Journal of Geotechnical and Transportation Engineering
Volume 3 | Issue 2
A Case Study of Trial Grouting using Grouting Intensity Number (GIN) and Conventional Method at Tarbela...
Shahzad et al.
Received 9/10/2017 Accepted 11/16/2017
Published 12/1/2017
Corresponding Author:
Muhammad Imran Shahzad;
imranshehzadgeo@gmail.com
www.jgtte.com

A Case Study of Trial Grouting using Grouting Intensity Number (GIN) and Conventional Method at Tarbela 4th Foundation Tarbela Dam

Muhammad Imran Shahzad
University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan
Associated Consulting Engineers (ACE) Pvt. Ltd., Lahore, Pakistan
imranshahzadgeo@gmail.com

Noor Zada Afridi
University of Peshawar, Peshawar, Pakistan
ACE Pvt. Ltd., Lahore, Pakistan
noorgeologist@gmail.com

Tufail Ahmad Jadoon
University of Peshawar, Peshawar, Pakistan
ACE Pvt. Ltd., Lahore, Pakistan
tufail_geologist@yahoo.com

Sohaib Ahmad*
University of Peshawar, Peshawar, Pakistan
Power China, Pakistan
sohaib.geologist@gmail.com

Jawad Khan
Bahria University, Islamabad, Pakistan
ACE Pvt. Ltd., Lahore, Pakistan
jawadkhangeologist@gmail.com

Abstract

Grouting is essential to enhance the integrity and ensure stability of the foundation rock by filling of all the discontinuities with the cementitious material. Trial grouting work is carried out to specify all relevant parameters required for grouting operation and finalize the most appropriate method. During trial grouting work both methods were adequately exercised and focused to thoroughly undertake the operations appropriately. To evaluate the effective grouting method between conventional and GIN grouting methods in term of time taking, grout take volume and cost effectiveness, two panels are set for drilling and grouting in the foundation area of Unit 17 Powerhouse. Trial grouting work analysis showed that both methods are effective for foundation treatment. However, the application of GIN grouting method reveals that it is more effective in the perspective of foundation treatment, economical and time-saving, which are of due concerns for project management and early completion of mega projects.

Keywords: Grouting; GIN; Conventional; grout takes volume; parameters; Drilling; Foundation

1. Introduction

The term grouting is utilized in the field of foundation engineering for the process of injection of setting fluid through pressure into cracks, voids, fissures and cavities during the construction of tunnels, shafts and dams in order to reduce the permeability and increase the mechanical stability of soil or rock [1,2,3]. In the early days, the conventional grouting method was mostly commonly used, in which pressure could be decreased by increasing thickness of grout mix in addition to unstable grout mix [4, 5]. The new concepts in the grouting methods were introduced by Lombardi and Deere [4]as Grouting Intensity Number (GIN) grouting method by the combination of the grouting pressure and the injected grout volume (P·V). This method involves grout mix which is stable and pressure is progressively decreased with constant cohesion. This research is conducted in the foundation area of Unit-17 during construction of Tarbela 4th hydropower project in order to conclude that which grouting method is more effective and economical for this project.

