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Chairman: Prof. Victor F.B. de Mello

I have just asked the Moderator if I could make a brief comment with respect to these problems of grouting versus drainage etc. I do understand that this item is of very great moment and it has been discussed for a long time. I would like to make these two points: it seems to me that the discussion of one versus the other is not really the point. Safety, as far as dams are concerned is, usually, connected with control of stresses within, principally, let us say, the downstream end of the dam, and therefore it is obvious that, if we are discussing safety of the dam, the drainage is the real means of controlling safety, because drainage is the direct remedy for control of stresses. At the point of a drain I can determine exactly what pressure I have. Therefore, around it, to the extent to which there is a foreseeable flownet around any point, of course, I have reasonably good control of stresses, of pressures, and therefore effective stresses which control the safety of the dam.

Now, you do not control stresses by introducing a semi-impervious pseudo-curtain - you control flows. Obviously control of flows is, to some extent, connected also with control of stresses because one is connected with the other, but it is very indirect means! It is very indirect getting a control in the downstream end of a dam by applying more or less imperviousness in the

upstream part or zone of a dam. As geologists, you know that one of the very stable structures geologically is, for instance, a rock-fill deposit that has flow going through it. This is a sort of crude example. In other words, in the case of water gushing through a rockfill, regardless of flow that you lose, usually you do not really affect the safety until you get up to very high velocities and pressures. This is a sort of an example of how it is flow that you are directly trying to control when you discuss curtain grouting.

Now one other item that I would like to emphasize is that we have to try to quantify most of these statements. Unfortunately, as we discuss them qualitatively, there is obviously a position of people trying to stay either on the black or the white side etc, and this is never the case. One of the reasons why curtain grouting has been unfortunately very badly looked at, is because it is a serious misconception, in may way of thinking (and I have pointed this out in a discussion in volume 3 of the International Soil Mechanics Conference, Montreal 1965, p. 577), to think of a grout curtain as creating an impervious barrier or discontinuity. The very name "curtain" conditions one into such a misconception, historically derived from the intuitions considered pertinent to steel sheet pile curtains in pervious soils. What a grout curtain really achieves is not to create a discontinuity in a continuous pervious medium, but to homogenize, within a zone of variable thickness, the effective perviousness of a discontinuous medium. Those who would measure the efficiency of a grout curtain by attempting to record the "significant head loss" between points a few meters apart, one immediately upstream of the dx-thick grout curtain, and the other immediately downstream of it, are labouring in the most foolish delusion that has nothing to do with the reality of the behaviour of a grouted rock. We assume, due to, let's call it a sort of a historical reason, driving steel sheet piles in alluvium, we assume that we are introducing a highly impervious and essentially infinitely impervious width of impervious material within a continuum that is pervious and that is not what the grouting curtain does. If you stop to think a little bit, some of the greatest mistakes, in my way of thinking, of the discussion between one group and another are made because of that. What you are really doing is, by series of holes and pressures, you are trying, when you put in a hole and you cross a medium that is really heterogeneous in as far as permeability is concerned, (if you allow me, I could draw on the blackboard): If I pump grouting here, obviously it goes much farther in the wider cracks than I would in the thinner cracks. Therefore, in a case in which I have a distribution curve of wider cracks at greater spacings and thinner cracks at closest spacings what I really do is I pick a mass that is heterogeneous in getting preferential flows and I do introduce a homogeneizing treatment. It is not a curtain that I am introducing here, it is a homogeneizing treatment that assumes greater width where greater widths are needed.

Therefore I am in favor of a type of treatment like that, to the extent which, where it is most needed, the slurry grout etc will find its way. It is a sort of a preview of what the water will do. If we coulf find a way of grouting by merely doing this, let us suppose, let the water pressure from the dam itself force grout in, that would be the ideal condition, there would be no holes, much cheaper therefore and we would let the water with some slurry etc fill in where it is most needed. Incidentally, that is done in blanketing. In blanketing with slurries we do that.

I would suggest that ideally that was what we would like if we could have a suspension that could be forced in here, by the very pressure of the water. Then we could have the ideal grouting situation, which is blanketing. Incidentally, a lot of blankets are placed that way, or at least they are improved that way. So, some of the discussions as to whether or not a grout curtain did introduce or was checked by differences of pressures measured by piezometers upstream and downstream is obviously wrong. You would only observe a difference if you had a homogeneous medium crossed by a discontinuity, then if you measured the pressures at one end and the pressure at the other you should obtain a great difference.

However, how many of you have been present at grouting where you will find that grouting will travel tens of meters in wider cracks whereas it will travel only a few decimeters or so in thinner cracks. Therefore, if you put a piezometer here and here you are basically putting in a piezometer within a homogeneized mass in which you can not, you should not detect differences of piezometers and pressures.

Therefore, this is another misconception, in my way of thinking.

Coming back to my first statement, all you have to do is look at the superstructure because the infrastructure has to have functionally the same things as the superstructure. Why do we put chimney drains in the superstructure?. Merely to control pressures. By doing that I have atmospheric pressure at this point, I force my flow net to come down. Whereas by merely putting more impervious material here I have no control. It is just an indirect way of trying to improve the conditions of flow here, I do got the flow somewhat. How much does a grout curtain decrease the permeability? Reduction ratios have been mentioned in many publications, usually of the order of 5 to 6. If you decrease the permeability of any zone to one fifth or one sixth of what it was, you will hardly detect much of a difference in the flow net. But if you introduce a drainage, by definition a drainage has to have at least 100 times more permeability, then you are really controlling your stresses. Therefore it seems to me that there is a little of a misnomer because of talking in terms of adjectives and I would very much plead to the interest of getting down to numbers: do we benefit or do we not benefit? Benefit in what respect? Flow? Sure. What is the value of the flow? How much do I cut down the seepage? How much is the value of that? How much is the value of the treatment as far as grouting is concerned? As far as flow is concerned, we can discuss in terms of economy. As far as safety is concerned, by probalistic reasoning or on the inverse value of a catastrophe, we can also discuss in terms of money. Thank you.

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Moreover, there is a question I should like to submit to discussion. I have a little bit of difficulty in understanding the thought that we would be applying tensions to the soil or rock mass upon reservoir filling. On the other hand, I do not quite see either that we would apply compressions; depends on where we are. Let us look at it this way: as has been proven over almost forty years ago by the principle of effective stress brilliantly enunciated and proposed by Terzaghi, the behavior of any mass of porous materials depends on effective stress. Now, effective stress is total pressure minus pore pressure. Therefore, when we apply the reservoir load many zones will be really within this submergence effect, with effective stress essentially unchanged as total and pore pressures increase simultaneously. Admittedly for another zone just above the reservoir water level the total pressure doesn't change practically (the saturation changes very, very little) the pore pressure increases because of some rise of the abutment groundwater flows into the reservoir, therefore there would be a decrease of compression. With a decrease of compression you might have a very small increase of permeability but it should be very small indeed.

I really thank Dr. Tilford for having opened this subject: yesterday, when I heard the lecture and the mention that was made of the increase of permeability, I really could not understand. I would like very much to ask Mr. Sabarly to expand that a little bit more. If we did go into a condition of stress release to the point of opening cracks, of really eliminating compressions, then we could get a discontinuity in the curve. Let us call it two straight lines, compression straight line and tension straigth line with an angle of discontinuity between them; we all know the thorough investigations by Profs. Mayer and Habib showing how much higher the permeability can be in many rocks in which these cracks, these fine fissures, can be opened. But you have to really change from a condition of positive stresses to really tensile stresses in order to get that. I would join my request to that of Prof. Tilford.