Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 52 (1986)

Artikel: Planning and design

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DOI: https://doi.org/10.5169/seals-40360

Planning and Design

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Nicolet, Chartrand, Knoll + Associés; Montréal, PQ, Canada

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Rüdiger Rackwitz, Dr.-Ing.
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Taking part in the discussion from the floor:

G. Breitschaft, Berlin
R.A. Dorton, Canada
A.G. Frandsen, Denmark
L. Grill, Australia
B. Hillemeier, Fed. Rep. of Germany
T. Kuesel, USA
J. Menzies, UK
A.G. Meseguer, Spain
S. Ono, Japan
D.W. Quinion, UK
B. Richmond, UK
A.G. Simpson, UK
W. Smyth, UK
J.S. Sodhi, India
K. Sriskandan, UK
C.J. Turkstra, USA
L. Vu Hong, France
J.H. Willenbrock, USA
J. Wynhoven, Australia

R.E. MELCHERS, Australia, MODERATOR
It seems to me that this Seminar Discussion may be a good opportunity to try and put into perspective some of the presentations that we had this morning. We had some suggestions that the state of the art is perhaps not what it should be. We have had some suggestions that some of this may be attacked by some sort of mathematical modelling and that within that framework of mathematical modelling we need to collect data, we need to quantify the sort of things that we are talking about. It seems to me that this is perhaps a useful and perhaps provocative way of starting off the discussion.

If we perhaps initially focus our attention on the sorts of ideas that Dr. Rackwitz was trying to present to us this morning and ask ourselves the questions: "Is it possible that we can in fact address all the significant factors in a mathematical way? Is it possible for us ultimately to do what we have been doing with structures?"

We have been talking about stresses and stress analyses, can we also do this sort of process for these more difficult areas involving human processers, construction processers? If we are able to do such a thing, is it likely - and this is looking into the future now - that we will ever, as a profession, use such techniques? Now, that's a value judgement and a difficult one. But I think we ought to address it.

So that is really asking the question: Are you, as preponderantly people from industry, likely to go in this sort of direction? I know some of you have got some quite strong viewpoints on this. I will not at this stage ask for the participants to review or to restate their arguments. I think it is now up to the floor to make the input.

Would anyone like to comment or ask a question or make a statement?

G.F. FOX, USA
From Dr. Rackwitz' talk I can imagine that one could take the model that he was describing and utilize it now. The only problem that I see is what do you substitute into it, where do you obtain some of that information? It seems like a lot of it is not really developed as yet, e.g. throughout the talk we talked of errors, I wonder what would be the definition of an error, because there are so many different types of errors in calculations, say for example, somebody might make an error and not have enough section modulus and the bridge falls down, or one can make an error in the spacing of one reinforcing bar, which does not mean anything. So one would have to define things like that and also have an enormous amount of information available before we could substitute into the model. I wonder if you could perhaps comment on that.

R. RACKWITZ, FR Germany
Let me first go a little into the philosophy of quality assurance. As engineers we are used to models for structures being verified by experiments. The question is, if that was always the case. I believe that men like Euler did no experiments and even Navier did not perform any experiments. Only in the late 19th century were experiments performed and they proved that some of the theoretical models are correct.

Now, with respect to errors: I really believe that you see what you expect. In other words, first there is a model and then you can observe the parameters of the model, sensibly. And if you find out that collected data do not fit the model, then you change the model.

Now a second philosophical point on modelling, which is also relevant here: we do not use those models as engineers to explain nature, we want to make decisions with them. So they may be rather crude but if they serve the purpose of decision making, then they serve the engineer completely.

So, then, more directly to your question about the definition of errors. An error is any action not according to the rules of our engineering game. A human error is unintentional, it can also have positive outworkings, of course. I should refer in this respect to the relatively wide literature on this subject, especially to the report of a recent symposium in Ann Arbor, USA, at the University of Michigan, organised by Andy Nowak and including quite a number of such definitions and discussions of those definitions. I think the profession is now settling down in this area.

MODERATOR
Perhaps an editorial comment at this stage. Some of the discussion about errors will of course occur tomorrow. So the business of modelling may well be deferred until then.

F. KNOLL, Canada
I would just like to try, if you allow me, and repeat Mr. Fox's question to Dr. Rackwitz: How far away, do you think, are we from a possible application of these thinking models, theoretical models I may call them perhaps, on error and error treatment. How far away are we from the application of these models to practical cases, because after all that is what all engineers are interested in, to bring these models to practical use.

