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Prof. M. COSANDEY

Vous avez vu que dans le programme il y a deux présidents. Alors nous allons dans cette deuxième partie exercer la participation M. le Prof. Finzi et moi. Alors c' est M. Finzi qui commence.

Prof. L. FINZI

There are two discussions concerning paper no. I-4 by Mr. Zerna. The first question is by Mr. Kawamata asking: Could you comment on the advantages and disadvantages of the dynamic relaxation method as a tool of design and comparison with the finite element method?

Could you explain your question more fully and then get the answer from the author.

Dr. S. KAWAMATA

I think the dynamic relaxation method and the finite element are representative tools for the design of PCPV today and both the methods are quite different, the dynamic relaxation taking esclusively the iterative form and using a finite difference system rather than a finite element system. What are the advantages and disadvantages of the dynamic relaxation as a practical tool of design.

Prof. W. ZERNA

Of course this is always a question to compare different methods.

But actually it is not always possible to compare, it depends on the problem. We have problems where one method or the other has advantages or disadvantages. If you use the one or the other method, sometimes it is also a matter of how you have started in developing programmes. And then you have the programmes and you improve them. Thus, your method has advantages compared with the other methods you do not know. Of course it also depends on the computer you use. We did some work on dynamic relaxation, Mr. Argyris used the finite elements method and we did some comparisons. We have found that for the problems we have considered so far there actually is not so great a difference that one could say, it is important to use one or the other method. There may be of course certain problems where you have advantages with the one or the other method, but on the whole it depends on so many parameters that you cannot give one single answer to that question.

Prof. L. FINZI

Thank you and now Mr. Schimmelpfennig, one of the co-authors of paper I-4, would like to add something to the paper.

Mr. K. SCHIMMELPFENNIG

Ladies and gentlemen, in the interval between sending the paper to the secretary and this seminar I got some more recent results with a little advance concerning compression fracture in triaxial loaded bodies, I think. Let me show you some of these results. The quality is not very good, but I hope that you can see the things that are important. I used for my calculation deep restrainted slabs which were tested by Taylor & Woodrow as published in Berlin last year by Dr. Garas. These are slabs with a diameter of 30 cm and a height of 7.5 cm, pretressed laterally with 57 Kg/cm^2 or 114 Kg/cm^2, respectively. The figures show radial sections of the slabs, and also the concentrical loading plate and annular bearing plate. The principal stresses in the radial planes are plotted for each computing mesh. In Fig. 1.1 it can be seen that tensile cracking starts near the edge of the loading plate. On Fig. 1.2 one can see that tensile cracking is going on in this region and also starts in the center of the slab and near the edge of the bearing.ring. In this stage compressive cracking starts at the edge of the loading plate. Fig. 1.3 shows a state when load is already decreasing. Tensile cracking has spread throughout the critical plane. Compressive cracking has enlarged and like in a central plug is going to be punched downwards. Where compressive cracking has taken place it is assumed that the material behaves isotropic, the shear modulus being reduced in a certain mode. One can say that the concrete there has gone into a granulated state, like coarse sand. Now some figures where the supporting ring is larger and thus the critical plane is vertical. Again in Fig. 2.1 you see the start of tensile cracking at the edges. In Fig. 2.2 tensile cracking has spread throughout the critical plane and compressive cracking starts at the edges. In the state shown in Fig. 2.3. compressive cracking has proceeded along the whole critical plane and this is already a state where load decreases.

All these results are not systematic up to now, but I hope that in the near future I shall be able to make progress herein. These effects of compressive cracking are very important when failure of structures subjected to triaxial stresses has to be examined. Thank you.

Ing. F. SCOTTO

Dr. Zerna, I was very much interested in the calculations that you have made in order to try to evaluate the effect of the creep on the PCPV structures. My first question is the following: you have tried to evaluate the deformation of the structure, due to creep in function of the time. This is one topic for the design of pressure vessels because we must know what happens to the penetrations during the life of the structure with special care for the operability of the control rods. Under this respect, I believe that in the area of the penetrations, at present, we are not in the condition of simulating the hundreths penetrations we have, and therefore to predict correctly the local deformations by means of calculations.

