DAM FOUNDATION GROUT MONITORING SYSTEM

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ABSTRACT

Expansion of the Los Vaqueros Dam near Brentwood, California required the extension of the original grout curtain along each abutment. The grout curtain was comprised of two rows of primary, secondary, tertiary, and higher order holes as required by the grouting program. A real time grout monitoring system was utilized for monitoring of the water testing and grout injection. The real time data presented by the system provides graphical as well as a numerical data that allows for informed real time decision making. Each of the grout headers is equipped with a flowmeter and pressure transducer that transmits wireless signals to the grout monitoring trailer, located on the job site. The grout monitoring trailer contains the Grout Monitoring System that receives the wireless signals from each of the headers, and presents the information in real time. The Grout Monitoring System has multiple screens, each dedicated to a single grout header, allowing for multiple grouting or water testing activities to take place simultaneously. The graphical display of the flow, pressure, and Lugeon value illustrates the grouting behavior for every stage. The real time monitoring of the curtain grouting expansion at Los Vaqueros Dam provided accurate, instantaneous, accessible data that helped ensure quality and efficiency of the curtain grouting.

INTRODUCTION

In April 2011 the expansion of the Los Vaqueros dam project near Brentwood California broke ground. The objective of the project was to increase the reservoir capacity by 60,000 acre-feet, which was achieved by raising the crest of the dam 34 ft. The original grout curtain was extended into each abutment to accommodate the new height of the dam. This extension of the grout curtain was constructed using pressure grouting methods. The grout curtain was constructed in claystone and sandstone formations. By the time grouting started, the overburden on the rock slope had been removed, and dental concrete had been used to fill surface voids and create a working platform. The pressure grouting method on this project, employed the use of real time monitoring for water

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pressure testing and grout injection. The Grout Monitoring System provided accessible, instantaneous data that ensured quality and efficiency of the curtain grouting operations.

PRESSURE GROUTING SETUP AND OVERVIEW

The pressure grouting setup allows for grouting operations to take place over a large area with minimal movement of grouting equipment. The main components of the grouting operation consist of a batch plant, transfer station, grout header, and monitoring trailer. The batch plant is typically centrally located and may only move a couple of times, if at all, over the duration of a job. The transfer station, which consists of an agitator and a progressive cavity pump, is placed nearer the grout injection point. Multiple transfer stations can be used and are more easily moved as the grouting operation progresses. The grout header, which is fed by the transfer station, is placed at the injection point, and can be carried from one hole to the next. The monitoring trailer, which houses the Grout Monitoring System, is placed onsite, but out of the way of the grouting operation. The basic setup for pressure grouting is illustrated in Figure 1 below.