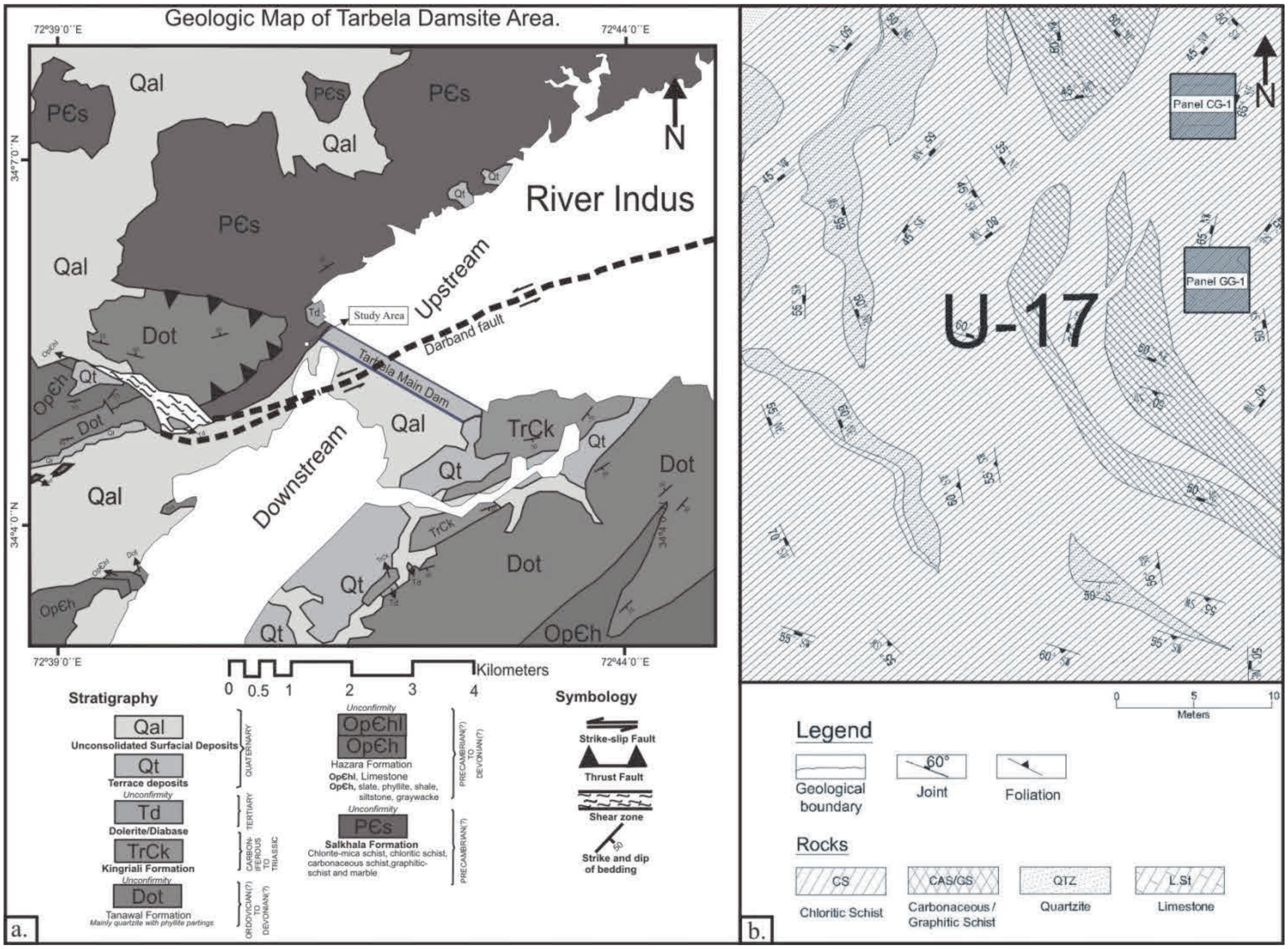

Fig. 1. (a) Geological map of Tarbela dam site and the study area (after Calkin et al., 1975). (b) The local geology of units 17 foundation and square boxes shows layout of two trial grouting panels (C-G-1 & G-G-1).

Before commencing the actual grouting, work field trial exercise was conducted to evaluate different parameters and choose better method between conventional grouting and GIN. It is prudent to identify and carry out two trials Panel of CG-1 and GG-1 within the foundation of unit-17 which consisted of homogenous rock unit i.e. chloritic schist (Fig. 1). Trial design pattern consisted of a hole drilled at each corner of the equilateral rectangle. An inspection hole within the centre of each panel also drilled and grouted. All the boreholes are vertical. The spacing between each hole is 4 meters. The drilling was done through pneumatic drilling rig. Grout holes drilled, washed and Lugeon test carried out for the determination of permeability before grouting. All the holes in CG-1 and GG-1 panel grouted through conventional grouting and GIN methods respectively. In order to analyze the effectiveness of the two-grouting panel area, the inspection holes of each panel is conducted to measure the groutability.

