International Journal of Mine Water, Vol. 3 (2), (1984) 27-32
Printed in Granada, Spain

ESTIMATION OF GEOMETRICAL PARAMETERS AND THE QUALITY OF IMPERVEOUS GROUT DURING GROUTING OPERATIONS

O. Ju. Lushnikova

Chief Engineer

Specialized Association Spetstamponazhgeologia
7a Petrovski St., Antratsit, Voroshilovgrad Region, USSR

ABSTRACT

The paper deals with a method for estimating geometry parameters of the sealing barriers formed during grouting and quality of filling the fissures within the barrier. The method is based on carrying out special hydrodynamic investigations in aquifers and continuously monitoring the technological parameters of the grout injection.

INTRODUCTION

Until now the principal method for quality control of grouting has been the method of specific water absorbability. Depending on its value, which is differently prescribed in different countries, grouting is considered to be satisfactory or unsatisfactory. In the latter case additional holes are drilled or existing ones are redrilled, and the grout injection is repeated. Undoubtedly, this method allows only approximate evaluation of the quality of grouting operations. When employing the method, one can estimate neither the size nor the geometry of the barrier formed; neither the quality of filling the fissures and voids within the barrier nor the spatial change in permeability of the treated strata within the barrier. To guarantee the water inflow shut-off after grouting a method for estimating geometry parameters of the sealing barriers formed and the quality of filling the fissures within the barrier has been developed at the Spetstamponazhgeologia association.

The method is based on a special technique for interpretation of the data obtained during flowmetering and other hydrodynamic investigations, and on continuous monitoring of the pressure and capacity changes of the pump during grout injection.

SPECIAL FEATURES OF THE PROCESS OF SEALING BARRIER FORMATION IN STRATA OF DIVERSE FISSURING

As far as it is known, fissures and voids have various size and can differ considerably with regard to quantity for each aquifer. This fact in great extent contributes to the difference in the character of filling the fissures and voids in strata of diverse fissuring.

Let us first consider a particular case when all strata fissures are equal and uniformly distributed. Then, the hydraulic losses of the grout flow in all fissures would be equal and, therefore, the radii of the grout spread in all fissures would be equal also. In this case the shape of the barrier and extent of filling the fissures would be as it is shown in Figure 1. However, this case is very uncommon in practice.

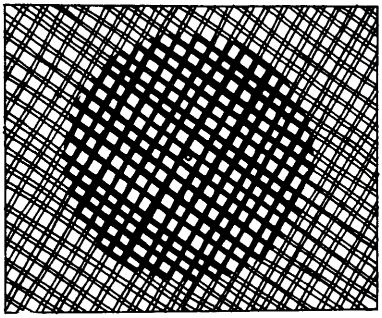

Figure 1. Grout propagation scheme in isotropic medium with identical fissure opening

More common is the case when strata fissures are not equal either in size or in quantity. In this case the character of the grout spread would be quite different (Figure 2). In the vicinity of boreholes

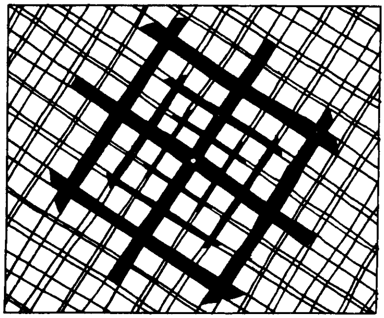

Figure 2. Grout propagation scheme in isotropic medium with diverse fissure opening

practically all fissures from small to large are grouted. Moving away from holes, the number of fissures penetrated by the grout decreases because of the pressure losses, and at the barrier boundary only the largest ones are grouted. If rocks are anisotropic, the shape of a barrier is stretched towards the main system of fissuring (Figure 3).