R. RACKWITZ, FR Germany
The ambitious plan to compare different quality assurance systems for larger project areas will clearly not be realized for several years to come. But in narrower fields, where you can limit the type of errors or the size of errors, we are ready to implement these models. Those errors can be observed. Otherwise they must be estimated, even subjectively. You carry out the computations, which, in my opinion, are now a straightforward job, find out the most sensitive, most critical uncertainties in your reliability model and then use, for example, a Bayesian procedure to update the most relevant parameters of your model. If this is not sufficient, you update also the mathematical structure of the model. I believe that we can and we should start now with the application of these concepts. Otherwise the civil engineering profession somehow would lose face because the user or the victim cannot understand why a technical object should not be as perfect as possible.

F. KNOLL, Canada
I am not sure the engineering profession's patience is going to be that short. We have been studying concrete beams for a century and we are still doing so, so I think we are going to have a few more years of allowance to study errors which seem to be a harder problem to deal with than concrete beams used to be.

R. RACKWITZ, FR Germany
But the first step is the step of modelling. If this is not done, we do not go beyond the stage of verbal discussion. What has been done in this conference and in another series of conferences on the subject, what could be done to define the whole problem in verbal terms has been done. Now is the time to try to get to the numbers and to be able to compare using numbers. Therefore, even a bad model is much better than simply a quasi linguistic structuring of the problem as a whole.

MODERATOR
I am afraid we are going to dig a hole for ourselves if we keep going in that direction but there will be an opportunity tomorrow to discuss some of these issues in Session D. I see a question from Mr. Grill.

L. GRILL, Australia
My comments are based on my own experience in a private consulting office. I really cannot see any private consultant being inclined to use any kind of mathematical model just to determine the degree of risk in failure, or the possibility of failure of a given structure. This time could be better applied in a different way. Generally we have short deadlines. Everybody is under pressure and it is unrealistic to dedicate time to something which apparently is still on a level of half philosophy and half science.

We have here the idea of applying mathematical models to quality assurance, where the human factor is essential. I do not really see how a mathematical model could be applied to something where human nature is involved. I have seen the work of a very large number of engineers with different academic backgrounds, because Australia is a country of immigration. I have seen projects designed by people from practically all European countries, South American countries, the United Kingdom, Canada etc. This large variation further increased by different education levels as Masters or PhDs, would make it practically impossible to devise a single mathematical model. In most cases simple judgement is more appropriate than mathematical models.

MODERATOR
Thank you Mr. Grill. Perhaps as a fellow countryman I might just make the observation that at least one company I am presently associated with is in fact using reliability methods to assess their risk problems. But I do not think that it is necessarily quite as bleak as you indicate. It seems to me that it depends very much on the risk and the benefit that the organization perceives. It may well be that for certain types of work we do not want to go into the reliability area but in other types of problems that may well be the case. I am sure there will be other people with similar experiences.

C.J. TURKSTRA, USA
As professionals we must always try to use our intellects to the greatest extent possible. In many cases the use of our intellect means that we abstract and make models and do what we can to systematize the world. It seems to me that one of the biggest gaps in our history of analysing the world is the question of checking. There is to my knowledge no systematic theory of checking.

Do we know how to check? Every office seems to have its own procedures, which no one wants to talk about. It seems to vary from person to person and from organization to organization. It is a deep professional secret. I assume checking happens, but I am not sure how often it happens and how effective it is. I think a theory of checking would probably be more useful to the profession as a practical matter than a study of the impact of errors on reliability. After all we want to prevent the errors. We do not really care what the effects of not detecting them are as much as we want to detect them.

I would like to ask if anyone knows of a study anywhere in the world that reviews the process of checking design calculations and design processes. People have said here, for example, that they are just doing calculations over again. One man reading another man's numbers is an almost useless exercise.

Is it not possible to construct a model of checking processes, building in all the sensitivities of the impact of the different kinds of errors along with the appropriate definitions?

MODERATOR
Some years ago I tried, in fact, to set up a checking model system and asked various consultants to participate in checking a design and see whether there were some errors. Despite all sorts of assurances that we would be very careful as to how we would use the results, ultimately none of them were very interested. They only wanted to know how good they themselves were so that they could use that in a commercial sense, if you like, but the study never got off the ground. It was too difficult and too dangerous for them.