2. Geological Setting

Geologically, the Tarbela and the surrounding areas are laying in the northeastern part of Peshawar basin. The country rock comprises meta-sedimentary sequence with different units of schist's of Salkhala formation [6]. The Pre-Cambrian Salkhala formation spread all over the project area and mainly consists of graphitic schist, carbonaceous schist, chloritic schist, marble, limestone and gypsum with the intrusion of dolerite dyke of Tarbela Alkaline Complex [7]. Tectonically, Tarbela dam is bounded by seismically active regional faults along with local Darband fault that passes through the Main Embankment of dam which has impact on the study area by developing complex geological structure as a consequence of intense faulting, shearing and folding (Fig1), [8]. A number of discontinuities have been identified (during geological mapping) which facilitates water ingress and can be the cause of foundation subsidence. Filling in the discontinuities and improving the integrity of foundation rocks with impact on preferential reduction in water ingress various sorts of foundation treatments are done (1, 9]. Pressure grouting with the cementitious material is an ultimate approach for foundation treatment to form a monolithic unit beneath a structure [2]. Grouting is done to consolidate the bed rock and improve the mechanical characteristics of the near surface rocks [1].

3. Trial Grouting

3. 1. The Borehole's Plan and Drilling Operation

For trial grouting two panels of 4m*4m equilateral rectangle shape area is prepared and four vertical boreholes of each panel at angular points having dia. 76mm drilled through non-coring pneumatic drilling rig into the bed rock up to design depth of 12.0 m (fig. 2). Inspection holes are drilled in the center of each panel to check the groutability work of the foundation.
The three stages are shown in the following fig. 3. Boreholes drilled up to 12.0m and grouting carried out with ascending order. The top stage is 2m and the other two stages are 5m long. Hydraulic pneumatic packer of diameter 56 and 72mm are used in grouting operation. Pressure and flow rate monitored as per set parameters and recorded in real time during trial grouting operation.

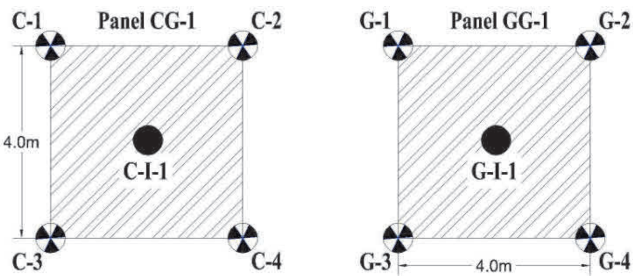

Fig. 2. Two Grouting Panels, C-G-1 and G-G-1 having primary holes and centered inspection hole in each four.

Fig. 3. Plan of borehole to be drilled and grouted in three stages in ascending order.

3.2. Water pressure test

Water pressure tests (Lugeon test) are helpful to judge the hydraulic conductivity/ permeability of the rock mass before the execution of the grouting works.
In the study area, lugeon tests have been carried out at 0–2.0, 2.0–7.0 and 7–12.0 m depth. Results from the water pressure test (WPT) summarize in fig. 4.

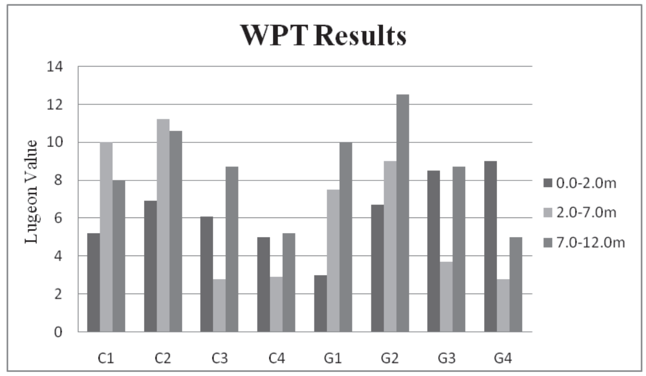

Fig. 4. A graph showing the water pressure test results in eight primary holes in two grouting panels, CG-1 and GG-1.