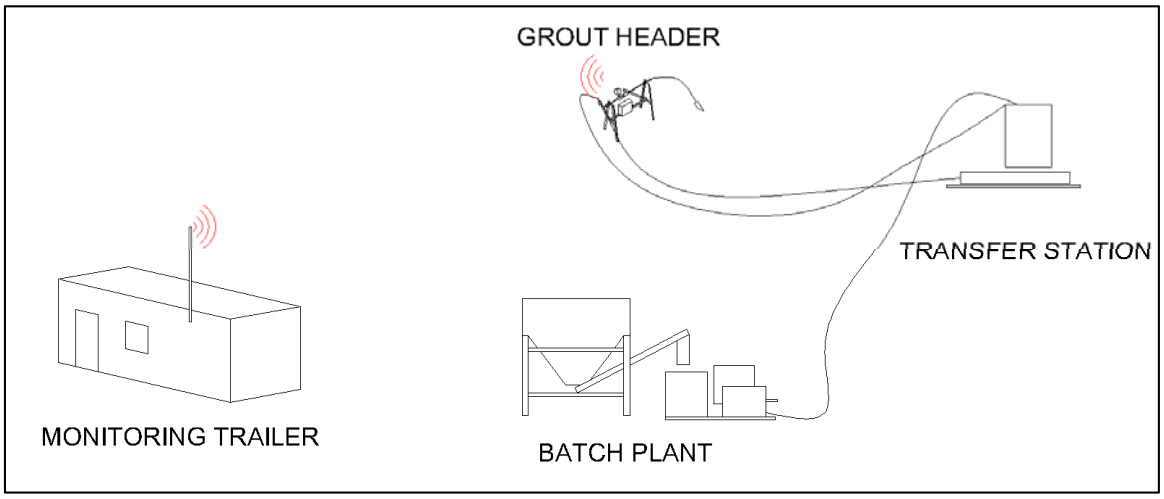

Figure 1: Pressure Grout Setup

The grout curtain at Los Vaqueros consisted of two grout rows of primary, secondary, tertiary, and higher order holes, as required, when grout take reached or surpassed a predetermined cement take per linear foot. The two rows were battered in opposite directions to provide maximum grout coverage. The extension of the curtain along the abutments at Los Vaqueros required drill hole depths between 120ft to 170ft, which was determined by the depth of the sandstone layer.

Each grout hole was water-tested in ascending stages, in 20ft stage lengths. These stages were then grouted until the contract refusal criteria had been met. Real time monitoring

of both the water testing and grouting operation was performed to provide instantaneous data to aid real time decision making and ensure quality performance.

WATER TESTING

Water testing was conducted in each 20ft stage, using a straddle packer system to isolate a 20ft zone, to determine the Lugeon value. The Lugeon value is a function of the flow rate of injected water, the injection pressure, and the stage length over which the water is injected. The resulting Lugeon value is related to the geology's hydraulic conductivity. Generally speaking, higher Lugeon values indicate fissures in the geology and a greater likelihood of grout take. Low Lugeon values indicate a tight geology, and the likelihood of grout injection is low.

All the primary holes at Los Vaqueros required a five step water test, varying the pressure with each step. The Grout Monitoring System recorded each water test, displaying both graphically and numerically the instantaneous injection pressure, injection flow rate, and Lugeon value. A screen shot of a water test operation, as displayed by the Grout Monitoring System, is shown in Figure 2.

