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IV-5 Prof. M. FANELLI

Ladies and gentlemen, the paper we presented to this seminar is a classical exercise on finite element analysis of an arch dam having an inspection gallery through its thickness. As such this problem does not seem to have any peculiar interest, but we presented it in order to bring to light some points and I will try now to outline the interest we think these points can reveal.

First of all I think we showed, at least by way of example, that finite elements computation can complement physical models in some cases where, by way of complicated or recessed shapes in zones subjected to triaxial stresses, the physical model could present some difficulties - and I think that this aspect of complementarity between two entirely different means could be of some help in such cases. Of course we tried to gather some information from the particular case we examined, because this case of an inspection gallery running through the thickness of an arch dam is of some interest in itself. Very often we find that along the sides of such inspection tunnels there are cracks - many times horizontal cracks - running for a considerable length and it is interesting to try to ascertain whether such cracks are due to loads or to thermal effects.

So we tried first with live loads to find the stress concentrations, if any, around such inspection tunnels and the conclusion we came to is that in the case of an arch dam the live load, namely water pressure on the upstream face, does not seem to have any particular adverse effect on stress concentration around this inspection tunnel. So that we are left with the suspicion that where we find these cracks in actual dams, they are probably due to some thermal or hygroscopic effect. This is an interesting point and of course one should be willing to go further and analyze such effects by our mathematical model - and at least in the realm of elasticity there is not any particular difficulty to doing so in principle. But there are practical difficulties. One of these is that it is very difficult to know in detail the thermal and hygrometric situation in the material surrounding such tunnels. So we are practically left with little or no information at all about the input data that we should feed into our mathematical.model.

The second factor which adversely affects our possibility to do such calculations is that, as every designer of arch dams well knows, if we try to do an analysis of thermal stresses in dam - especially in an arch dam - and we assume the same elastic modulus that we use for live loads, we will end up with very severe thermal stresses, which do not appear to have any possibility of occurring in reality. So much so that many dam regulations, and among them the old Italian regulations on dam construction, allow the designer to select a very low elasticity modulus, reduced by as much as 50%, to calculate his figures for thermal stresses. So you see that this is a very important problem because for arch dams thermal effects certainly cannot be neglected and it is very important that we should know which physical parameters to use for our mathematical model. There is a certain contradiction here. From our experience of comparing computations of displacements and observed displacements in actual dams we see that we achieve a fairly good correspondance between theory and observations and so we cannot draw any inference from this about how we should differentiate between the material properties that we should use with one kind of load and the other kind of load. I'll try to make myself clear.

Whatever value we assume for the elastic modulus for thermal effect, as long as we do not change the expansion coefficient we wind up - as you well know - al-