G. BREITSCHAFT, Berlin
The question of independent checking of design was raised yesterday by Mr. Fox also. We established in Germany, starting about 70 years ago, such a system. It is a required by-law that the design - with the exception of buildings with little importance - has to be checked before the permission to build is given by the local authority. The requirements on the so-called Prüf-Ingenieur are very high. The requirements state, in principle, that he should be very highly qualified, he should be experienced, experienced both in design and in execution. I think he has to prove that he has been successful in the profession for 10 years. Then he can get the licence.

I did this job for more than 10 years and I would conclude from this experience, that the necessity of third party checking depends on a lot of things. I want to mention here first of all the legal situation in the country. What does the public law require? Is there in the law stated an overall personal responsibility or not. It will depend on the contract between the client, the designer and the contractor. In which way are the responsibilites stated? Then, the necessity, in my opinion, depends very much on the qualification of the designer. Are these requirements for the qualification of the designer or not? For instance in our country we do not have up to now any legal requirements for the qualification of a designer. In recent years a new danger has arisen in connection with computers. Everybody can buy a personal computer and the necessary software and then produce as many calculations as you wish. In many cases these people do not have the necessary qualifications to understand what they produce with their computers.

Another item may be the size of a design firm. In larger firms it is possible to introduce an internal independent control of the whole design process. In smaller firms this is not possible because the necessary people are not available.

MODERATOR

Before you go on, can I just interrupt you for a moment. I think, you have raised a couple of points there and I think they are probably worthy of discussion; they are pretty important. It seems to me that the issue of the legal situation in computer use may well be the issue that we might discuss before we move on to some of the other issues.

T. KUESEL, USA

The characteristic symbol of modern civil engineering is the computer. It has enabled us to undertake works of great complexity and to resolve problems that were so difficult they could not be approached by previously available methods. But I am troubled that the danger of this marvellous instrument, from the standpoint of quality assurance, is not properly appreciated.

I would give three examples:

The first is a space frame for the roof of a sports arena, which was very thoroughly analysed with a thick computer output, thoroughly checked, and the full formal quality assurance program was carried through. It was only after this large structure collapsed in a huge heap of twisted pipes that it was discovered that the structure analysed by the computer was not the one that was built. The analysis assumed that each node of the space frame was braced in both lateral directions but in fact it was braced only in one direction and so the first pipe buckled, which led to the next, which led to a pile of twisted pipes.

The second example is the erection of a tied arch bridge. It happened to be designed by my firm. The construction contractor chose to erect this structure in a special way. He submitted a very detailed analysis of all the stresses under erection conditions and followed through each stage very carefully. Again, a huge pile of computer output. I suggested to our engineer who was assigned to check it: "make me a hand figure on the stress at the mid-panel point." He came back in half an hour and said that the bridge will fail and fall into the river. The contractor reported a day later that we were correct and the reason was that the computer had not been programmed to print out the stresses at that point. This much computer output without finding where the critical point was, which was obvious by inspection.

The third case is even more astonishing: a railroad station which includes a bridge across the railroad tracks to contain the passenger concourse. The structure was beautifully designed, very thoroughly detailed, very well constructed, with independent checks, and a construction manager for the construction. The entire process was carried through beautifully. The structure was indeed erected, short of the finishing stage, structurally complete. At that stage the construction contractor proposed some small change in the erection of the interior finish and the construction manager, thinking this might have some effect on the design, dug out the original calculations. He discovered that the calculations were based on the use of high-strength alloy steel. But no one had bothered to indicate this on the drawings and specifications. The contractor had made it out of mild steel. The lawyers argued over this for two years and last month they finally started to take the structure down and start all over again.

Now, the common thread of these three incredible stories is computer mesmerism. That reasonable, competent, honest engineers, who plainly know better, were blinded by the fact that this was all done on the computer and, therefore, it must be right and the details were all checked without anyone thinking of the overall problem.

I call for reinforcement of Dr. Knoll's careful man, of the one who thinks of everyone else's problems, who gives an overall view to the frame and who is not getting lost in the forest of checking over details that are irrelevant to the real questions.

MODERATOR
Thank you very much for those entertaining anecdotes. I think, just to keep the proceedings going, we must limit the length of the contributions a little. So I would like you to stick to about 3 minutes or so if you can possibly manage to do that.