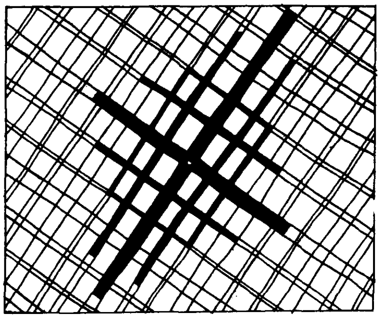

Figure 3. Grout propagation scheme in anisotropic medium with diverse fissure opening

ESTIMATING QUALITY OF FISSURE SEALING WITHIN THE BARRIERS FORMED

The quality of filling the fissures with the grout depends not only on specific features of rock fissuring but also on the grout properties and injection pressure. It is obvious that if the pressure overfall on an aquifer ΔP was constant during the total time of injection, the amount of grouted fissures within the sealing barrier contour would alter inversely proportional to the radius of grout propagation. But since ΔP is, as a rule, not constant, different zones of the sealing barrier are being formed under different values of ΔP. Thus, dependency of the size of grouted fissures from the radius of grout propagation has more complex form.

Let us consider first a particular case when ΔP is invariably growing in the course of injection. Divide the total process of grouting into such time intervals during which the given parameter can be assumed as constant. Let the pressure overfall at the first instant of grout injection be ΔP_1 and the radius of grout propagation be R_1. Since at the second time interval the pressure overall has increased, some of the fissures into which the grout did not penetrate under ΔP_1, would be grouted under ΔP_2. Thus, a certain volume of the grout injected during the second time interval would be used for filling some of the fissures within the barrier of the radius R_1, and the remaining grout would be spent for filling the fissures within the radius R_2. Thus, despite that at the first instant the grout was injected under ΔP_1, by the end of the second time interval the barrier would be formed under the pressure overfall ΔP_2. Similarly in the posterior periods of injection with the grout propagation radius increase filling of ungrouted fissures will occur within the barrier's contour. As a result, the barrier will be formed at the pressure overfall that was at the end of injection.

If ΔP was both growing and falling during grouting but still its maximum value has been observed at the end of injection, then in this case the fissures within the barrier will be grouted at the maximum pressure overfall attained. Thus, the pressure overfall in an aquifer does not always correspond to the pressure overfall ΔP at which the barrier has finally been formed.

In a common case, to establish the pressure overfall value at which the grout propagation occurred at each given point of the barrier's contour, it is necessary to find the maximum value of ΔP fixed during injection. Until this particular moment the barrier has been formed at this pressure overfall for the injection period left, it is again necessary to find out the maximum value of ΔP. It will correspond to the pressure of barrier formation between the preceding and given maximum values of ΔP. This will be going until the end of injection.

In accordance with the above mentioned and using equations obtained that make it possible to determine total fissure voidage, share of fissures of different opening, radius of grout propagation, and amount of grouted fissures in regard to the injection pressure, calculation of all parameters of the sealing barrier may be accomplished.

EXAMPLE OF CALCULATION

Let us consider the results on definition of sealing barrier parameters formed in one of the aquifers during pregrouting operations at the skip shaft of the Ukraina Mine.

According to the data of flowmetering carried out at intervals prior to the grouting operations, it has been established that the water bearing zone lies at the depth of 277-334 m with a thickness of 32 m, strata pressure of 2.94 MPa, anticipated water inflow of 0.95 x 10^{-12} m^3/s, and total fissure voidage of 1.57%. Moreover, according to the technique developed at the Spetstamponazhgeologia association definitions of the spacing of fissures, direction of the main fissuring system, and also the size and share of fissures of diverse size in the total strata voidage have been developed.

To form a sealing barrier, grout with a yield value of 192 N/m^2 was employed. The volume of injected grout totalled to 469 m^3. The process of grouting was controlled by means of the SKC-2M station that was monitoring pressure, flow rate, volume and grout quality parameters. On the basis of the obtained data the actual pressure overfall has been defined, and its change during injection is plotted in Figure 4. As it may be seen, the pressure overfall fluctuates in the range of 7.9 + 10.5 MPa The maximum value has been attained after injection of 340 m^3 of grout, the minimum value - at 280 m^3.

