pend onthe temperature and the stress. The strain due to stress will also depend on the E value, which depends on the temperature and again on the stress. In addition to that there is displacement due to direct temperature expansion or contraction, so you have those three displacements coming into the calculation. The resultant displacements of course must be included in the compatibility calculation, for whatever compatibility to boundary conditions applies.

The method I have suggested is simply a proposal to take account of the possible weakining of concrete over a long period of time due to creep, in addition to temperature effects and also due to the temperature effects increasing the extensional strain. There is one thing one must be clear about, and that is that it is possible to get an extensional strain, even though the concrete is in compression. If your confining compression is not sufficient to prevent the strain normal to the main stress due to a high Poisson's ratio the concrete extends laterally, but at the same time it has lateral confining compression and it seems to me reasonable to assume that a limiting value of that extensional strain is the stage at which the bond between the mortar and the stones begins to breakdown sufficiently to cause internal instability.

III-5 Dr. P. ROSSI

Ladies and gentlemen, I would like to add some words and to emphasize some points in the paper presented by Mr. Bellotti and myself for this seminar: "New prospects for evaluating the degree of safety in concrete structures subjected to multiaxial stresses". Also if we are sure we are in a domain which is "far" from a failure condition, namely when stress states are very "internal" to the failure surface, it is very important to know how the material behaves in the actual stress condition and above all the degree of safety associated with such a stress condition, not only as regards the failure, but especially in relation to the loss of efficiency of the structure itself.

To this end knowledge of the failure surface only is no longer sufficient. To arrive at satisfactory practical results, it remains, in our opinion, to emphasize the experimental research in order to investigate and locate those factors which are, as far as possible, characteristic and determinant of the appearance of fundamental phenomena considerably affecting the physical and mechanical properties of a material.

Part of the experimental work carried out at the Niguarda Laboratories of the Hydraulic and Structural Research Centre of ENEL was presented to the RILEM Symposium in October 1972 and part is summarized in the paper presented at this seminar. Because we cannot consider as completely satisfactory for establishing the degree of safety the definitions which lead to the determination of coefficients as "values" which somehow or other "map" or "compare" the actual stress state with a failure stress state (in fact the failure stress state to which it is necessary to refer cannot definitely be determined from among the infinite points of the failure surface) and because it is also not always permissible or possible to fix a priori the stress path along which the failure should be reached, at the present state of research in our opinion it seems advisable that any consideration concerning the degree of reliability and safety should be related to the actual physical conditions of concrete as we have tried to recognize and represent by the four fundamental domains described in our paper.

Then the stress states are subdivided into four fundamental groups in relation to the ensemble of the physical and mechanical phenomena that they can induce in the material. Therefore both general and particular safety criteria can be established, on each occasion if you want, by demanding that suitable stress states belong to one or more predetermined groups depending on the efficiency and the safety requirements of the whole structure or of its special parts.

We have introduced the correspondence between domains and groups because the domains can vary, while the groups are to be considered "fixed" in the sense that each group is a representation of a certain well-determined condition of the material to be approximately ascribed to all stress states belonging to the same group. In our opinion safety criteria have to be established along the lines outlined before as regards these last groups.

As a matter of fact to consider the influence of time and of the stress path means to consider that the failure surface and the other limiting surfaces can change; and so the domains can change too. Lastly a consideration with reference to some papers of Prof. Zienkiewicz and Dr. Argyris and others, which I have read with care even if I am not a "finite element man". I would like to suggest that our "limiting surfaces", the failure surface too, behave very well as "loading surfaces": in this case it is possible to incorporate every safety criteria established as outlined before in the constitutive relations themselves, as it should be. Thank you.

III-6 Prof. O. DE DONATO

Ladies and gentlemen, I will briefly discuss one point regarding the way in which the path-dependency of the material constitutive laws has been taken into account in the underground opening problem considered in the paper. The assumed plasticity condition for the soil was the extended Mohr Coulomb criterion, proposed by Drucker and Prager; the same criterion was also adopted for the concrete but assuming a small tensile strength and elastic perfectly plastic behaviour.

As everybody knows, the path-dependency is a very important aspect in soil problems because it is related both to the path-dependency of the material constitutive laws and to the history of the loads. The latter depends greatly on the assumed sequence of the phases of construction, such as, in the problem in hand, the consolidation, the opening, the centreing of the tunnel, the concrete casting, etc.

Among the different non linear analysis procedures so far proposed for these kinds of problems, the incremental method has been very frequently used and, in fact, it is attractive. But there are well known circumstances for which the procedure becomes very laborious involving increments of the external loads at each step which are too small and then requiring a high number of steps to reach the given final loads. It would be more advantageous instead to choose a procedure which subdivides "a priori" the loading history in finite loading steps. This is operated in a recently proposed procedure named "multi-stage method" explicitly divised for general non proportional loadings and here applied to the problem in hand.

The main aspects of the multistage method are: (i) piecewise linearization of the yield surface, (ii) subdivision of the loading history in a sequence of families of loads (loadings stages) each governed by only one parameter monotonically increasing,