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Prof. R. N. WHITE

The first question is from Prof. Baker, on Prof. Fumagalli's paper II-2. "Were cables bonded? Could long term pressure load and temperature effects be assessed from the test? "

Ing. F. SCOTTO reply

As concerns the first question the answer is: the cables (monowire type) were not bonded.

In so far the second question is concerned our experience on long term effects was just devoted to follow the variations in the prestressing: see Fig. 6 of the paper II-2. The figure reports the losses up to 10 days (in our tests we were more interested in the ultimate condition and related safety factors than in the long term effect) but the tests went on along 3 months without remarkable changes in results.

In any case we believe that in principle, it is possible on our models to follow the behaviour of the structure along a reasonable period of time (i. e. one year) in the sense that realibility of the instrumentation can be ascertained, and the temperature in the test room can be satisfactorily kept constant. (this test is very expensive).

In the reality the actual structure will experience any kind of operational and accidental conditions along its life: this cannot be simulated on models. It must be taken in mind that it is already a great problem to assess the variation in the prestressing forces due to intricate loading and thermal hystory of PCPV. This in turn will change the state of stress of the structure and the corresponding long term effects. For the above we believe that this problem must be studied on the basis of a mathematical approach with simplified conservative assumptions.

Prof. R. N. WHITE

A second question from Prof. Baker, on Dr. Garas' s paper II-4: "Did the shear cracks start as bending cracks? Test of short unreinforced beams give deviations of shear strength several times greater than typical deviations for bending strength. Will this also apply to pressure vessels and slabs? "

Dr. F. K. GARAS

As an aid to further understanding of the shear compressive failure of restrained end slabs, we have tried to simplify the problem by examining visually the inclined crack patterns leading to the two-dimensional mode of failure of restrained deep beams.

A number of restrained beams representing a strip of an end slab, having a span to depth ratio of 2.5, were loaded under different degrees of restraint and using similar loading conditions to those adopted in the end slab tests.

The investigation has shown that the nominal shearing stresses at failure were similar to those which occurred in end slabs. Typical values were given in the national report (paper no. I-5) Table 1.

Prof. R.N. WHITE

Could I also ask a question while you are here? You mentioned the breakdown of shearing force was about 45% in the concrete compression zone, 50% in the interlock and maybe a few percent in dowel action. How did you determine this breakdown?

Dr. F.K. GARAS

The contribution of each component in resisting shear forces was assessed using experimental data: (i) Compression zone: the shear resistance of this component was abstracted from our experimental work on restrained deep elements failing in shear compression. Part of this work was published in an earlier paper. A relationship between the amount of hoop restraint and the shear strength was developed. In end slab models the biaxial compression was directly derived from the hoop prestress forces above the tip of the haunch crack. Using this information the shear resistance of the compression zone was about 45% of the total.

(ii) Aggregate Interlock in Tension Zone: the magnitude of this component is a function of crack width and crack displacement. From end slab tests the cracks widths just prior to failure were derived by substracting a value for the elastic strain, based on a linear extension, from the total radial deformation of the slab. By extrapolation using Fenwick's work on aggregate interlock and the measured crack width and shear displacement from our models the aggregate interlock component was about 50% of the total shear force.

Prof. R.N. WHITE

Next paper for the questions is no.5: the question in for Prof. Hornby, from Prof. Baker, who has supplied us with many good questions. This question runs like this: cables on British reactors are non-bonded, therefore with accidental overload splitting the liner, gas pressure will spread in wide cracks. Is the disappearance of vapour pressure analogous?

Mr. I.W. HORNBY

The reference I made in the introduction of our paper to the vapour pressure during the heating up is a totally different condition to gas pressurising cracks after the splitting of the liner.

The vapour pressure is analogus to gas which has got behind the liner through, say, a small undetected pin hole in a weld. This gas, if it did not dissipate, could cause a pressure build up behind the liner or in cracks (if, in fact, any cracks exist at working pressure). The vapour pressure in the hot spot test dissipated very rapidly (see fig. 12 of Irving et. al. 1974) and other more recent tests with gas, have measured large flows away from a liner concrete interface. Consequently the possibility of a build up of pressure behind the liner is very unlikely.

Reference: Irving, J., Carmichael, G.D.T., and Hornby, I.W.
A full-scale model test of hot-spots in the prestressed concrete pressure vessels of Oldbury Nuclear power station. Proc. Inst. Civ. Engrs. 1974, 57 (June) 331-351.