3.3. Conventional Grouting Method

The conventional grouting method is most commonly used in many ground engineering projects. In conventional grouting method water-cement ratio is changed from thin to thick to meet the needs of small cracks initially & large and open cracks respectively. The current criterion is achieved by decreasing the water cement ratio from 2:1 to 0.5:1 in the trial. The grouting pressure for each section is determined on the basis of Thumb rule i.e., 22.63 kilo Pascal/meter (kPa/m) and the condition of the rock. The inspection borehole (C-1-1) drilled in order to check the effectiveness of the grouting method.
The stopping criteria for grouting operation as:
When grouting pressure reached up to the design value, and injection rate is not more than 1 decimetre^3/minute (dm^3/min) holding on for 5minutes, upon achieving this criterion grouting operation is stopped.

3.4. GIN method

The GIN represents a set of limitation on volume, pressure and the product of both to avoid the opening up of fractures due to an addition of extra energy into the discontinuities (Lombardi, 1993). The GIN parameter values are being designed based on the mathematically, experimental or observation and consideration [5]. In the GIN method, the single water cement ratio and stable slurry are used. In the trial grouting stable grout mix (bleeding <3%, Marsh flow 29-35 seconds) having 0.70:1 Water: Cement ratio with 3.0% of bentonite, 1.5% of Sikament® NN and 1.5% of Intraplast®-Z by the weight of cement is used. The proposed GIN value comprising 50 Mega Pascal*decimetre^3/metre (MPa*dm^3/m), with maximum allowable pressure (P_{max}) 500 kilopascal (kPa) and volume (V_{max}) 500dm^3/m (Fig 5). The whole grouting operation (groutability vs. time, flow vs. time) monitored through real-time by PC in order to avoid bursting pressure and lose of extra energy and volume [10,11,12, 13). In order to check the efficiency and quantity of grouting, the inspection borehole (G-I-1) is drilled in the centre of GG-1 Panel.

The stopping criteria for GIN are as following limitations are achieved
1. When the grouting path hit the selected GIN hyperbolic curve or

2. When the grouting path hit the maximum pressure (P_{max}) limiting curve or
3. The injected volume per metre reached maximum volume (V_{max}) limiting curve.

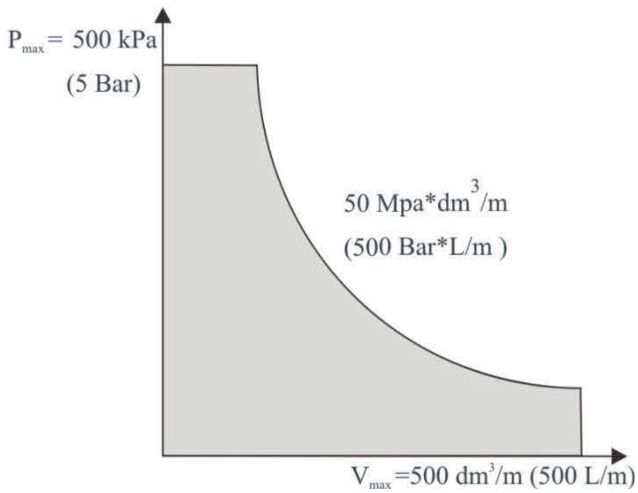

Fig.5. GIN parameters adopted for G-G-1 trial grouting panel in the unit 17 foundation.