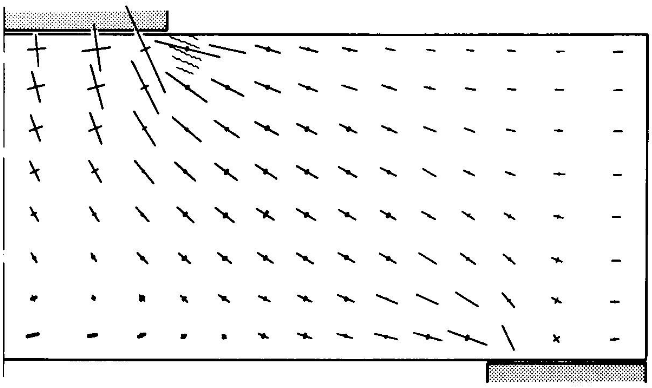

Fig. 1.1

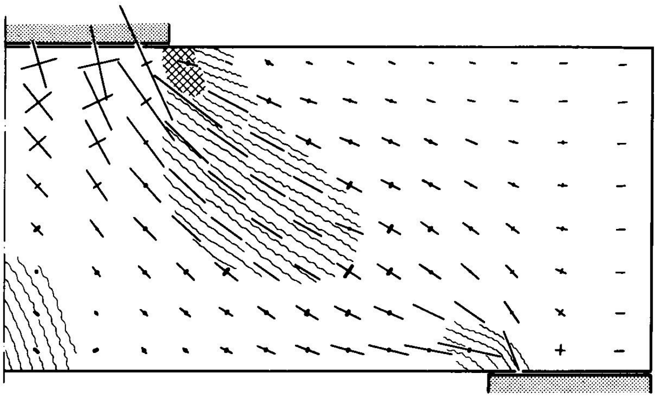

Fig. 1.2

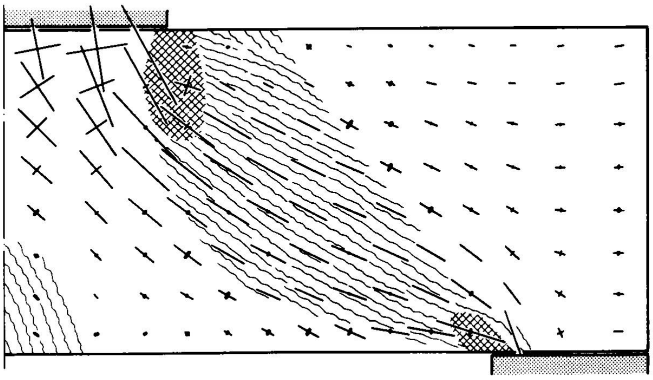

Fig. 1.3

Key for figures 1 and 2:

compressive principal stresses

tensile principal stresses

0 500 kp/cm^2

regions with tensile cracking, lines showing crack directions

regions with compressive cracking

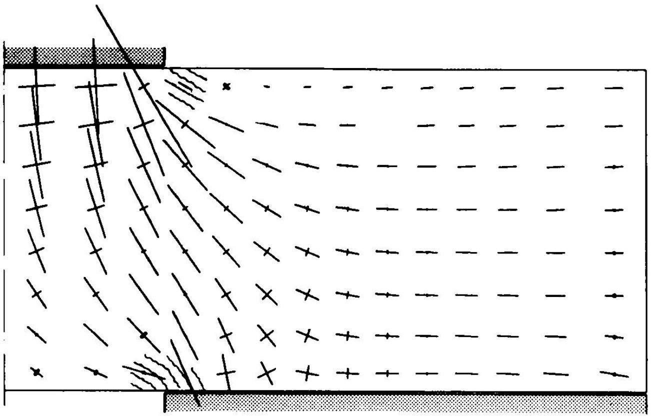

Fig. 2.1

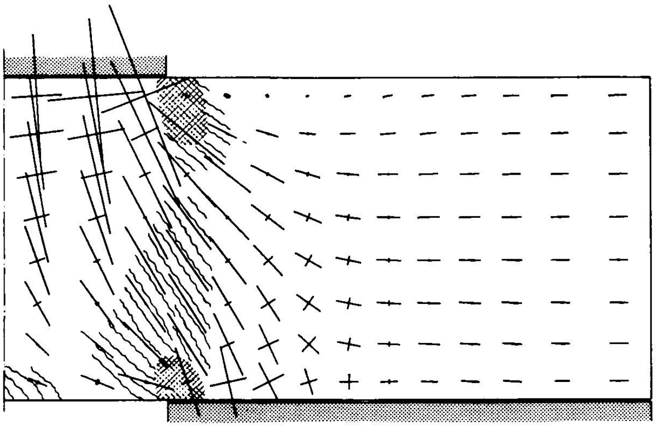

Fig. 2.2

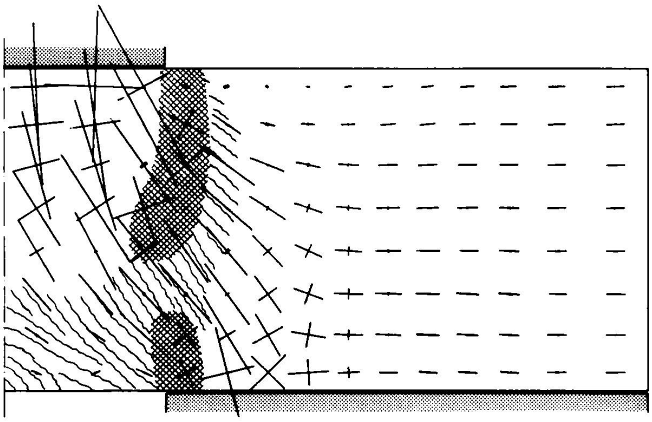

Fig. 2.3

Key for figures 1 and 2:

compressive principal stresses

tensile principal stresses

0 500 kp/cm^2

regions with tensile cracking, lines showing crack directions

regions with compressive cracking

The second question is related to the governing laws to be selected for creep modelling. With reference to big gradients of temperature, and big gradients of stresses typical of the penetration area.

Now the point is, what is your opinion about these two topics, the possibility to evaluate the more probable deformative behaviour versus time, the reliability of the creep governing laws you have applied to.

And third, which is your opinion about the degree of safety of the concrete versus time because of the effect of creep. Thank you.

Prof. W. ZERNA

Thank you very much for your questions, Mr. Scotto. On the whole I think you are right, there are certain problems and I am afraid I cannot give you a completely satisfactory answer. We cannot calculate all these problems which have been mentioned in such a way that we actually simulate the physical behaviour. I think, however, that it is not necessary. What we want is nothing else than to have a design which is safe. There arises of course another problem in connection with the deformation, not only with the penetrations but also with the liner we have in the vessel, which is influenced by the deformations of the whole vessel and also of course in connection with the penetrations. As the design philosophy is today, we calculate, I may say, just what we can calculate, and then of course we have to introduce some factors of safety. A safety factor must be greater the worse our calculation is and it may be smaller if our calculation is improved. But I think on the whole that our calculation method does not matter, finite elements or another method, the dynamic relaxation. It gives us in any case a good idea about the magnitude of the stresses and deformations and so on, so that our design is such that we have a safety which is sufficient. I do not know if this answers your question completely, but I think that the point you have raised is too difficult to go into with all the details connected with it.

Prof. W. DILGER

I have a question about the final statement of Dr. Schimmelpfennig with regard to the compression cracking of concrete. I have been working on reinforced concrete problems particularly in shear for many years but I have never come across the term "compression cracking" in the literature. Do you mean the splitting of concrete due to concentrated axial forces or do you mean the cracking which is observed in concrete prior to compression failure? Cracking in concrete normally occurs due to tensile stresses and not due to compressive stresses.

Dr. K. SCHIMMELPFENNIG

My opinion is that if you consider principal stresses you cannot speak of shear failure because there are no shear stresses That is why I used this term. Let me add the following: cracking can be determined by a certain failure envelope, usually in the triaxial stress space like in Dr. Browne's report for example. Not all these cracking states on the failure envelope are tensile cracking states and you must define a certain limit between tensile cracking and compressive cracking. Since it is not yet possible to get sufficient information from tests about this limit between tensile and compressive cracking I have done some parametric studies checking several assumptions in order to get a little step forward in describing cracking behaviour of concrete continua.

