jet Grouting System

This system is used a high energy jet of water rather than the binder to break up the soil surrounding the drill string. The passage of the jet of water through the soil is aided by an aureole of compressed air concentric about the jet. The compressed air increases the radius of influence of the jet of water and it "lightens" the mixture of soil and water in zone of influence of the jet, creating an air-lift that pumps excess water soil fines, through the annular space between the borehole well and the drill rods, to the surface.

At the same time the binder is injected into the soil water mix at approximately 5 MPa through a second nozzle. In time, the soil and binder mix sets to create a column of stabilized material whose diameter may exceed 2 meters.

Grouting contractors need the following equipment for this jet grouting system:

(i) A high pressure, high flow pump for the water jet (70MPa,300l/min);
(ii) A low pressure pump for the binder (7 MPa,120l/mn);
(iii) A 3-way, coaxial drill string made up of drill bit, a drill bit adapter, a nozzle holder for the cement nozzles, a high pressure nozzle holder with the coaxial air/ water nozzle, the drill rod, and a 3-way swivel.
(iv) A jet grouting drill rig, fitted, with a suitable timer that can accurately binder;
(v) A reservoir for water.

The 3- fluid jet grouting system is advantageous where the soils are difficult to drill because fewer holes are required to that the same volume of soil. A larger volume material is discharged from the boreholes; increasing costs and causing potential problems in soils with low permeability.

The monofluid jet grouting system is more versatile; it can be applied at any inclination and consequently finds wide use in the stabilization of existing structures and tunnels where spaces are restricted. Set up an excavation time considerably shorter; the method is also cheaper, cleaner and less noisy tan the 3-fluid jet grouting system.

(c) The "2- Fluid" Jet Grouting System

This newer system is a combination of the monofluid jet grouting and the 3-fluid jet grouting systems. It based upon the principles of the monofluid jet grouting system, but to enhance its radius of influence uses an aureole of compressed air concentric about the jet of binder. Typically, the diameter of the

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