3.5. Results of Trial Grouting

The total grout slurry injections in the conventional grouting method are 1953.7 dm^3in which 1396.0kg is cement. The average grout injection of boreholes remained is 40.7dm^3/m (29.0kg/m). While total grout slurry injection of GIN remained 530.25 dm^3 which contains 495.3kg with 11 dm^3/m average grout injection (10.3 kg/m is cement). The average grout injection in both inspection holes C-I-1 and G-I-1 is 2.03dm^3/m (0.86kg/m) and 2.6 dm^3/m (1.1kg/m) respectively (Table 1; Fig. 6). The grout injection quantity per square metre in the CC-1 is 122.10 dm^3/m^2 (87.25 kg/m^2) which is more than CG-1 having 33.14 dm^3/m^2 (30.9kg/m^2).

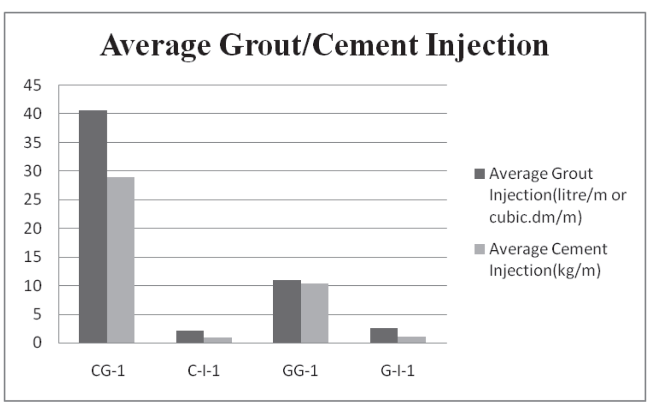

Fig. 6. Comparison of average grout volume injection in C-G-1 and C-1-1 through conventional method with G-G-1 and G-1-1 through GIN method respectively.

Comparing both grouting methods with respect to primary holes, in the conventional grouting method, the grout injection volume is 3.6 times and time is taken for the grout injection is 1.5 times more than the GIN method (Fig. 7). The results of Inspection holes of GIN and conventional grouting panel show that both methods are effective and can fulfill the need of foundation treatment.

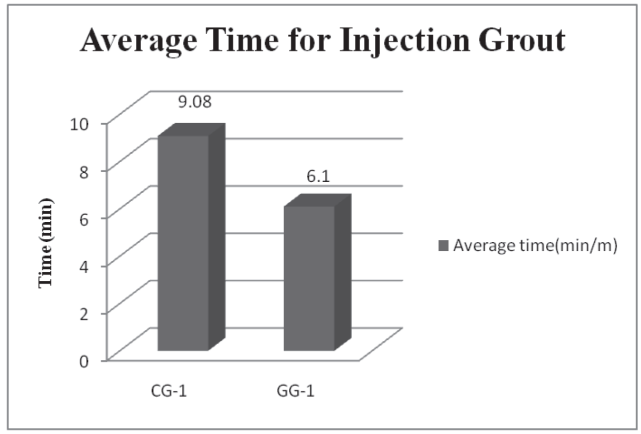

Fig. 7. A graph shows the comparison of average time taken to inject the grout in the primary holes of CG-1 panel through conventional method with GG-1 panel through GIN method.

4. Discussion and Conclusion

The grouting assignment is considered as rather difficult since all the fractures within the subsurface may not take grout properly and completely due to subsurface unforeseen geological condition, therefore an accurate and precise method is required to be chosen for design and execution of grouting work. Two trial grouting methods applied in the foundation of Unit 17 Powerhouse with emphasis on computation of consumption unit cements and recording of elapse time of each process in real time (Fig. 1). Compared with injected slurry; in conventional grouting method, different types of volumetric composition (with cohesion increases) of water cement ratio (2:1, 1:1 and up to 0.5:1) of grout mix is used while in the GIN method slurry is single, dense and stable water cement ratio (0.7:1) is consumed. Dense and stable grout mix has strong cohesive forces deem necessary for the penetration into the fractures and joint of the rock mass. Single water cement ratio in the GIN method being uniform and does not necessitate to change in the ratio/mix design as the time-consuming process that usually take place in the conventional grouting process when takes exceed beyond certain limits. The real-time graph path determines the subsurface condition and grout take volume based on the set parameters. Refusal criteria for the GIN remain fixed, set in accordance with limiting curves (P_{max}, V_{max} and GIN Value). Conversely, refusal of conventional method is based on grout absorption rate when becomes less than a design value and continue to grout for 10-20 minutes. Regarding injection quantity in the both methods shown in comparative analysis in fig. 6, it is obvious that unit consumption of cement slurry in the GIN is less than conventional as it can lead some quantity to loss in the operation.
Based on the above observations the critical disadvantages of conventional grouting are complex grouting process and operation which come up with slurry segregation, excessive grout lose, causes of frequent incident and damages in terms of hydro-fracturing and hydrojacking to the foundation and high project cost based on grout take volume. Consequently, it is preferred to adopt the GIN method as it is more efficient, quantity control, time-saving and reduce the cost of the project and enhanced the productivity along with ensuring the quality of grouting work.

