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Opening Discussion

Moderator: Carl J. Turkstra, Prof. Dr.
Polytechnic Inst. of New York; New York, NY, USA

Panelists: Bernd Hillemeier, Dr.-Ing.
Hochtief AG; Frankfurt, Fed. Rep. of Germany

Franz Knoll, Dr. sc. tech.
Nicolet, Chartrand, Knoll + Associés; Montréal, PQ, Canada

Robert E. Melchers, Senior Lecturer
Monash Univ.; Clayton, Vic., Australia

K. Sriskandan, Chief Highway Eng.
Dep. of Transport; London, UK

Yoshio Yokoyama, Dir.
Ohbayashi Corp.; Tokyo, Japan

Taking part in the discussion from the floor:
R.A. Dorton, Canada
G.F. Fox, USA
L. Grill, Australia
G. Haaijer, USA
P. Mtenga, Tanzania
G. Nawar, Australia
F. Nishino, Japan
A. Nowak, USA
L. Vu Hong, France
B.P. Wex, UK
J.H. Willenbrock, USA

C.J. TURKSTRA, USA, MODERATOR
Welcome to the opening discussion of this conference on quality assurance. This discussion is meant to be very general in nature. We hope to identify some of the major questions involved in safety and quality assurance. We also hope to establish useful themes for debate and analysis. Most importantly, we hope to initiate active audience participation which will continue throughout the conference. Earlier this morning we heard four excellent lectures which provide an exceptional foundation for our task during this opening session.

To initiate today's dialogue we have a distinguished panel of engineers with a wide variety of background and interest. Starting from the left we have Dr. Franz Knoll who is a Consulting Engineer from Canada. Dr. Knoll has designed and inspected many exceptional structures in America and in Europe. To his right is Dr. Bernd Hillemeier who heads the quality assurance department of a large German construction company. Next is Dr. Robert Melchers from Australia who has been active in research studies related to human error and other aspects of quality assurance. To his right is Mr. Yosho Yokoyama who is the General Manager of a major Japan based international construction company with many years of practical experience in construction engineering. Finally, to his right is Mr. Sriskandan, who is Chief Engineer with the U.K. Department of Transportation with general responsibility for all aspects of highway construction. In the proceedings of this symposium he has presented a study of the causes and practical means of control of errors. I will ask each panelist in turn to make a brief statement of what they think are the major issues as seen from their individual professional perspectives. Then we will open discussion to the floor for comment, questions and suggestions.

Let me begin the discussion briefly with a personal statement. When I think of quality assurance in construction, the first thought that comes to my mind is the idea of conflict: conflict between man and nature to build. A conflict between profit motives and good practice; conflicts between individuals with different interests and loyalties; conflicts between the requirements of the task and the talents and skills and resources needed to do it.

Not long ago - this is not a true story - the President of a major American University was disturbed by the conflicts between his professors. To understand the nature of this conflict and its origin he decided to do a small survey - in other words, a bit of research. He decided, he would ask several people a simple question and compare their responses.

He went first to the Head of his Mathematics Department and said, "I want you to tell me how much is 2 + 2?" "Well", the Professor said, "that's easy - 4". Next the President went to the Head of his Engineering School and asked again: "How much is 2 + 2?" The Professor picked up his calculator: "the answer is 4 point 0000". Finally, the President went to the Head of his Law School. He went into the Professor's office, sank comfortably into a deep leather chair, rested his feet on the thick Persian rug, looked around at the antique bookcases and asked his question again: "how much is 2 + 2?" The Lawyer moved nervously in his chair, looked out the window, got up, went to his office door, carefully locked the door, came back, leaned over the President and said: "what do you want it to be?"

I would like now to ask the panel to make a statement of what they think the major issues and problems are in quality assurance beginning with Franz Knoll.