Prof. R.N. WHITE

The next question on paper 7 is directed to Mr. Lemasson; this is also from Prof. Baker: "French vessels have bonded cables, British have non-bonded. Do you still think non-bonded cables are better?"

Mr. M. LEMASSON

Je pense que le sujet est inépuisable et je crois que pendant très longtemps on parlera encore des câbles injectés et des câbles non injectés. Il y a effectivement deux techniques possibles, qui ont chacune leurs avantages et leurs inconvénients, mais je ne pense pas que quelqu' un ait trouvé de conclusion définitive. C' est tout ce qu' on peut dire. Dans le cas de la précontrainte par enroulement de fils ou câbles ("wire winding") des caissons du type HTGR, je crois que là effectivement il serait très difficile de protéger autrement que par de la graisse. Mais pour les câbles sous gaine en France nous continuons à les injecter et nous avons toujours pensé que l' adhérence qui existait de ce fait entre le câble et la structure apportait un complément de sécurité. Je pense que c' est tout ce qu' on peut dire à ce sujet qui je crois ne sera pas épuisé tout de suite.

CHAIRMAN

Are there more remarks on this subject? You know, from the very beginning when prestressed reactor pressure vessels came into the idea, this question about the grouting or not grouting was very important. I think more or less every country now has a particular philosophy on this point. For instance in Germany we grout mainly from the viewpoint of the protection against corrosion, because we have the feeling there is no better way to have a good corrosion protection. And then we have all the benefits which grouting gives. We think in any case there is no need to change a cable at a later time.

Prof. A.L.L. BAKER

Could I pose one supplementary question? I just wanted to ask whether anyone has had experience of removing a non bonded cable, examining it and putting it back again. Has that been done yet after these ten years or so? and if so, how does it work? I mean, can it be done fairly simply or is it very difficult?

Mr. I.W. HORNBY

In Britain, a system of cable inspection has been in operation from the completion of the first concrete pressure vessel. The inspection includes the destressing and total withdrawal, of a number of cables every year. These cables then undergo a through examination particularly for evidence of corrosion. The operation is relatively straight forward and has to date presented no difficulties. The cables that are withdrawn are not reused but replaced with new ones.

Prof. A.D. ROSS

I think two points ought to be made. Grouting in conventional civil engineering structures has not invariably protected the tendons from corrosion. I think that is a point that is worth making. What Mr. Hornby said about stray electric currents, of course we do understand and this is a risk we are aware of in Great Britain. If there are tendons or other corrodable materials at risk, electric welding and especially direct current welding should be avoided on the construction. One point only I would like to add: if at any time, 10 years, 15 years hence, you are concerned that the pre-stress in your vessel may have declined too much it is very simple to re-tension and restore the full prestress. This is one of the major advantages of ungrouted tendons.

Dr. R.D. BROWNE

I would like to ask Dr. Scotto whether there is any guarantee that a grouted cable under conditions of modest temperature will inhibit the formation of macro-electrolytic cells over a long period of time? We have been looking at the mechanisms of corrosion of reinforcement in concrete in relation to offshore structures. It appears that there are instances where certain materials can contaminate concrete, giving a reduction to the passivation of the reinforcing by the alkalis in cement: a corrosion macrocell can develop with the steel. I am wondering whether perhaps I can throw it back to Dr. Scotto to ask whether any work has been done on grouted cables to establish that over a substantial period of time under site operational conditions, rather than under laboratory conditions, that the grouted cable has shown to be satisfactory.

Ing. F. SCOTTO

If I have understood it correctly, you said that in your country your opinion is to grout the cables with cement mortar. As far as the "winding system" is concerned, which is your opinion assuming that you cannot grout these cables?

I would just like to give you the results of the famous enquiry we made in Berlin, on the subject "to grout or not to grout". We divided the people who where talking about this argument in categories, that is to say, the purchasers, the authorities and suppliers. It is clear that the suppliers liked to grout and not to speak about these problems in the future, while the purchasers were of different opinion, because they are committed to keep these structures for their whole life, and finally the authorities, who are people grouted of doubts, were reluctant on the subject. Generally speaking authorities and purchasers were against grouting while the suppliers were in favour of it.

We have known of negative experience in the French famous first pressure vessel. They were oobliged to change some cables because difficulties arised during the construction. Steel was not suitably protected, but this is something that happens. In fact it is very difficult during the construction stage to be 100% safe, on the quality of the work, especially nowadays, that we have troubles for strikes and so on. So the probability of corrosion, because we have to talk in terms of probabilities, the probability to loose the vessel or the overall plant, to loose millions of dollars, is very high.