A.G. FRANDSEN, Denmark
I am very astonished to hear Professor Turkstra stating that he does not know how to check. I have been practicing checking in my professional life for almost 40 years. We have descriptions for doing this. It is not imposed on us by law, it is pure common sense and experience why we do it this way. We have different degrees of checking. We have an overview check on the one hand, where we check all assumptions and main dimensions and that the results have been used correctly in the drawings and specifications. This is one thing which is always done. It is done by an experienced engineer and it will take care of gross errors and all the things mentioned by you should be covered by such a check.

At the other end of the process we have a detailed check. It is not necessarily done by doing exactly the same calculations once more. It might be done in a different way, but we shall check all results and that the results are based on the right assumptions and that the results are carried through to the final points in the correct way.

The things mentioned by Tom Kuesel should have been covered by such a checking, as I have described here, because you have to see that the results are correctly used in the final design and also that the assumptions correspond to the actual drawings. I am also astonished to hear Professor Melchers say that the consulting engineers are not willing to say how they check. Now I have told you about the way we do it.

MODERATOR
Nice to hear so. I think the point of Carl Turkstra's remarks and perhaps the sort of thing that I was talking about is that we would like to look at comparative systems. Is one way of checking better than another and what are unimportant things to check? But I will leave that to you to think about.

D. QUINION, UK
I have a very small dictionary and its definition of assurance is "comforting assertion that all is well". It does not say anything about that it is "probably well" and I believe the public, in assessing structural engineers, want positive assurance. They want to be comforted that the structures we build are fit for this purpose, and that they will not entail wholesale repair and maintenance which disturb their use or lead to the waste of public money. Probability must relate to acceptability, under the consequences that something might not have performed in the way that we would wish it to.

Take an example from temporary works. You have to decide, for instance, what the maximum wind speed might be during the life of your particular erection. It is uneconomic to design for something which might possibly occur. So, in the design of structures for wind conditions, wave conditions, other severe environmental conditions, one has to make a judgement. The judgement one makes is: what is the consequence if you get a worse wind speed or wave loading than the one you have taken in the design. If you can accept the consequences, then you can design on a much lower loading. When you design for a maximum wind speed of 40 miles per hour, you know work has probably stopped on that structure. At 60 miles an hour, it is probably stopped all around that structure. If you can accept the cost of repairing or replacing it if it does happen to sustain damage or collapse, then that is a sound basis on which to proceed; particularly if you took the additional step of making sure that when these wind speeds are approached, people are cleared from the area. If on the other hand the consequence of collapse goes into a public street where other people are, then you have got to design it absolutely safe.

I would want to make one comment on the probability design against ship collisions. What if they redesign the ships in the next 50 or 100 years? So instead of being of conventional shape and load, you have something more akin to a hovercraft, perhaps with a 1000 ton load, moving at 60 or 80 miles an hour. It will go straight up an articifical island and go straight into your pier. Or have you catered for that?

O.D. LARSEN, Denmark
When making risk analyses for ships colliding with bridges, you always try to look into the future and that is impossible. So, it is very likely that there will be ships in the future, that we did not think of, when we designed the pier protection, but I feel that the main thing is that we at least now consider this problem. We will have to trust that, when ships appear in future, which are dangerous to the bridges, then somebody will notice it and take action. Hopefully, he will assess the risk and upgrade the pier protection if needed.

G. NAWAR, Australia
May I just ask Mr. Quinion, when he mentioned that if there is a risk of loss of life in these temporary works, he endeavours to make his design absolutely safe. I am just wondering what he meant by "absolutely safe"?

D. QUINION, UK
When the public could be at risk then you would design it so that physically it could not be removed unless something absolutely abnormal occurred.

G. NAWAR, Australia
Now, "absolute" is not quite "absolute".

D. QUINION, UK
If it would be so abnormal or unpredictable, I would be satisfied that people would not be placed at risk.

G. KÖNIG, FR Germany
I would like to refer to the definition which was given by Michael Baker that quality assurance is to assure good performance of the structure. I would like to exclude those cases reported now, and previously by Mr. Kuesel and which can only be excluded by independent checking. But by looking for a good performance during the service life, I would say, it is possible to model the problem. Sure we need to gather more knowledge about the elements we introduce into the model.

J. WYNHOVEN, Australia
I would like to get the panel to talk a little bit more because it must be awful sitting there and just having to listen. That is why I will direct a couple of questions to them and the first one is to Mr. Nawar concerning his lecture. I would be interested to know how much compensation that organization has paid. I wish I had my house on top of one of those mines, then I could attend IABSE-Conferences on that basis. At the moment the firm has to pay.

