The GROUT LINE

Grout Line

Paolo Gazzarrini

Overture

It's time to celebrate the second anniversary of The Grout Line and what better occasion to celebrate with an international guest? For this issue we have an interesting article, as a comment, from Dr. Giovanni Lombardi from Switzerland.

I don't think Dr. Lombardi needs any introduction in the geotechnical and grouting industry being the "inventor", along with Dr. Don Deer, of the well known "GIN method" for grouting in rock. For those of you who don't know him, Dr. Lombardi is the founder of Lombardi SA Engineering Limited, based in Minusio, Switzerland, an international consulting firm working in underground, hydraulic and civil works. *(info@lombardi.ch).*

One of the first publications related to the "GIN method", for grouting in rock, was published in 1993. Since then the method has been the object of several hard critics and much controversy but, for the moment, no one has been able to propose a different and more interesting alternative. This issue will present the answer from Dr. Lombardi to another criticism to his GIN method.

Everything started in October 2006 when at the 58th Canadian Geotechnical Conference, held in Vancouver, a paper was presented by Dr. Dawn Shuttle (Associate Professor at the University of British Columbia), Vafa Rombough and Grant Bonin (both with Golder Associates) with the title "Penetrability Control of Gin Mixes During Fractured Rock Grouting".

I sent this paper to Dr. Lombardi considering I was very interested in having his opinion and having myself used the GIN method on several jobs with wonderful results.

I didn't expect an official answer form Dr. Lombardi, but he found the time to prepare the answer published below, and with his permission for the publication, you will find below his comments to the CGS paper. I believe it is perfect for stimulating some discussions.

Unfortunately due to space restraints, we were unable to publish also the original paper of the CGS. For those of you who don't have the paper, you can find it in the Grout Line web page at *www.groutline.com* under "Other Articles".

Closure

I am sure I will receive some additional comments by the authors of the CGS paper, but it will be interesting, to receive also your opinions or some case histories on grouting in rock.

Send your grouting papers, articles or comments to:
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Ciao!

GIN Again Misunderstood

Giovanni Lombardi

Introduction

In a recent paper by Vafa Rombough, Grant Bonin and Dawn Shuttle /1/ some comments about the GIN Grouting Method were presented.

Based on theoretical considerations as well as on tests on various grout mixes some incorrect conclusions about said method were drawn. They are due mainly to misunderstandings as well as to a lack of information.

Also, some well-known facts are presented as new findings.

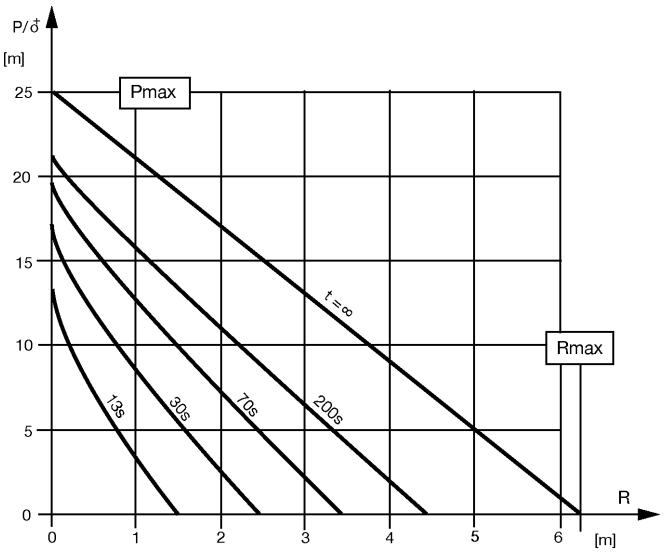

Figure 1. Pressure distribution along the joint at different time intervals during a grouting process using a given pump.

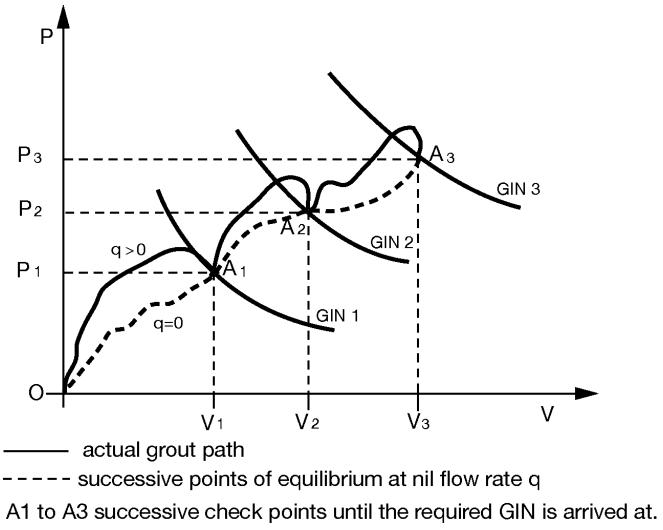

Figure 2. Actual grouting path and Grouting Intensity (GIN).

Mathematical Model

To analyse the flow in a theoretically flat open joint the so-called Chhabra Richardson (1999) formula is used. In doing so it was however overlooked that this formula, among others, was developed by the writer already in 1985, that is 14 year earlier, in the paper "The Role of Cohesion in Cement Grouting of Rock" /2/ although using somewhat different symbols.