If I had to decide about this question, I believe I would decide to be against grouting, just to tell you my present position.

CHAIRMAN

I think it is a very interesting question we are discussing now, but strictly speaking it is not the subject of our seminar, because it has nothing to do with tri-axial stresses. As we have no more written questions I ask the audience if there are questions on the papers. We have some time left for the discussion. I hope that you will use this time.

Ing. F. SCOTTO

I was very much interested in the French paper by Mr. Lemasson. They say that they have made some frictional tests. Can you kindly give us some figures and the method followed to ascertain these frictions?

Mr. M. LEMASSON

Nous avions effectivement construit un anneau à l' échelle 1 par rapport au caisson, c' est à dire un anneau de 25 m de diamètre environ avec une gorge circulaire dans laquelle nous pouvions placer différents câbles de précontrainte, introduits dans différents types de gaines. Celles-ci pouvaient être des gaines rigides, des gaines souples en feuillard, revêtues on non revêtues. Dans le cas du câble BBR et avec une gaine souple revêtue de zinc nous avons obtenu 0,16 comme coefficient de frottement global: ce coefficient était un peu plus important dans le cas de tubes rigides et je crois qu' il était de l' ordre de 0. 20.

Prof. R.N. WHITE

I'd like to address a question to Mr. Kawamata. One of your slides showed the comparison of normal stresses and shear stresses; the shear stresses did not agree nearly as well as the others. Is this an inherent difficulty with this layered substructure?

Dr. S. KAWAMATA

I think Prof. White is pointing out a difference in the shear stress distributions from the method of sliced substructure and from the ordinary three dimensional analysis using isoparametric elements shown in fig. 13 (d).

Last evening I asked Prof Zienkiewicz about the latter distribution of shearing stress. The result is not natural because the shearing stress does not vanish at the free surface. Prof. Zienkiewicz opinion is that this result may be based on the way by which we are representing the value of the stress. When we use some points near the boundary of the elements, we will often have irregular distribution of stress. His suggestion is to use the values at the Gauss points in linear or parabolic interpolation of the stress distribution. Therefore, a part of the difference may be attributed to the wrong interpretation of the solution by the iso-parametric elements.

Using the IBM 360/195 axi-symmetric analysis required 7 seconds of CPU time. For our new system of substructure analysis, we used 47 seconds. The letterCPU time includes 27 seconds of matrix inversion during the condensation procedure. I think this is a rather big amount which we have experienced so far and I think something is wrong in the inversion procedure. So this will be further reduced. But for the three dimensional iso-parametric method we cannot make comparison because we used the Gauss-Seidel's iteration using the initial value, which was the results we got from the method of sliced substructure, and it converged very rapidly.

Prof. A. D. ROSS

I have a very brief question relevant to the splendid films of the tests of the models that we saw. Having seen many model tests over the years this is the first time that I have seen a top cap fail so suddenly in a hydraulic test. I wanted to ask if there was a long pipeline which might have stored a fair amount of strain energy in the system.

Ing. F. SCOTTO

First of all, I must explain the reason why you have assisted to this kind of ultimate condition in this model. The final collapse you have assisted to in the film was related to the third model. This final condition was reached at 140 atm. The difference between the third and the second model (that is the first that you have seen with all the hooping cables that were broken at 120 atm) was simply due to the fact that we improved the diameter of the wires from 6 to 7 mm, from 7 to 8 mm, etc. just to try to find out what were the results, in terms of safety, of this wasting of steel. In terms of costs we are talking of half a million $, a very big amount of money.

Coming in the question, because we had an hydraulic pressurization and the pressurized copper bag that was inside to allow the deformation of the concrete did not fail at all, as you have seen, we were able to assist to the collapse of the internal portion of the cap slab, non reinforced, and to the explosive effects of the releasing strain energy. It resulted a sort of opening like a flower of the upper outer ring of the barrel and then a cutting out in pieces of the internal portion of the slab and consequently, finally, the explosive failure. The reason of this strange collapse was due to the fact that we did not improve (as per the rest of the structure) the cap slab hooping cable system.

CHAIRMAN

It seems that there are no more questions, then it is left to me to thank all the authors, to thank those who have taken part in the discussion.

The session is closed. Thank you very much.