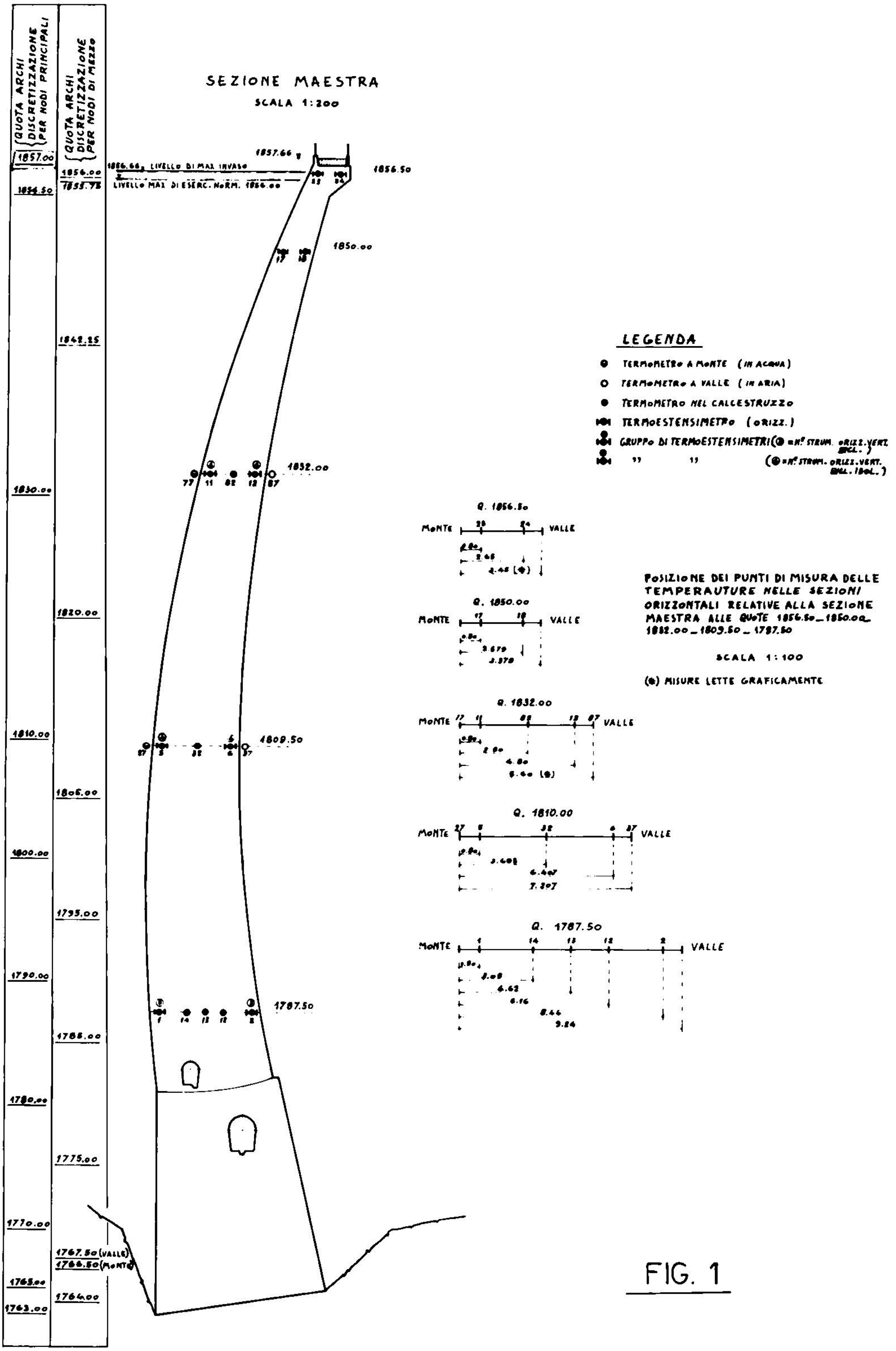
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FIG. 1

ways with the same results on displacements, but of course we wind up with different results for stresses. It is very difficult to measure stresses directly. Practically the only thing that we can measure directly with any certainty are displacements or unit deformations around some point. Thus in the interpretation it is very difficult to separate the effects of live loads and thermal loads - and I propose this subject for discussion because it seems to me, at least according to my own judgement and information, that this is very much an open point.

By way of a parenthesis I would like to show you some results of our comparisons between computed and observed displacements for arch dams. In fig. 1 you see the crown section of a thin arch dam, and on this (Neves) as on a number of other ones we tried a certain method of predicting displacement values from observed temperature in a certain number of points (from embedded thermometers) and from water level variations. The results of such computations are given in Fig. 2: the first diagram represents the water level variations, the second diagram the hydrostatic component of the displacement in a certain point, the third diagram the time dependent component which was statistically computed from a comparison between computations and observations, the fourth diagram the thermal component of elastic displacements as from the computations, the fifth diagram the comparison between computed and observed values - you see that they are very very close and sometimes you cannot distinguish between them - and the last diagram shows the difference between the two.