Acknowledgment

The authors acknowledge WAPDA for the permission to publish this paper, as well as Tarbela 4th Consultant Joint Venture (T4CJV) and Power China involved in the testing program for the Tarbela 4th Extension Hydropower Project.

References

[1] K. D.Weaver and D. A. Bruce, “Dam foundation grouting, revised and expanded edition,” *American Society of Civil Engineers*, ASCE Press, New York, pp. 504, 2007.
[2] G. Lombardi, “Grouting of rock masses,” *Proceedings of the ASCE Specialty Conference in Grouting in Geotechnical Engineering*, New Orleans, LA.2003.
[3] A. C. Houlsby, “Construction and design of cement grouting: a guide to grouting in rock foundations, *Wiley Series of Practical Construction Guides*. 1990.
[4] G. Lombardi and D. Deere “Grouting design and control using the GIN principle, *“Water Power & Dam Construction*.1993, pp. *15-22*.
[5] G. Lombardi, “Selecting the grouting intensity,” *Hydropower and Dams*, Issue 4, pp. 62-66. 1996.
[6] J. A. Calkins, T. W. Offield, S. K. N. Abdullah and S. T. Ali, “Geology of southern Himalaya in Hazara, Pakistan, and adjacent areas,” *United States Geological Survey Professional Pape*r,716-C, C1, 1975.
[7] S. Rahim. “Stratigraphy and structural set up of Swabi and adjoining areas, N.W.F.P., Pakistan” M.Phil Dissertation. National Center Excellence in Geology, University of Peshawar, 1992.
[8] K. R. Pogue, P. B. Sak and W. U. Khattak, A geologic reconnaissance of the Indus Syntaxis, northern Pakistan, in *D. A.* Spencer, *, J. P. Burg, , and C. Spencer-Cervato,, eds., 10th Himalayan-Karakorum-Tibet Workshop* - Abstract Volume: Mitteilungen aus dem Geologischen Institut der Eidgenossischen Technischen Hochschule under Universitat Zurich, Neue Folge., no. 298, pp. 114-115, 1995.
[9] D. A. Bruce and T. L. Dreese, “Specifications for Rock Mass Grouting,” *Association of State Dam Safety Official Conference*. Seattle, WA. September 19-23, 2010, pp.*12*.
[10] S. Kobayashi, H. Stille, G. Gustafson, and B. Stille,“Real time grouting method, Development and application using Äspö HRL data,”SKB R-08-133, Svensk Kärnbränslehantering AB, October, 2008.
[11] G. Gustafson and H. Stille,“Stop criteria for cement grouting,” *Felsbau*, no. 23,vol. 3, pp. 62-68, 2005.
[12] A. C.Houlsby, “Interpretation of Dialation as a Kinematic constraint, proceedings of the Workshop on modern approaches to plasticity,” *Horton Greece*, 12-16, ISBN 0-444-89970-7, pp 19-38, 1992.
[13] F. G. Bell, “Methods of treatment of unstable ground,” *Butterworth Heinemann,* London, 1992.