F. KNOLL, Canada
Since I am the first on the panel to introduce my problem, I may say that I am representing the practical engineer who is usually the first party on the scene, in a way, in the building industry and I would like to point out how the problem of quality assurance confronts us in practice. Classically the engineer is one of the very few parties who is intimately involved in the construction process from beginning to end, from the conceptional design and the digging of the foundations until the building is finished and completed and even used. This has been true even in ancient times, when we were was not called engineers but simply builders.

Now the engineer starts without a design, makes some calculations and then he considers the structure to be and, if he is not a great fool, he is never quite satisfied with what he has done. So, he goes back and checks. Checking means to review the design, to think about it, to turn it around and to look at it from various angles until he runs out of time, in most cases.

B. HILLEMEIER, FR Germany
The quality is strongly influenced by the following three factors: responsibility, precision and competence. One must be aware that these are human factors. Quality assurance in civil engineering construction is quite different from quality assurance in manufacturing industries. This difference lies in the fact that in civil engineering each construction is a prototype whereas in manufacturing industry products are manufactured in series under relatively constant conditions.

How is it assured that we promote the human factors? A great part of our quality assurance work is quality control. We must look at the detail and that is normally done by checking. Too much stress on checking, however, can lead to bad quality. Machinery production requires permanent checking. But people should not be checked like machines. A checking on people is a psychological task and we are often not prepared to do this task well. Of course, our construction personnel must be always aware that they may be checked at short notice. This checking is but one of the Quality Assurance measures to avoid problems in construction. In our company another means for improving quality was introduced which may be described as follows: An independent quality assurance department with experts for the relevant construction works. The construction personnel know that they can put their technical questions any time to the quality assurance experts. The experts do not hesitate to give them a very fast answer. So we realize that training and giving information to the people on the construction site and the feed back of the experience is a large field which has to be considered even more effectively.

R. MELCHERS, Australia
There are two points that I want to make as an academic. The first I would like to take up is the one of definition. We have had Jörg Schneider tell us in publications about the quality of structures, Marita Kersken-Bradley about excellence, Michael Baker started talking about performance and then he revised that and talked about

fitness for purpose, Professor Shinozuka talked about tighter reliability levels and they all had different meanings to different people. What I think we need is an operational definition. I think that things that have not been mentioned and ought to have been mentioned are: risk, cost, benefit, analysis, utility theory, perhaps in a multi-objective sort of sense. It seems to me at least that that is a common basis for discussion. We are going to ask questions about how much will all of this cost, what is the risk involved, but we need to have some common basis.

I think it must be multi-objective because we need to consider not only the individual parties to our contracts, that is the clients, the users, the engineers. Ultimately, also society is somehow involved and we need to be able to put that into our evaluations. It is interesting then to look perhaps at Professor Shinozuka's other comment about the medical profession. It seems to me that they are in a way involved in a political process both at the micro and the macro level. They look at individual politics between the patient and the doctor but also the politics within society. There is a parallel way that we might explore a bit further. But it comes back to the questions of "what are our objectives and how do we evaluate them?"

If we look at a subquestion that comes out of this discussion we see that reference has been made to comparisons between e.g. the Japanese system of contract administration and e.g. the Anglo-Saxon or American system. Within the latter perhaps the European is yet another possibility. When we talk of multi-objective evaluation, it would be a very useful to start doing international comparisons. There is an interesting paper in the Preliminary Report, which is not to be presented, by Angus Wilson on the French-Italian insurance scheme and that is yet another version that apparently is not very widely known - at least within English speaking systems.

That brings me then to the legal system within which we operate. This is a boundary condition. One which sometimes we can quietly ignore. However, if we are not happy with the boundary conditions within which we operate, perhaps we as engineers should try and change them.

