

## Grout Line

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### Overture

Here we are at the 25th issue of the Grout Line and, as promised, Dr.

Lombardi's answer to Dr. Bruce's article, published in the June 2011 issue, has arrived quickly.

Following are the comments of Dr. Lombardi (Studio Lombardi- Minusio-Switzerland-info@lombardi.ch)

### Introduction

In the recent paper titled "Rock grouting for dams and the need to fight regressive thinking" [1] Dr. Eng. Donald A. Bruce presented some general comments on the grouting methods in use, subdividing them into classes of "old", "new" and "regressive" methods or concepts.

Many observations that he made are quite interesting and can be entirely shared. Others are difficult, if not impossible, to understand and seem to be based on a lack of information or on some misunderstanding. It is my feeling that a few comments on these points are due and could be of some interest. The comments will be restricted to the pure grouting activity, leaving aside the problems related to the drilling methods.

### On "Old" Methods

It can be entirely agreed that the methods used in the USA from 1920 to 1980 - and in some cases also to the present time - that is, since about the time of the grouting of the Hoover dam to today - should be finally changed.

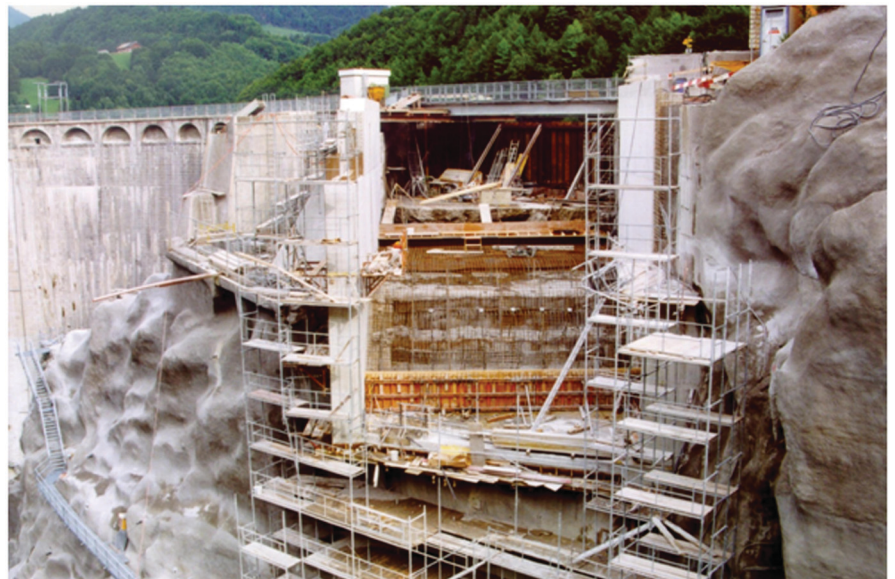
The main points of these old methods are:

- the drilling of vertical holes to a target depth;
- the "one row" curtain;
- the relatively low grouting pressure;
- the use of "thin" mixes;
- the "thin to thick" mix grouting method;
- the use of drillings of higher order holes to sometimes "ridiculously close centers"
- the use of thin mixes injected in karstic cavities.

It is completely agreed that these "old ways" contain major flaws and have to be changed!

### The "New" Method

The "new method used in the USA" is claimed to have improved the grouting procedure in a number of important points. Mainly:



Montsalvens Dam (Canton Fribourg, Switzerland), built in 1920. One of the first arch dams in Europe.

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- consideration of the importance of the “pressure filtration coefficient”. This coefficient corresponds essentially to the old French “presso-filtration”;
- use of various chemical admixtures and not of water to the grout to reduce the cohesion (and the viscosity) of the mix, ensuring an enhanced penetrability;
- introduction of computer-based systems of monitoring the grouting;
- use of new methods of scrutinizing the wall of the drill hole;
- “curtains must have at minimum 2 rows of holes”;
- use of inclined holes to upstream;
- declaring and measuring of the residual permeability;
- definition of a “stage refusal”.

In general one can share the principles mentioned under this title, with, however, a few comments which will be presented later on.

### The “Retrogressive Principles”

For sure, there are still existing cases where old methods are used again, in spite of the problems and flaws they present. So e.g. the use of different mixes from thin to thick.