By the way in that paper, the plane joint was considered to be grouted radially in all directions out from a borehole. This assumption appears to be a bit more realistic than to grout a strip of constant width (w) as done in the paper mentioned hereabove/1/.

Grouting Process

First of all it was overlooked that the "Intensity number" (GIN) refers to the final status of the process, so it corresponds to the target (penetration distance) and applies thus to a flow rate nil; it does not refer to the actual grouting path.

Indeed, the reach is function only of the cohesion of the mix, while the time required by the grouting process depends mainly on the viscosity of the same, as well as of the grouting path.

Thus the statement by the authors "The GIN method … assumes a Bingham material" is correct, but the comment "... (it) makes only reference to the yield stress c' to compute the penetration distance" is out of place, because this is not an assumption, but a fact. Indeed it is overlooked that, as said in paper /2/, "The duration of the process is determined by the viscosity of the grout mix and the pump characteristics. Theoretically the duration of grouting can be infinite but the injected volume is always finite as long as a cohesive grout is used."

The grouting process of a plane joint of constant thickness is represented by Figure 1, which reproduces Figure 11 of said 1985 ICOLD Congress paper /2/.

To avoid to have to grout for a infinite long time in order to reach the theoretically required penetration distance, which corresponds to a given GIN number, it is usual to overpass somewhat (let say by 10%) for a short time interval said intensity and than to return to it checking that the flow rate is actually nil. This fact was explained at various opportunities so in the papers /4/ and /5/ as well as in the final discussion in New Orleans /3/.

It is shown again by **Figure 2** taken from these papers.

The main remark to the paper by Vafa Rambough and co-authors is therefore that the target was confused with the way to reach it.

Very amazing is indeed the fact that the authors of paper /1/ did overlook that the penetration distance considered by the GIN method can be directly derived from their formulae in a very simple way[1].

This shows that the reach of the grouting process (possibly at an infinite time) depends only on the cohesion not on the viscosity. This is in fact not a "GIN idealisation", which would imply

[1] At the end of the grouting process - indeed after an infinite time in their case -the flow rate q will be nil. Consequently according formula [6] $\alpha = -3$, thus following [7] $\theta = \cos^{-1}(1) = 0$, further with [5] $\phi = 2 \cdot \cos(1/3\,\pi) = 1$, then according [4] $\frac{dP}{dx} = \frac{2c}{b}$ thus $\frac{dP}{dx} = \frac{p}{x}$ (linear pressure distribution, see Fig. 1), and finally in accordance with GIN: $L = x = \frac{P \cdot b}{2 \cdot c}$

a "theoretical limitation of the GIN method". It is simply a fact following the assumptions made.

The way to overcome the infinite duration of the process and to shorten the actual grouting time was already explained. It consists simply in stopping grouting shortly before reaching a slightly overestimated GIN-Value.

The Model and the Reality

The simple model of a single plane joint of constant thickness perpendicular to the borehole used in [2], as well as in [1], represents in fact just a first quite schematic approximation of the reality. Indeed the joint will be only occasionally of constant opening but will present, as a rule, a variable thickness and also possibly a number of contact points, which have to be circumvented by the grout; therefore the average volume to be filled by the grout may be higher than the one which would correspond to be "hydraulic opening" of the joint and the actual way of the grout will be greater than the radius. These facts do imply the use of corrective factors. Additionally, the joints are generally not perpendicular to the borehole nor perfectly plane. This fact needs be taken into account in estimating e.g. the thickness of the grout curtain or the distance between the boreholes to be selected.

Obviously, the frequency of the joints needs also be considered.

Finally, it must be recalled that, as a rule, not a single joint's system, but a complex intersection of a number of them with different characteristics and of erratic discontinuities has to be grouted. Not to forget also, that the actual opening of the joint is not fix and given beforehand but may be somewhat influenced by the grouting process itself. Following, said simple model cannot claim to be able by itself allowing to compute the GIN value to be used in an actual grouting process, but is intended to define the main principle, that is the actual "dimension" of the problem and to confirm the theoretical validity of the GIN-concept. The real value of the GIN to be used must thus be defined by grouting tests on the site and by a correct interpretation of the actual results of the process.

By the way, it is a pity to ascertain how many useless water pressure tests and how few useful grouting tests are generally carried out worldwide. Indeed, the "groutability" of a given rock mass by a given mix has little to do with the socalled "permeability" measured by any water pressure test. It depends mainly on the cement grain size.

The Merits of GIN

In fact the main merit of the GIN-concept is to have shown that the reach, or the practical penetration distance, at the end of the process, that is at a nil flow rate, depends only on the cohesion of the mix, not on its viscosity. This last property influences the time required completing the process. To shorten the grouting duration, higher pressures can and should be used for a while during the same.

Indeed, the GIN method makes also the final grouting result practically independent of the actual viscosity of the mix.

Even more, it makes it largely independent of the actual "pressure-take" path and needs to consider only the final values of these variables.

Exactly this aspect of the question was misunderstood by Vafa Rombough and co-authors; so some of their conclusions are not acceptable in spite of a number of interesting theoretical and experimental results presented by them in their paper.

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