I point out the comparison between predicted and observed displacement which seems to me to be very good. Now for another point (Fig. 3) where the maximum absolute values of displacement were found, and you see that the comparison is uniformly good for all points and all I want to infer from this comparison is that an elastic mathematical model, at least after a certain initial time during which we observe time dependent effects (but these effects die out after a certain time) can reproduce quite faithfully the displacement behaviour of such structures. But this goes only insofar as displacements are involved. As soon as you try to analyze strains, for instance if you have some embedded extensometers in the concrete, you wind up with comparisons between computations and observations which are worse by at least on order of magnitude - and this relates in my opinion to the fact I was referring to a moment ago.

For this subject of comparison between computations and observations which can be translated into a very efficient method of continuous control of the safety of such structures, I can give some more details later on if any of the delegates would find it interesting.

Closing this parenthesis I would take advantage of this chance to point out the necessity of developing advanced rheological models for concrete, taking into account both time dependence and thermal effects. In particular it seems to me that the different advanced rheological models that we have seen for instance this morning or other advanced models that one could think of, should be reviewed in the light of a consistent thermodynamic approach to the behaviour of composite materials. In particular one should want to explain why apparently thermal effects produce so little stresses in our structures, a thing which we are unable to explain at the moment. Anyway such advanced models should retain a fundamental quality, at least for engineers: they should be simple enough to encourage engineers to apply them and to incorporate them into their mathematical tools. I think I have nothing more to say and thank you for your attention.

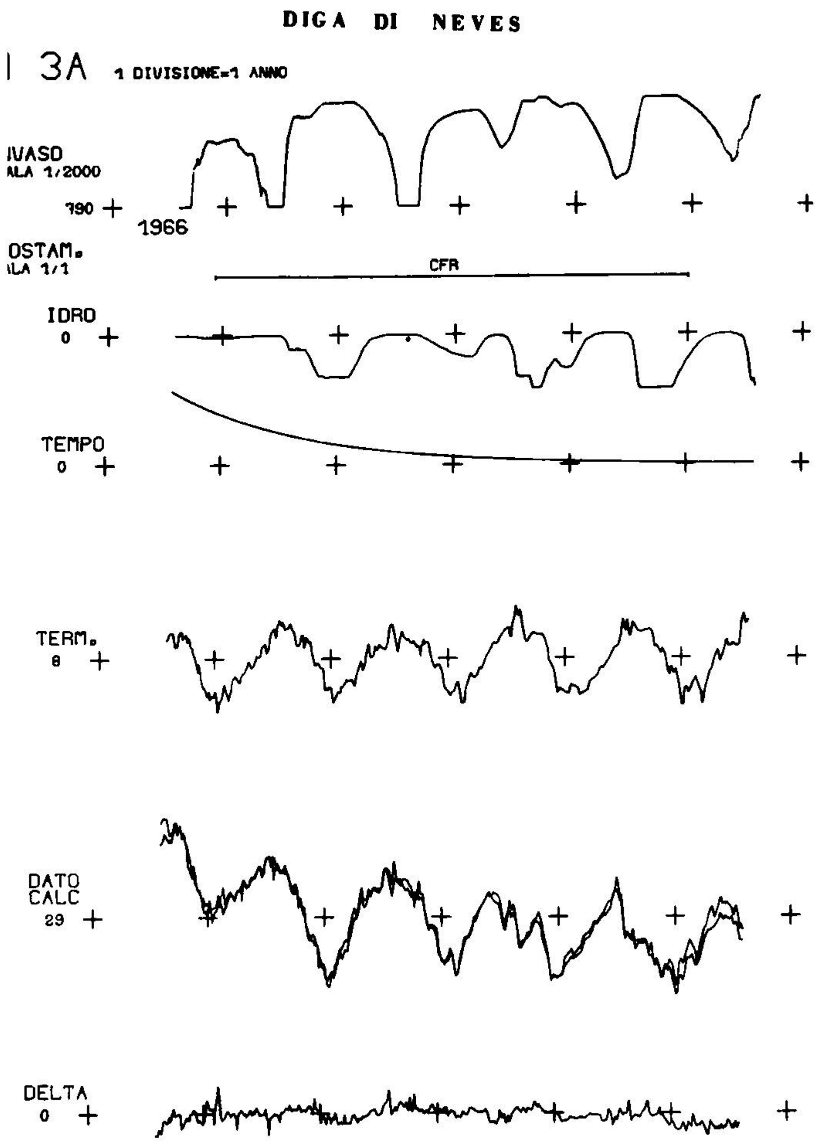
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FIG. 2