And the other one is a general question to Mr. König and also to Mr. Knoll and that is looking at the problem with the concrete bridges and their deterioration. Most of those problems were created 25 years ago. If I look back on my career 25 years ago, supervising concrete and to insist on contractors to actually provide adequate cover to reinforcement, it was not easy. The belief was that as long as the steel was out of sight, it would probably last forever. I of course started young enough now to be involved in having to fix some of those problems. Not all were created by our firm, but I think those problems occur in every country, I think even in Denmark, where they do that checking. I would like to hear the panel say what can we do now to ensure that the new materials which we are using are not going to cause problems 20 years from now. How do we get that quality assurance, how do we convince the people out there doing the work - it is a human issue.

MODERATOR
Thank you Jack. I just pass this on to the panelists before we move on. - Perhaps you could give us a quick answer, George, about the compensation.

G. NAWAR, Australia
I am sure that the level of compensation can be related to the sort of damage that has happened. But in most cases the purpose of the study was not really to assess the amount of compensation. The reason for the study was to provide a decision making tool as to what is the expected total cost of repair to the damage at a particular area, not really as related to one individual house.

J. WYNHOVEN, Australia
Once you have established that you have caused the settlement of 40 mm and the house is all cracking up and the wife leaves the husband because she cannot live in the house anymore, surely you do have to pay. I mean, once you make an issue of these things, you have to pay. The Court would surely make you pay and you must have paid out compensation.

G. NAWAR, Australia
This is really going a little bit into the legal aspect. The housing is controlled by a Mining Subsidence Act which stipulates quite clearly that we are only liable for the repair and not for paying compensation for a wife leaving her husband.

MODERATOR
Thanks George. - I think we will move on to Professor König.

G. KÖNIG, FR Germany
I think, answering the second question of Mr. Wynhoven, thorough examinations, thorough research, thorough tests and pilot studies, and providing some additional elements which can compensate if your new material does not work in the way you expect, can settle the issue substantially.

F. KNOLL, Canada
I would like to add a little bit of background. The background of those bridges in Germany - I was active in Switzerland at the time which had rather similar cases - is quite involved with political circumstances, where at the time the public and the public leaders were led to believe, that you could get bridges cheaply - as cheaply as theoretically possible. So the saving of the last cm^3 of concrete or of the last gram of steel was a matter of nearly religious belief and everybody tried to make more slender bridges and save small quantities to make it look good on paper. Also, of course, the work was always given to the lowest bidder. Now, that is probably still the same, politically and in society and it becomes now a matter for, I think, our careful man in the sense of the whole profession, to persuade the public that this is not really the best way to go. Here we are looking again at what came up yesterday, which is the total cost of structures as a criterion, including maintenance and the cost of future trouble rather than just initial construction cost.

R. RACKWITZ, FR Germany
I would like to generalize this a little bit. There are of course problems with new materials, new production and construction methods, which are not foreseen. The same may be true for new types of buildings for new purposes. But there should be a clear distinction between what can be foreseen by the profession and what cannot be foreseen. What cannot be foreseen we have to leave to later generations. But we have to be very careful to shoulder our responsibility for what is foreseeable.

B. HILLEMEIER, FR Germany
In practice the involved parties proceed pragmatically in the following way: If we develop a new material, for instance a fibre reinforced concrete, then we are taking a step into a unknown area. The size of this step must not be too big. It results from extrapolation of known and approved facts and of experience. Neverthe-

less, the client regards this new development as a increased risk which he is not willing to bear alone. Thus, he tends to prolong the period of guarantee of the contractor. This obliges the contractor to perform extensive testing and to involve experts in order to minimize his risk. Additionally, this request of the client may increase the motivation of our personnel to reach a high quality standard.

J. MENZIES, UK
I would like to add to the debate on the question of "what do we do now to prevent problems occurring in 20 years' time?" In other words, how do we provide assurance that the future performance of current constructions will be satisfactory. I would emphasize that the problem has to do with innovation and change. We must monitor changes. We must try to identify changes which are going on and assess whether they are of benefit in terms of longterm performance of our constructions or not. Some changes are obvious and we see them and we can easily assess their effects. But others are more difficult to recognize. Take, for example, changes in the constituents of cement. They may be quite subtle in terms of, for instance, fineness of grinding or in terms of particular materials put into cements. In what way might these changes effect the longterm durability of concrete structures?