Dr. K.J. WILLAM

I would just like to follow up that previous question asking what kind of failure criterion is Dr. Schimmelpfennig using for describing concrete failure under triaxial conditions (and what kind of constitutive model is adopted in the case of cracking and shearing).

Dr. K. SCHIMMELPFENNIG

In former time we have done some work in our institute summarizing the results about this fact and we developed a failure surface which is very similar to that Dr. Browne showed in his slides. If you consider theoretical demands, it is not correct that this failure envelope has sharp edges, but if you treat the problems numerically that does not matter, I think. So it is good enough and moreover it is always on the safe side, as we have been able to demonstrate.

Prof. O.C. ZIENKIEWICZ

A further question for Dr. Schimmelpfennig. While I agree that a Mohr type envelope is a reasonable approximation for the ultimate behaviour, and indeed we have been using this ourselves, the problem remains, what happens to material after crushing has occured. When failure has been reached in concrete, the material becomes sand-like and loses its cohesion, nevertheless in a compressive environment it still possesses a certain degree of strenght. How does Dr. Schimmelpfennig deal with this matter?

Dr. K. SCHIMMELPFENNIG

I think that indeed it is very important to take care of the mode of decrease of stresses versus strains after failure. If the crushed region is near the surface of a body, then there will be no restraint and stresses immediately fall down. But if it is confined on all sides one must take suitable assumptions for the decrease of stress-strain curves. As I do not know any experimental results about this I have made an assumption on this subject with a decreasing curve like a parabole and I have checked different slopes. I think one can find by this way a reasonable solution. But you must indeed take account of this effect, you cannot calculate realistically if you consider an immediate fall down when the element is confined on all sides.

CHAIRMAN

Alors nous avons maintenant une question touchant le point 7, il s' agit d' une question de M. Mérot à M. Scotto. Comme M. Scotto est multilingue je pense que je peux poser la question en français, et je serai reconnaissant si vous voudrez bien ensuite la traduire en anglais parce que vous prendrez la parole. A page 6 de votre communication le tableau montre une très grande économie de précontrainte dans la solution mince. Comment cela est-il possible, puisqu' il est connu que la section nécessaire de la précontrainte est déterminée dans un projet épais comme dans un projet mince par la sécurité par rapport à la rupture.

Ing. F. SCOTTO

I have shown in one slide , relating to the safety factor of the structure, that the thick and the thin solutions are, more or less, in the same conditions as far as the safety factor of the structure is concerned. In table 6 of my paper you can find the great difference in the quantity of the concrete between the thick and the thin solutions. The unit quantity of prestressing steel for cubic meter is more or less the same for both the solutions (of the order of 150 Kg/m^3). This is the reason for which we have this so big drop of the cost on this item due to the important reduction of the steel quantity. As it is known at present the cost of the prestressing is 2 $ per Kg in our country.

Prof. J.P. MEROT

Je voudrais bien d' abord féliciter le Dr. Scotto pour ses études qui sont très intéressantes et je ne voudrais pas qu' il croie que je suis seulement critique. Je suis d' accord avec lui sur beaucoup de points. Il est certain que avec les connaissances actuelles on peut faire des caissons avec des épaisseurs de béton plus petites. Il est certain qu' il sera possible de faire comme cela des économies et que c' est intéressant aussi pour les fondations, pour la résistance au séisme, pour beaucoup de choses comme l' a dit le Dr. Scotto. Il est certain aussi que quand les dimensions du caisson diminuent la longueur des armatures de précontrainte diminue et donc on fait certainement une économie. Ce qui m' étonne c' est la chose suivante: si je prends un exemple très simple, comme un caisson pour un réacteur graphite-gaz, comme on en a construits en France, la plus grande partie c' est la paroi latérale cylindrique. On détermine habituellement en France la section nécessaire des armatures de précontrainte (par exemple pour les armatures circonférentielles) en vérifiant qu' à rupture elles équilibreront l'effort dû à une certaine pression qui est la pression de service multipliée par un coefficient de sécurité qu' on peut discuter mais qui est imposé che nous à 2,5. A ce moment-là la section et donc le poids des armatures de précontrainte est déterminé. Et ensuite on détermine les autres paramètres, comme par exemple le gradient de température admissible pour que le béton résiste avec cette précontrainte déjà déterminée.