Coming back now to the point that F. Knoll has already made and was implicated in some of the earlier discussions, I think we also need an operational definition to answer questions like the allocation of resources for quality assurance. Just how much money do we spend on checking and what is its effect? Just what sort of documentation do we need and what does that cost? What are the costs of codes? And when I say cost then I really mean a broader picture than just monetary cost. Perhaps turning a little closer to my own interests now: I am interested in the sort of research which is necessary in this area. The sort of question I would like to ask is: Can we, as engineers, do that research, can we do it all or can we only do some of it? Do we have to get involved with our research operations people from the management side and from operational research sciences? I think the answer to that is probably "yes", but it is not going to be easy. Do we need to look at sociology and psychological sciences for some clues in these areas?

Y. YOKOYAMA, Japan
I am going to discuss quality assurance from the point of view of general contractors. The overall quality assurance of the structure is an integrated effort of the people concerned with the planning, design, construction and the maintenance of the structure.

In Japan most major general contractors have established a inhouse architectural and engineering department together with a construction department. Those departments are ready to serve clients, assisting in planning, designing, construction and maintenance of the structures they need. I like to call this a "turnkey-service". The advantage to the client who receives this "turnkey-service" is that the procedure of the project is simplified and it is clarified on whom the responsibility lies to maintain the quality, program, cost and safety of the project. When the contractor is employed to serve a client on a turnkey-basis he should assure the quality by integrating the departments concerned.

During the initial planning stages of a project, the clients make specific requests to the general contractor. The general contractor's district manager is involved at this early stage to materialize the clients wishes by organizing the various departments concerned. The design department has the responsibility for the next stage of detailed design. During the construction stage, the site office has the main responsibility to assure the quality and costs. Once the job is complete, the district manager takes responsibility, together with supporting departments, for proper maintenance of the structure. We can see that for the Japanese contractor the system of quality assurance is an integrated effort of the various departments concerned, not just one quality assurance department. So, the Japanese system for quality assurance is a little bit different from that of our colleagues from the Fed. Rep. of Germany.

However, in the Japanese system, there are some problems. For example, the client needs to know how to choose the appropriate general contractor for a turnkey contract. Should he choose by price, by company size, by experience or by some reputation? The less expensive price does not always give the better quality assurance. Also the client must have complete confidence in the general contractor's in-house quality assurance procedures and personnel.

Furthermore, in Japan, like in most countries of the world, for the majority of the projects, especially for public works, design and construction are usually done by separate organizations. But no matter which contracting system is employed for quality assurance, the integration of the people or departments concerned is mandatory. Even in the case of design and construction being separated, close communication or feedback from both sides is very important to assure the quality of the project. We, therefore, should find appropriate ways of communication between the designers and constructors to achieve the comprehensive quality assurance.

K. SRISKANDAN, UK
I am supposed to speak as a client and, I will assume that I am a lay client and, therefore, I do not know what quality assurance means. However, as a client I will have certain requirements for structures that are designed and built for me. I would want the structure to be safe and be usable for its intended purpose over a prescribed period, subject of course to my not materially changing

the use of the structure and carrying out regular inspection as advised by my advisor and carrying out routine maintenance as necessary. I emphasize routine maintenance because as a client I would not want to be having to carry out excessive and expensive maintenance.

What this means is that the client will want the design to be conceptionally correct in all respects. At one extreme, he would not want the structure to be simply a mechanism that fails at its outset, nor would he want the structure to be beautifully designed and constructed, but then fail because of some part of the structure cannot be inspected or seen during inspection and therefore fails during its life due to corrosion or some aspect like that.

The client will then want the structure to be designed by suitably experienced people in accordance with normal standards and constructed in accordance with specifications. There will be the normal controls applied during the design and construction process. But as a client I would wish to know firstly, how much resource effort to put into these control processes and also what should be the distribution of this resource effort between say the concept, design and construction processes.

Mr. Baker said that you could have data banks which can give you some idea of the types of problems that have arisen in the past from which you will have some experience, but what does one do about the future, because every time we think we have solved one problem, new problems crop up. We have, for example, changes due to the energy crisis in the properties of cement, new additives in concrete, new technology resulting in sophisticated computer programmes in design, changes in the organization of construction personnel with more and more disciplines being introduced, highly competitive tendering due to a perceived reduction in total construction budgets. Now how can all of these new hazards change the quality of the structure? I think these are subjects which we hope we will have answers to in this symposium.