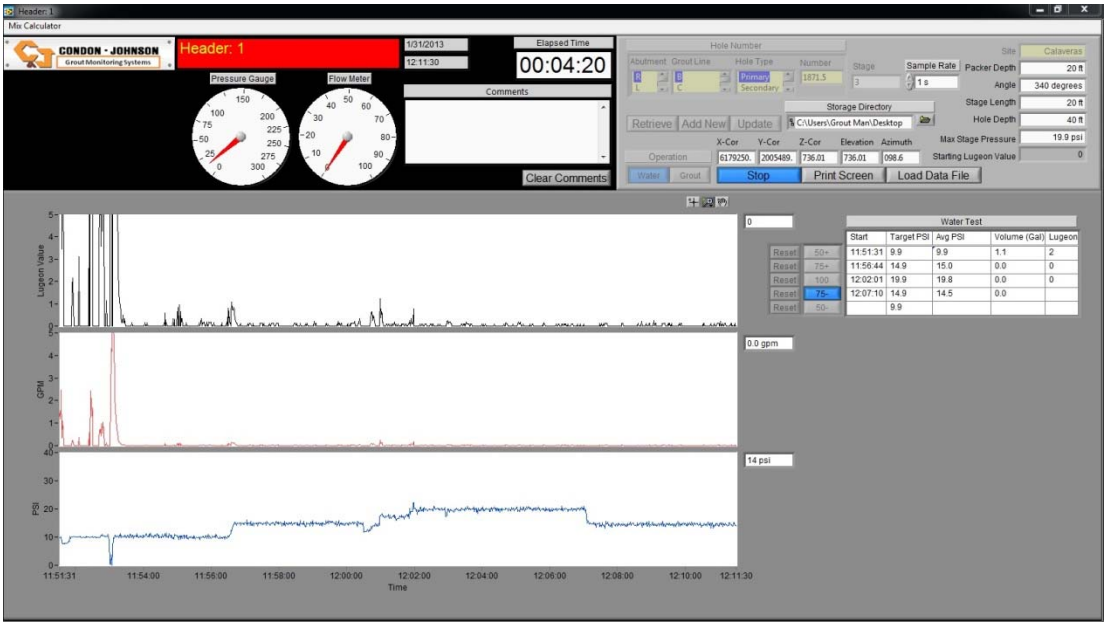

Figure 2: Water Test Operation

To the right of the graphs, shown in Figure 2, the information of each of the five water test steps is illustrated numerically in a table. The table displays the start time, target pressure, actual average pressure, volume injected, and the Lugeon value for each step. In addition to the tables, the graphs display the real time flow rate, pressure, and Lugeon

values over the entire five step duration, allowing the grout technician to easily and quickly recognize trends.

GROUT INJECTION

Much like the water testing operation, during grout injection the Grout Monitoring System displays graphical and numerical data in real time. In addition to the graphs displayed during water testing and during a grouting operation, an apparent Lugeon value is also graphed. This value is calculated in the same way as a Lugeon value, except that it takes into account the ratio of the viscosity, as determined by Marsh Funnel API RP 13-B test procedure, between water and the selected grout mix. A screen shot of a grout injection operation, as displayed by the Grout Monitoring System, is shown in Figure 3.

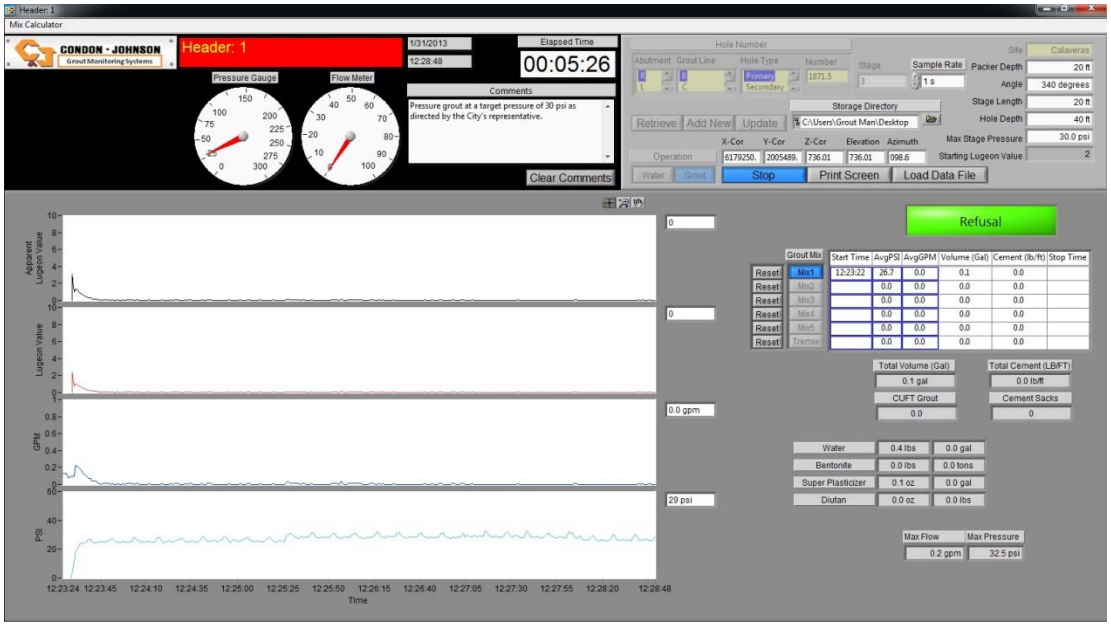

Figure 3: Grout Injection Operation

To the right of the graphs, shown in Figure 3, a table contains grout injection information for several different mix designs. This information includes start and stop times, average pressures, and flow rate, total volume injected and total pounds of cement per foot of stage length, for each of the different mix designs. This information provides the grout technician and inspector the necessary information to make real time decisions, for example, when to change mixes.