On the contrary it is quite difficult, or even impossible, to understand why the GIN method is declared as “retrogressive”. The following considerations need to be made:

- The commentary that the GIN method was developed to “assure for the client a certain standard of care and quality ... on projects ... in remote areas ... or by contractors with limited experience and expertise” is difficult to understand, unless one considers, for example, Austria and Switzerland as remote areas and their contractors as having a limited experience and expertise!
- Since the GIN method theory was first elaborated, it has been declared that a grouting work should be “designed” (engineered) not “specified”. This appears now and finally to be quite a “new” concept.
- From the beginning the GIN method has been based on the use of a unique grout mix, the “best one”, - obviously among the ones that are

available in practical terms - (cost, availability of certain material and so on). This is now claimed to be a “new” concept.

- The definition of the best mix must be based on two aspects: the “best for grouting” and the “best for the final result to be achieved”. Therefore some compromises may be required in special cases. Obviously throughout the decades the “best mix” changes due to technological progress (e.g. due to available chemical admixtures), but this does not change the principle of the GIN method.
- The continuous monitoring and representation of the data from the grouting of any stage such as pressure, flow rate, volume and penetrability of the grout was always one of the principles of the GIN-method. Obviously, the way to do it did follow the continuous progresses of the electronic equipment available. In some of the new ones the GIN value itself is directly shown on the screen and all the required graphs automatically produced. Now this should also be considered a “new” concept.
- Generally speaking, it is also clear that some improvements were implemented from time to time in the GIN method, in order to keep it continuously “new”.
- It is also felt that the definition of a maximum pressure is unavoidable at least to define the pumping equipment to be used. This is not a “new” nor an “old” concept.
- The definition of a maximum take is also to be considered necessary to avoid excessive losses.
- In any case the three limits (maximum pressure, intensity and volume “limit”) must be the result of previous grouting tests not values arbitrarily “specified” a priori. They should be changed if the rock conditions are locally different from the general assumptions made.
- It was shown, by theoretical considerations as well as by events during grouting, that in given conditions the hydro jacking is a function of

the “grouting intensity”, that is of the energy pumped in at any stage. The definition of a number GIN is the logical consequence of this fact.

- By the way, it was always clearly stated that the numerical values indicated in the papers on GIN are not “recommendations” but are just “naming” for typical cases which represent the average of a number in particularly successful grouting works. These statistics allow us to recognize the type of grouting carried out (low, medium, high, etc.). In fact, it would be quite difficult to recommend, at the same time, an extremely low as well as an extremely high grouting intensity.
- It is well known that Prof. Ewert doesn’t like the GIN method. Indeed, when in certain cases the grouting causes too many occurrences of hydro-fracturing, this means simply that wrong values were chosen by the user, often because the required preliminary tests were not carried out.
- If he found that in certain cases the volume limit is too low to fill the voids of certain rocks, this means again that the limit selected was too low, maybe for the same or any other reason. In any case, the GIN method is not intended to fill karstic cavities!
- Indeed, these and other misunderstandings of the GIN method are due to the fact that many people are mostly looking for fixed norms and specifications and are not very interested in understanding ideas and concepts.
- Furthermore, the basic idea of the GIN, in limiting the intensity ( $p \cdot V$ ), is to allow high pressure in order to increase the reach of the grout where the penetrability and thus the take are low and, at the same time, to eliminate - or at least reduce - the cases of hydro-jacking when the take at low pressure is too high. It must be repeated that the risk of hydro-jacking is the highest by the combination of high pressure with high take. Should the hydro-fracturing (indeed hydro-jacking) still be too frequent, then the GIN value

should be reduced and adapted to the actual conditions of the rock mass.

- By the way, it is strange to have to take notice that the GIN is criticized by Dr. D. Bruce because of volume limits considered to be too low and at same time because the method allows one to overpass the same limits due to the fact that they are considered to be a point of decision not an absolute limit. The GIN method has also been blamed for having adapted, at some date, the interpretation of the limit for the maximum take. Maybe, this was just an improvement of the method in order to remain “new”! In any case only the “last version” of the method needs to be discussed.
- All this is independent of the fact that the three limits are to be defined by the designer on the basis of preliminary grouting tests and not “specified” a priori.
- It has to be noted that in many cases a wrong use of the method was carried out, leading to poor results. This fact apparently authorized a number of authors to accuse the GIN method of not working properly and obviously at same time to excuse the engineer who did not understand it. A typical, many times repeated case, is the one of karstic rock. It should be finally clear to everyone that the method is designed to be used in “solid, fissured rock masses”, not in karstic nor in too weak rock or loose ground.