Si on prend, comme le fait le Dr. Scotto, une solution plus mince, les câbles vont être courts et donc si le Dr. Scotto me disait, j' économise 10-20-30% de la précontrainte, cela me paraîtrait tout à fait normal. Je crois qu' on ne peut pas économiser la moitié ou plus de la moitié de la précontrainte et je pense que le projet de référence sur lequel s' est basé le Dr. Scotto n' est peut-être pas très bien étudié.

Ing. F. SCOTTO

I thank Mr. Mérot for the appreciation to my work. It is true that the reference German design was a little conservative as far as the prestressing steel is concerned, because of the initial prestressing level of stresses allowed at that time by existing German codes ($\simeq 0.6\ K_{UTSG}$ instead of $0.7\ K_{UTSG}$). But the fundamental of the cut down of the costs, that is of the prestressing steel (2 $ per Kg), for the "thin solution" lies in the fact that the prestressing steel is not sized in order to achieve a reference safety factor say 2.5 or 3. The prestressing steel is sized in order to achieve an overall compressive state, in the concrete structure, for the pressure and temperature corresponding to the design conditions. From our experience on small scale models, we know that with the conventional way of sizing the prestressing steel, as you have indicated, the real structural safety factor is more than 4 because of the complex interactional effects (contributions) of the concrete cable ducts etc.

In addition we have a general reduction in the length of the cables and as a matter of fact we have found that practically we have an average density of prestressing steel for thick or thin solution of the order of 150 Kg/m^3.

In others words, the cut down of the cost depends on the different design philosophy we have adopted on the basis of our experience acquired in testing several small scale models in the ultimate conditions.

Prof. L. FINZI

There is a question concerning paper I-9 presented by Mr. McNeice, the question comes from Prof. Baker: will the curved box girder bridges lose transverse stiffness by excentric liveload causing longitudinal yield lines? Is the dead live load ratio sufficient to prevent this? Under what circumstances could this happen?

Prof. G.M. MCNEICE

We had a little chat about this at coffee and unfortunately I cannot give you the answer, the reason being that the three dimensional analysis is what we really have to have in order to answer it. What we do in the finite elements analysis is to go through the elastic range until we get to the cracking stress level, then we change the stiffness of the element so as to approximately simulate the cracked stiffness. Then go through another stage whith that. Comparing those numbers with what we can get from a perspex model may give us some feel for the so-called shear racking across in a transverse section. It is a very great problem basically I think because when you are post-tensioning your webs, if you do not watch the contractor very closely for example, he will not follow the pattern that the designer has laid out unless you stand beside them. He does not want to move his jacking equipment as he is supposed to. He wants to leave it in one place as long as he can and do as much tensioning in that position as possible, before moving on to the next one. What you are doing then is of course lifting your structure in a biased manner and you are already introducing initial stresses into the system. Now we hope from the three dimensional analysis that we will be able to give some definitive statements concerning the construction practice, because if we do not know the initial stress possibilities it is very difficult to answer the final question at all. I cannot give you numbers unfortunately, perhaps next time.

Prof. L. FINZI

Now Mr. Scotto from ENEL would like to ask some of the authors that have presented papers here this morning what their position is as far as the influence of the gas in the concrete is concerned, influence on safety and so on. I think that Mr. Scotto could explain his question a little more fully.

Ing. F. SCOTTO

One of the topics we have to face to, in designing the PCPV, is the condition in which we have an incidental leakage of gas throughout the liner. In my opinion at present the realistic way to approach the problem is that we must try to avoid this incidental condition by means of a suitable purging system, but in any case, the question that I would like to put here in this specialized seminar, is if some authors can expand on this subject and, in particular, if some people has made any test in order to know which is the safety of a concrete subject to the combination of a triaxial state of stress and an internal gas pressurization.