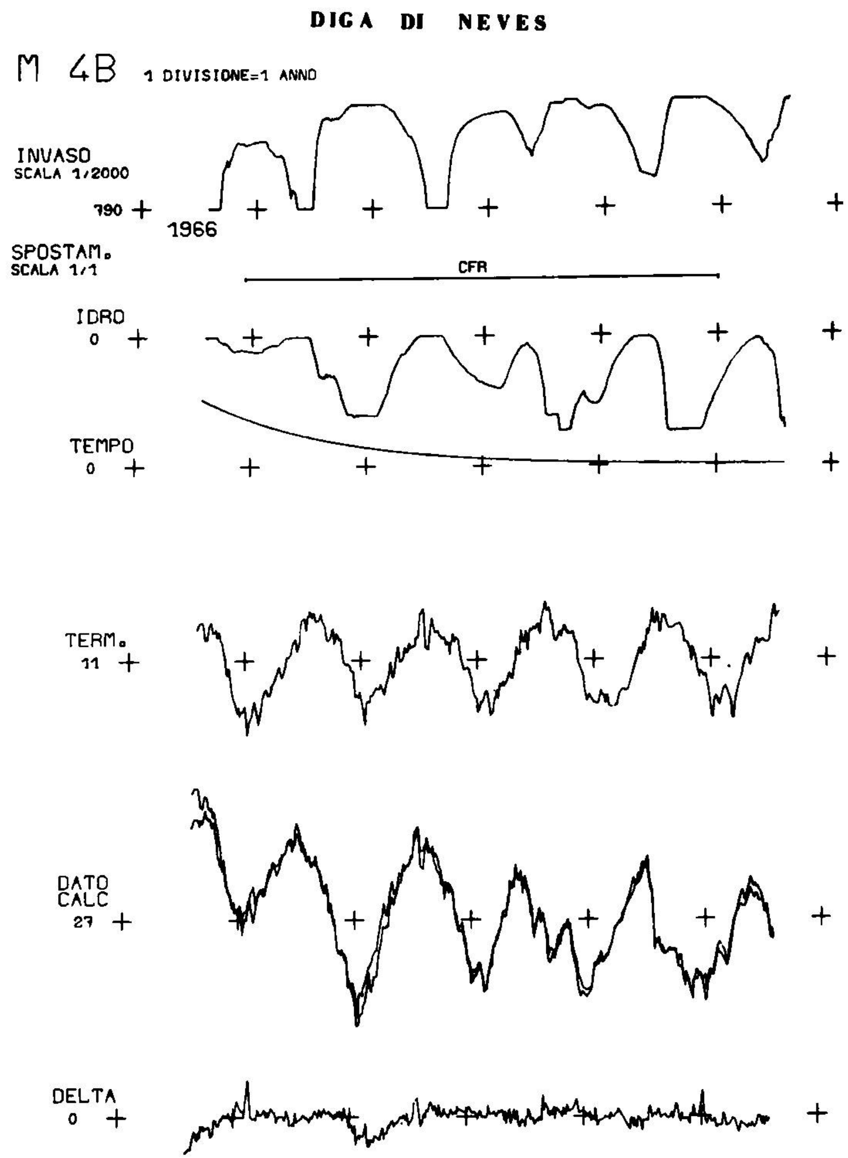
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FIG. 3