### Old Concepts Still in Use in the “New” Methods

A number of very old concepts are still in use in the so-called “new” methods and, in the opinion of the writer, should finally be changed:

- The first concept is the expression “refusal”. In the way it is generally used, it suggests that the rock mass would “refuse” any additional grouting. Indeed it is the designer who refuses to use higher pressures, or possibly the pump that does so! Never the fissured rock. Therefore, a different word should be used to describe the fact that

the specified, designed, or arbitrarily selected pressure value was reached while the flow rate is nil.

- A second old habit should also be updated. To stop the grouting procedure it is usual to maintain the prescribed pressure for a certain duration until the flow rate falls below an “arbitrarily” defined value. By experience it is much more efficient to overpass slightly the given pressure by - let’s say, 5% or 10% - to stop the pump and to observe the falling of the pressure at flow rate nil. According to the pressure arrived at after a short duration, the operation can be stopped or continued. Obviously, a certain tolerance of a few percentage points on the final pressure should be allowed. In many cases the procedure appears to be quite simple and effectively time saving. At least the two ways of defining the ending of the grouting should be accepted.
- It is felt also that in a number of cases some attention should be paid to the grain size of the cement.

Also the concept, about one century old, of having to limit the grouting pressure to the weight of the overburden should finally be abandoned because, while a limited heave can generally not be avoided, depending on the conditions, pressures many times higher (up to 3 times) can be used at no risk of substantially heaving the ground.

All of this is just to recall that the newly used concepts are not always as “new” as claimed or as they should be.

### General Comments on Grout Curtains

It has to be taken into account that with the depth below the ground the conditions are changing due to the increased stresses in the rock mass; so the permeability generally decreases. Also due to hydraulic considerations, the requirements to the grout curtain are decreasing with the depth because of the longer paths for the water to flow from upstream to downstream. Therefore one should not prescribe as a general rule a number of rows, but instead, adapt its number to the depth.

Additionally, the constant length of the grouting stages generally chosen for all boreholes of the curtain (e.g. 5 m), is the result of an “old concept” which can be improved by increasing the length of the stages with the depth. (No indication or examples are given here in this respect in order to avoid that they would be understood as firm numerical “recommendation”!)

This is a “new” concept not yet considered in the “new” methods, except in the GIN one.

The opinion that the depth of the curtain should not be fixed a priori but adapted to the geotechnical conditions is entirely shared by the writer.

The actual permeability across a grout curtain is always quite difficult to be measured and defined with precision. The relatively high pressure used by the Lugeon tests (not to be compared directly with the grouting pressures but with the reduced grout pressures at some distance from the borehole) may cause some damages to the curtain. The question thus arises whether the decreasing of the takes from borehole to borehole and to the control holes should not be used as a criteria to better define the results of the grouting curtain instead of using water pressure tests with possible damages.

Additionally, it has to be questioned whether in many cases a distinction and a difference must still be made between “consolidation” and “grout curtain grouting” or whether the definition at a unique, comprehensive treatment zone should not be preferred.

### Conclusions

From the above comments it results that a number of improvements in grouting rock masses are still possible in matters of “new concepts” not yet considered in the “new” methods.

In any case it appears quite clearly that, for the time being, the GIN method is by far not outdated and that it can in no way be presented as retrogressive. This could obviously happen in the future, should radical improvements of any kind take place in the field of grouting.

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For the time being, the GIN method can apparently claim for itself to be a “new” or even the “newest” one.

In front of these facts, it could be interesting to hear on the basis of which considerations the GIN method has been defined as “regressive” or “retrogressive”. This is independent of the fact that the method is “disturbing” a number of people and this for unknown reasons.

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..... to be continued?

With that I close this issue, hoping that you have had a nice summer and I remind you that, if you have additional comments or interesting grouting stories or case histories, you can write to me: *Paolo Gazzarrini, fax 604-913 0106 or paolo@paologaz.com, paologaz@shaw.ca or paolo@grououtline.com. Or tweet me @grououtline*

Ciao!

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