Prof. W. ZERNA

I think the answer to this question depends very much on the philosophy you introduce into the question, what is meant by safety for such a vessel. I perhaps can say at the moment what we have done in Germany in this case. We have assumed that the gas penetrates through the liner and then gas pressure acts in the cracked concrete. Then it must be guaranteed that the vessel can still take all forces and stresses which occur in this case. In other words, I may introduce the wellknown term "pressurized crack". We calculate the pressurized crack, but that is only one way perhaps to meet this point. You could consider this of course in a quite different way, but actually this is more or less philosophy.

Prof. A.L.L. BAKER

I should like to ask Prof. Zerna about the heat effects on the cables, because in many desings the gas is at a very high temperature and if penetrating the cracks it would not take very long to heat the cables and weaken them very considerably. I cannot speak directly about tests that have been done in England, they have been carried out by the Atomic Energy Authority, but they did carry out tests on models by gas pressure as distinct from water pressure. The earlier tests were done with water pressure and I think as a result of that this question of gas in cracks was not studied sufficiently in the early days. But fortunately the safety factors of the early designs were pretty high and I do not think there is anything to worry about, particularly because the capacity of the safety valves is also high and therefore one gets release of pressure. One should do so long before pressure rises to a value which would start splitting the lining. But in the model tests which were done, immediately the lining split the whole vessel explodedor at least in most cases, and therefore it does look as though the limiting factor in a gas pressurized, gas cooled reactor is the splitting of the lining. As soon as the lining splits, cracks in the concrete widen and the gas pressure extends around the wall, the cables are heated at the same time and failure occurs. In the code of practice which has now been published for pressure vessel designs, for gas cooled reactors in England we have special clauses for design against gas in cracks and we also have clauses in regard to the capacity of the safety valves, so that for the worst kind of accident which may occur, when the controls breakdown or fail, you can be sure that the safety valves will release the pressure before it can reach a value at which it will split the lining. There is a good chance that if one did in some extraordinary accident have a failure it would be due to splitting the lining, not the lining remaining intact and the cables breaking.

Prof. W. ZERNA

On the whole, Prof. Baker, I agree with what you have said. But here I think we have to distinguish between what actually can happen and what is only a merely hypothetical assumption. We have also introduced the term liner integrity, and that means that we want to know what the factor of safety is with respect to the liner. But we think that in reality the pressure can never increase up to such a critical level. We only assume such a case for calculation reasons. I think that is very important, because what actually can happen and what is only considered for calculation reasons is very often confused in the idea. I think also the experiments which have been done in this respect are wrong, because they have increased the pressure and they have shown an explosion of the vessel, but in reality the inside pressure of the gas is limited to a value according to the whole system of the reactor. It is impossible for it to increase and therefore we have do distinguish what we are calculating and what is the physical reality.

Prof. A.L.L. BAKER

There is one possibility of failure which the control rods and other safety devices will not cover and that is a fracture in a water header in the boiler system resulting in water turning into steam very rapidly. It has been calculated in certain cases that the pressure can rise so rapidly that the safety valves can scarcely deal with it, and the margin of safety is not as wide as one would like for that particular type of accident. Therefore one really needs to look at the gas in cracks position and make sure that one has got an adequate safeguard in case of excessive steam pressure due to a water header failing, and perhaps the safety valves being corroded.

Prof. A.D. ROSS

I think this seminar has touched on perhaps the most vital point - which Dr. Scotto raised - in the design of gas cooled reactors. It is true, as Prof. Baker said, that in our British Standard, which has now been published, we have required a minimum load factor for this pressurized crack condition, but we really do not know what the distribution of pressure along the crack might be and this is an important unknown. In my own mind I differentiate two cases of failure of the liner. The large split that I think Prof. Baker and others have talked about is one case, and I agree with Prof. Zerna, that this is really virtually impossible as I see it.

But what is always possible, is that there may be small leaks, allowing gas under pressure behind the liner and thereby possibly leading to pressurized cracks, the condition that we wish to avoid. I do not know what the answer is. Perhaps I might mention - although the work is not mine - that in England we are trying to discover, on an actual vessel, if a small gas flow could escape easily through the concrete structure or, if any cracks exist, whether they might be pressurized because of "choking". It is not much good examining small specimens for this purpose because there are construction joints and other leakage paths in the real structure along which the gas might escape. Hopefully in due course we might have a little more information on this point which I regard as being of primary importance.