At the same time I would support Professor König's remarks that we must monitor the performance of constructions which we put up yesterday and also those which are built today to assess their behaviour as time passes to give us an early warning if some of the developments which have been introduced into them should in the event turn out to be less satisfactory than we had hoped.

MODERATOR
Are you suggesting that some of that should be formalized? When you talk about monitoring.

J. MENZIES, UK
Yes Mr. Chairman, I think that it would be well worth the expenditure of resources to monitor the performance of at least a proportion of our constructions as time goes by. The question of course is: Who is going to do that and will the client pay and if not, who is going to pay?

MODERATOR
Well, I think that is a wide area for discussion and I will leave that for lunch.

W. SMYTH, UK
It is a question of data. Obviously the way much engineering goes on is a combination of theory and practice. We make theoretical models and we have to have data with which to check those models and calibrate them.

Now when we are talking about the behaviour of reinforced concrete or even the behaviour of new materials, we can actually make physical models and tests but when it comes to gross errors what on earth do we do and how do we get any data? One of the problems is that when there are serious accidents, there are usually law cases, there are insurers involved, everybody shuts up about it, and nobody wants to talk. Even if you wanted to talk about it, your insurers will not let you. So how do we go about acquiring the data which is necessary to put into these theories?

G. KÖNIG, FR Germany
I think the best way of monitoring is to observe a large family of buildings and to classify the damage data. Then you will find that more or less all structures are suffering from the same type of damage distribution, starting from small damages up to the biggest ones. It is just a question of time, of the lifetime of the structure, which part of the distribution is filled in.

G.F. FOX, USA
Just a short note. In the United States there is an Institute at the University of Maryland, I believe, that is devoted to doing nothing but collecting data on failures. It is called the AEPIC-Program - Architectural Engineering Performance Information Center, if I've got it right. So eventually we will at least have some data.

K. SRISKANDAN, UK
It was mentioned that we take account of things as much as we know today and leave the rest to the next generation. Unfortunately, in some cases, we happen to be the next generation, having to deal with structures which were designed by the former generation. I am referring to bridges which were designed a long time ago, which are now called upon to carry heavy loads and in the same way as in the ship collision question, there is - as far as I can see - only one way to deal with it; assess the structure to see whether it can carry the loads. If not, weight restrict or prohibit the use of these heavy loads coming on until the structures have been strengthened. In other words, in order to be assured of the performance of the structure as mentioned by Mr. Baker, control must extend not only during design and construction but also into the use and operational stage.

R.A. DORTON, Canada
I would like to go back to Mr. Turkstra's comment about checking, in particular related to Mr. Frandsen's assertion that his firm does very extensive checking and I am sure that is true of many or most large consulting engineering firms. The office at the Ministry of Transportation and Communication that I manage, processes 300 municipal bridges a year that we are by law required to check. So I have a pretty good insight into the level of checking that goes on. It was raised yesterday, as to whether checking really improves the situation or whether it downgrades the initial design level. In the municipal area, where we are mostly dealing with either small municipalities or very small consulting engineering firms, it is a fact, I am afraid, that the level of design is extremely low once they know that somebody else is going to check. This raises a real problem of responsibility, because we have to put our signature to the drawings and then there is divided responsibility if anything goes wrong. This has brought up major difficulties. So now we are requiring, before we will even check the drawing, that the consulting engineer or municipality puts two stamps on the drawing. One is the stamp of whoever designed it and the second of the person who has checked it. This is one way we think we can get over this legal complication. But in fairness to the consultants, they are in a tough situation being asked to compete for fees. So, one area they are going to drop is checking, if they know somebody else is going to do it. And the other is that they have to have liability insurance and in this tough, competitive situation, they often rely on

their liability insurance and get the job for a low fee and trust to luck.

So when we are talking about level of checking and how we are going to build it into reliability theory, it is a very, very difficult area and probably more so in small projects than it is in large ones.

MODERATOR
Did the requirement, having an extra stamp for checking, make any real difference to the results that you got?

R.A. DORTON, Canada
We are just bringing it in. They are objecting to it in the profession because the small firm, the one-man firm, says he cannot do that. He has got to have somebody else to do it. And we say, a one-man firm probably should not be in the bridge design business. It needs more than a one-man firm to produce the level of expertise applied to a project we think is necessary.