GROUT MONITOIRING SYSTEM

Monitoring grout injection operations in real time requires two major components - a header and a monitoring system. The major components of the header are the flowmeter and pressure transducer, which output a 4-20ma signal to a transmitter, also located on the header. The transmitter then communicates wirelessly to a receiver located in the monitoring trailer. This receiver then feeds the information into a computer containing the Grout Monitoring System software, which interprets and displays the information in graphical and numerical format.

The Grout Monitoring System software allows for multiple water tests, and/or grout injections to be performed simultaneously. A picture of the software running on the Grout Monitoring System, inside the monitoring trailer, is shown in Figure 4. The grout technician is able to monitor multiple activities at once, and with the use of radio communication can direct both the grout header, and batch plant operators.

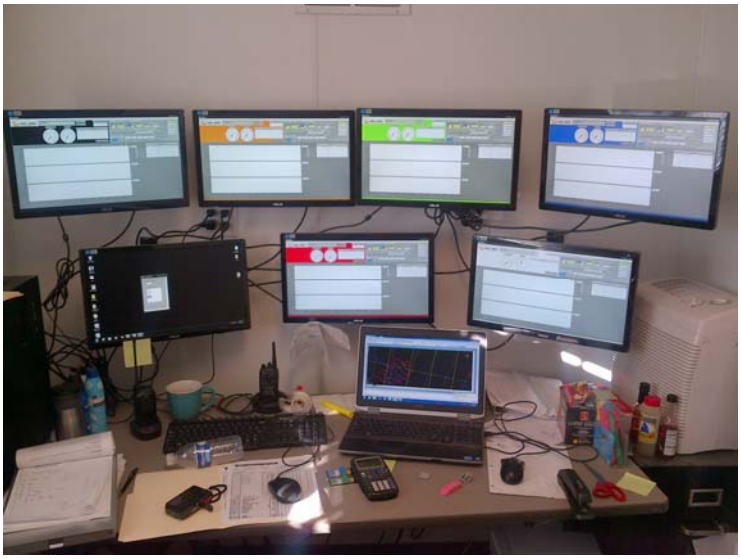

Figure 4: Grout Monitoring System

Each screen on the Grout Monitoring System contains one water test or grouting operation. In the top right corner of each screen the hole and stage information is input into the system, and the operation to be monitored is selected. Depending on the operation selection the system will display the monitoring screen for either water testing, or grout injection. The information corner of the screen is better illustrated in Figure 5.

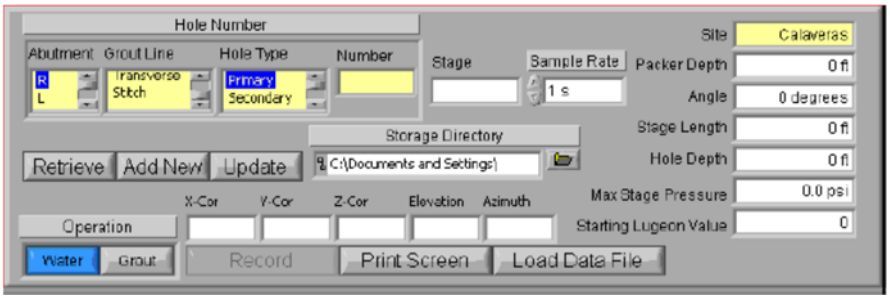

Figure 5: Hole Stage and Operation Information

In addition to viewing the grouting activities in real time, the

grout monitoring software provides organized and thorough reports of the water testing and grouting activities conducted at each stage.

CONCLUSION

Real time grout monitoring has several advantages. The real time information helps determine more quickly when grout mixes need to be changed, or when field adjustments need to be made. The centralized monitoring that the grout monitoring system provides reduces the number of personnel needed to monitor grouting activities, as several operations can be monitored from one location. The organized, thorough and accurate reporting of the Grout Monitoring Systems ensures that quality and consistency are maintained thoroughout the project duration. Implementation of the Grout Monitoring System for extending the grout curtain at the Los Vaqueros dam proved to be very effective in reporting, and contributing to the overall efficiency and effectiveness of the grouting program.