Prof. J. P. MEROT

Je voudrais répondre au Dr. Scotto en lui disant ce qui se fait en France, bien que je pense que je ne lui apprendrai pas grand' chose. A ma connaissance il n' a pas été fait de tests sur l' effet de la pression dans le béton. Le Dr. Scotto sait fort bien que dans le règlement français il y a une prescription au sujet de l' établissement de la pression de gaz dans l' épaisseur de la paroi de béton. En fait cette prescription n' est pas gênante pour les caissons que nous avons étudiés jusqu' à maintenant, qui étaient des caissons pour les réacteurs graphite-gaz. On trouve que l' épaisseur des parois n' est pas assez forte pour que cette condition soit gênante.

Si on faisait des caissons pour des pressions beaucoup plus fortes, par exemple pour des réacteurs à eau bouillante ou surtout à eau pressurisée, le problème pourrait effectivement se poser et peut-être ferait-on des expériences à ce moment-là. Je crois surtout que la tendance en France serait de prévoir, comme l' a proposé le Dr. Scotto, un système de drainage derrière la peau. C' est cela qui nous parait à l' heure actuelle la meillure solution.

Je voudrais ajouter aussi qu' il ne faut pas oublier que ce risque de fuite est très peu probable parce que la peau d' étanchéité en acier est plus chaude que le béton. Ceci, le retrait du béton, l' effet de la précontrainte font que cette peau est comprimée, tout au moins en service, au moment où la pression de gaz existe. Par conséquent le risque de fuites est très faible.

CHAIRMAN

Nous n' avons plus de questions écrites, nous sommes arrivés théoriquement à l' heure où nous devons terminer pour ne pas influencer sur le début de la session de cet après-midi qui sera présidée par M. le Prof. Zerna, mais enfin si quelqu' un avait encore une question importante qu' il ne pense pas pouvoir poser dans les trois demi journées qui restent nous sommes encore prêts à lui donner la parole.

Prof. O. C. ZIENKIEWICZ

There are two points I would like to comment on. The first one concerns the matter of gas pressure in the body of concrete. This is a very similar problem to that dealt with frequently by engineers in the field of dams and problems there are referred to as uplift. I believe the question of dealing with concrete reactors under the possible internal pressure of gas percolating through the porous medium should be dealt on

A second point which I should like to comment upon is that raised in the very excellent paper by Professor Fumagalli. He finds there experimentally a progressive failure and continuing deformation after repeated cycles of the load. In numerical analysis this matter of cyclic failure or continuing deformation has not received sufficient attention mainly due to difficulties and cost of reproducing several cycles on a computer. We have recently studied one such problem and shown that deformation in a jointed rock mass can continue for many cycles if sliding conditions are reached at any stage of the analysis. I believe it is not economical to extend the numerical procedures further and some attention should be given to shake-down theorems such as for instance, used in steel structures to determine whether deformation will be progressive in a particular engineering case. Some extension of these theorems is needed for frictional materials.

CHAIRMAN

Alors je pense pouvoir clore cette session. J' aimerais remercier les auteurs des communications de cette première session. J' aimerais également remercier ceux qui ont participé à la discussion. Le rôle, précisément, de ces colloques avec un nombre de personnes réduit est de faciliter le dialogue entre les spécialistes et je crois pouvoir dire que cette discussion a été extrêmement fournie. Je ne suis pas un bon juge, puisque je ne suis pas un spécialiste du béton et des caissons de centrales nucléaires, mais enfin je crois que cette discussion a été extrêmement utile et très favorable et j' aimerais donc vous remercie pour y avoir participé.

J' aimerais également remercier les traducteurs, c' est toujours difficile de faire la traduction de choses techniques, d' autant plus qu' aujourd' hui nous avons demandé à chacun de faire vite pour que nous puissions terminer dans les délais. Merci mesdammes et messieurs pour votre participation.

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