J. WILLENBROCK, USA
Dr. Knoll talked about the "careful man". He said, the question is asked, who that agent is and how institutionalized and formalized quality assurance will enhance rather than hamper him in his beneficial activity. At the end of his paper he says that "strategies for the pursuit of quality ought to concentrate on ways to help that careful man to make him more effective and circumspect through whatever means rather than degrading him to a clerk, whose job is to produce paper for somebody's satisfaction".

I think, what Dr. Knoll was implying is that the careful man is the original doer, either the designer or the construction superintendent who is responsible for the job in the field. I think what he is suggesting is, that these are the individuals that should be responsible for the quality and that if you put anybody else in the process of quality assurance it is not going to work. I would suggest that that doer, that mythical or careful man, is not so careful after all, that he is under an awful lot of pressure to produce a design, is under economic pressure, time pressure, everything else. The careful man called the superintendent on the project, has to worry about labour, he must worry about cost, about schedule, about safety, about everything else. In fact, the reason that society has begun to put an extra party in for quality assurance and quality control is because there are not that many careful men out there and our system is not working. I wonder if you could perhaps address that.

F. KNOLL, Canada
I do not know against what background I have to see this comment. I know of cases where institutionalized quality assurance has been carried out and is working. I have also seen cases where it did not work.

Now, when I am talking about the "careful man", I mean that as a catch word for in my case probably the engineer - because I am an engineer. I see my job in practice to be making sure that my own work is getting done properly and that does not just mean calculations and drawings when they leave the office, but also when the drawings get transformed into executed structures. In a wider sense

I would think that the "careful man" should be everybody concerned with construction who, after all, earns his living from that construction and should be concerned with the quality of his work because finally, it will be to his own good. I don't know if that comes close to an answer to your question?

J. WILLENBROCK, USA
It does to a certain extent, but what I am saying is that the reality of the world out there is that this "careful man" cannot possibly handle all of it equally well. I think what we have seen over the last 10 or 15 years is, it is necessary to bring in another "careful man" in there, who does not have to worry about cost, about schedule, about the other things - the only thing he is responsible for is the quality of the system. And we as engineers do not want that extra careful man in there, it has been imposed upon us. But perhaps we as civil engineers have not been as careful enough as necessary.

S. ONO, Japan
My pessimistic idea is that the present structural analysis is too computer oriented. We must probably bring up the youngsters so that they may develop proper structural senses through experience. Through such an apprenticeship we were taught by our seniors how to draw structural details, how to fasten high strength bolts, etc.. In that respect I would like to hear some comments from the German participants on the working value of the "Prüf-Ingenieur".

MODERATOR
Thank you very much for those comments. I think most of us appreciate the point that you are making.

R. RACKWITZ, FR Germany
Independent checking probabilistically means that we should have independence of error occurrence and detection. An error should not remain undetected because the checker relies on the design engineer and vice versa. We made some studies on this subject. In one alternative we allowed the design engineer to use double time for doing the job. In other words, he can check himself, which clearly should reduce his error rate. In another alternative, we introduced an independent checking by a "Prüf-Ingenieur" or an independent engineer in the same firm. We found with realistic parameters in our numerical study that the second alternative is more efficient. I do not say that these results are final. Nevertheless, wherever possible we should introduce these two levels. However, design and checking is actually organized.

G. KÖNIG, FR Germany
The checking by the "Prüf-Ingenieur" in FR Germany is done mostly in the way as it was described before, not using large computer programmes again, but going more into the governing details and assumptions and making just rough calculations of the overall behaviour. So, I think, gross errors can be detected and are detected in most cases.

A.G. MESEGUER, Spain
The qualification of the engineer has been recognized by everybody to be one of the main points in quality assurance. To my knowledge there is one country, Finland, in which a new code establishes three classes of structures and asks for and defines different levels of

qualification (education plus experience) for the engineers. This is important and I would like to use this occasion to put the question: Is there any other country with such a practice and can we have more information about this kind of experience? I know that our Finnish colleagues are happy with their system.

K. SRISKANDAN, UK
The experience in our country is not related to design but it is related to the independent checking of bridge structures, where we have three categories of bridge structures. The simplest structure can be selfcertified, in other words the designer certifies that he designed the structure and also certifies that it has been checked. The second category of structures must be checked by another team, but it could be from within the same office. The third category of structures is the most complex class of structures and must be checked by a completely independent office. We ask for complete independence in order to eliminate or minimize errors from in-house practices.