The actual sealing barrier plan is presented in Figure 5. As it may be seen from the plan, with the total fissure voidage m = 1.57% only one third is filled at the barrier contour where m = 0.46%. The minimum amount of grouted fissure changes is especially great. In the vicinity of boreholes all fissures from maximum to 0.18 x 10^{-3} m opening are filled with the grout; and at the barrier's contour with a radius of R = 51 m - only fissures with an opening of more than 1.95 x 10^{-3} m.

Reliability of these calculations has been confirmed by the shaft sinking data. The actual residual water inflow was 0.35 x 10^{-4} m^3/s with a calculated residual water inflow value of 0.4 x 10^{-4} m^3/s. All fissures were completely grouted according to the calculations.

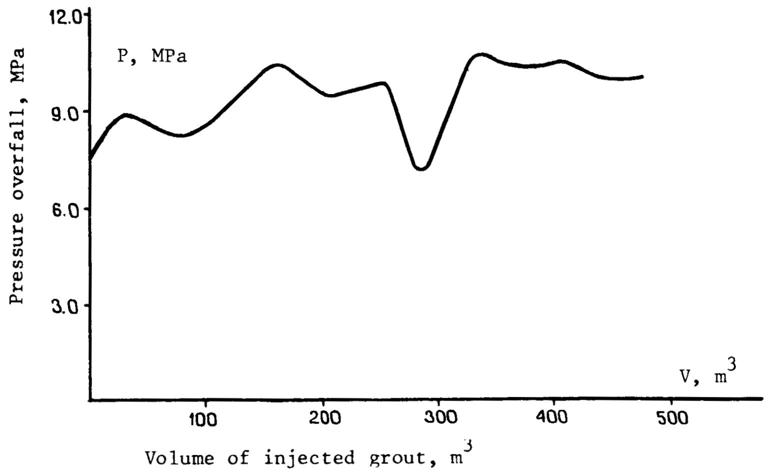

Figure 4. Pressure overfall change in the course of grouting

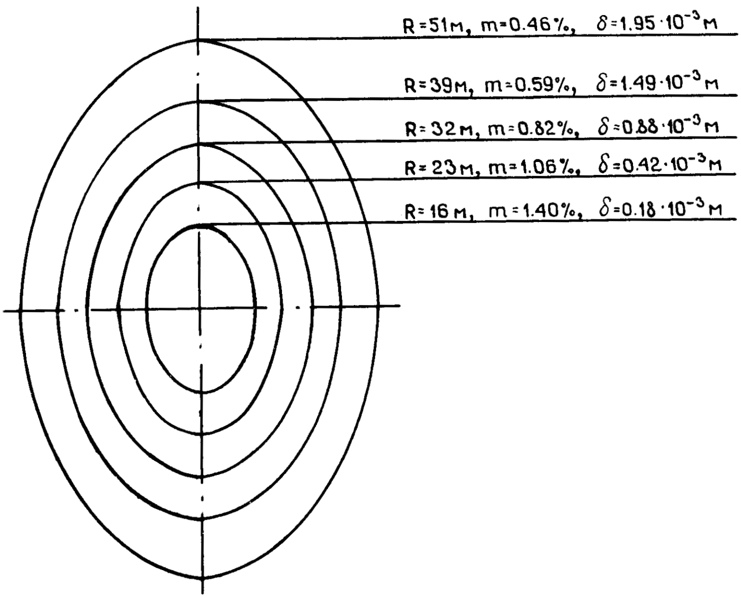

Figure 5. Sealing barrier plan

CONCLUSIONS

It has been established by the accomplished investigations that sealing barriers formed around a hole are inhomogeneous in filling quality and permeability. With the grout propagation radius increase resistance to its flow increases, reduces pressure overfall and, consequently, decreases share of grouted fissures. The developed technique makes it possible to determine geometry parameters of a sealing barrier, size of grouted fissures and share of voidage filled with the grout.

This technique has been proved experimentally and is being used during design and execution of grouting at the Spetstamponazhgeologia association.