A.G. MESEGUER, Spain
Thank you very much. Just one more question: do you then have three classes of engineers, first class, second class and third class?

K. SRISKANDAN, UK
It depends on experience etc..

L. VU HONG, France
The question is raised on the classification of structures. I do not want to present right now my paper of tomorrow morning, but I just want to say that the quality assurance system we have developed and implemented is based on the classification of not only structures, but also structural equipment and components for the whole project, and this for each main activity of a project. Depending on the classification, we will actuate a program not just for design control, but for everything, for procurement control and manufacturing, for construction and documentation etc. The classifications depend on various factors, depend on the complexity of the activity or the items we are going to do, depend on the maturity of technology that is new or a proven one and it depends mostly and lastly on the consequences of a malfunction. The classification list is done at the very beginning of the project and is part of the design and the classification document is a design document.

J.S. SODHI, India
There is one question on safety of structures. One of our speakers said that meeting with the requirements of a code is not enough. So, whoever the designer is, he must show that the building is absolutely safe. We build buildings and bridges for the government and so far as we are concerned, as long as we meet with the requirements of the code and provide for a reasonable safety, or a practical safety, it should be good enough. Even the big firms who build bridges for us on contract, would only provide that they will meet all requirements of the various codes as available in the country. Absolute safety in civil engineering structures is a myth. We are a rather poor country but I do not think that even a rich country can afford a structure that is absolutely safe.

B. RICHMOND, UK
I am actively concerned with the use of new materials as well as traditional materials related to bridge structures and other structures and consequently in determining new approaches and criteria for safety and performance. We find that probability methods, in particular, are of very great value to us in these developments. I would like to mention, however, one example where I think the potential use of a new material could perhaps help us in assessing whether we are thinking in the right way about the use of materials even though it is a hypothetical case. In fact this was an example given by Dr. Beeching of ICI and concerns glass as a material for windows used almost universally for buildings. What would happen if, until now, we had made use only of plastic windows and if a revolutionary invention had been produced, which suggested we should now use this material glass for windows. How would it be possible to introduce what we know to be, a first class, very effective material for windows. The questions of safety, the possibilities of windows breaking and lethal showers of glass fragments falling from 50 story buildings, covering the whole of a city would, I think, be the immediate reaction of all right thinking engineers, but also laymen. I think, if we keep such an anomaly in mind when assessing new developments, it perhaps helps us to put in perspective the criteria we adopt.

MODERATOR
Thank you very much. It is a rather thought provoking comment, but I wonder how much the legal system governs those sorts of situations.

We must close very soon, so there is probably only time for one more question.

A.G. SIMPSON, UK
I would like to touch on one or two points that have been mentioned in the context of the level of checking and to relate these to Angus Wilson's paper dealing with checking by insurance agencies. The fee available for insurance checking is extremely limited and a method has been developed which really falls into three stages:

Firstly, the concept is checked; is the structure suitable for its intended use? Is it suited for the natural conditions in which it will be placed? Secondly, some very quick hand checks are done in order to try and avoid the situation mentioned by Mr. Kuesel (gross structural errors). Finally, and perhaps the most important is that the details are checked. I would submit that the majority of deficiencies and failures are not because the concept is wrong, but because the details are wrong, because prestressing ducts are placed in the wrong position, because cover is inadequate, because cracking is inadequately controlled and stiffeners are missing. That, I fear, is the main source of errors and should be the main objective of our efforts in carrying out checking.

MODERATOR
Thank you very much. I was rather struck by Mr. Wilson's paper and the process they try to introduce in the U.K. It puts a slightly different slant on the whole business of checking. It may pay to look at that paper, even though it is not going to be presented.

J. MENZIES, UK
It occurs to me that we have this morning really been only talking about the major half of what is done to provide quality assurance, i.e. the work immediately associated with a particular project. The smaller perhaps, but nevertheless very important aspect which influences quality assurance is the legal framework within which constructions are made and the technical back-up of codes of practice and the like. It is not unknown for codes of practice actually to give inappropriate advice and for problems in structures to arise as a result of that.

MODERATOR
Thank you very much. It is rather remarkable that we had so little comment about the legal side of things. It seems to me that that governs a lot of what we do and perhaps you ought to think about that a little bit more in the next day or so.

Well, that brings us to the end of this seminar session. We must wind up, otherwise we are going to get into trouble with our organizing committee. I hope you found the discussion useful and stimulating. On your behalf, I would like to thank the panel very much.