MODERATOR
We will now open the session to questions from the floor: questions, comments to the panel and also comments concerning the previous speakers.

If I could summarize what we have heard so far, the consulting engineer says his problem is checking strategies; one contractor says his problem is dealing with human factors, education and training; the research person says his major problem is definitions and the statement of objective functions; another contractor says the problem is organization, differences in quality assurance procedures and communication within an organization; and, the public works official says his primary problem is resource allocation dealing with the quality assurance problem.

The first question?

G. HAAIJER, USA
I am a little hesitant to make a comment after we have heard from so many experts. As a respresentative of fabricators in the United States you wonder what the practical applications are. I think the basic objective, especially for civil engineering structures, is

really to do it right the first time. No matter how much you inspect and check afterwards, if you don't do it right the first time, I don't think you can come up with a quality structure. I believe that is what Mr. Yokoyama was talking about in the Japanese approach by integrating quality control during the construction process.

B.P. WEX, UK
I was very interested to hear Professor Meseguer say that the owner wants to minimize life-time cost. That seems to me an absolutely obvious and sensible requirement for any owner. One with which I would think no man in the street would quarrel, let alone civil engineers. Therefore, I would ask whether we should not be trying to educate politicians as well as engineers, because politicians seem to believe that you get the best answer if you minimize the cost of design and the cost of construction. Their mathematical formula (if they have one at all) seems to be minimum cost of design plus minimum cost of construction equals minimum total project cost. I think all of us in this room are sufficiently familiar with the realities of life to know that this is not true. I would, therefore, like to suggest that out of this conference should come an endeavour to persuade politicians that what they really should be looking for is the minimum overall life-time cost and that this is almost certainly obtained by competitive tendering on price for design and for construction.

G.F. FOX, USA
My question or comment is just to the question raised by Mr. Knoll about inspection: who, what, where and when. I think there is an axiom about compliance: to obtain what you expect, you had better inspect. And that axiom, I think, pertains to some comments that contractors should be allowed to do their own quality control which, I think, is good but I still think they must be checked for compliance. My question to Mr. Knoll is that we have two main figures in the construction process - the engineer and the contractor. What is the role that seems to be more and more popular of utilizing third outside parties to ensure compliance by these two main figures in the construction process. Is it advantageous, it certainly costs more, but is it really giving us a better product in the end?

F. KNOLL, Canada
I do not think I am qualified to give the answer here. We know that in some countries, like e.g. in North America, there is usually no such thing as a third agent to look over design and construction and to exercise quality assurance, whereas in other countries like FR Germany or France, such institutions are commonly used. I have not seen any proof or indication which of the two systems works better in the end effect. I think it would be very useful if somebody in the audience, who may be in possession of such knowledge, could give it to us.

F. NISHINO, Japan
I wish to make two comments. One is a short one. There are a number of subjects on gross errors. Our group has studied our Japanese steel highway and railway specifications and our conclusions are that the so called safety factor is mostly for the gross errors, but much less for variability of the material or the loads. This understanding may be a subject to debate, but at least we are believing our conclusion.

The second is - I really appreciated the presentation by Professor Meseguer - for making a distinction between the traditional and present design procedures and also I am appreciating the second comment from the floor. I believe that all engineers were conscious of the total cost, including maintenance throughout history on every project. Not too much attention may have been paid, however, because of shortage of money or tight budget. The engineers may have been forced to take the selections on which the initial cost could be cheaper, although they understood very well that in the future they might have to pay for that. Also politicians play a very important role to make the initial cost a minimum. That is why engineers have had difficulties to design properly. That is one of the reasons why we are now facing maintenance problems. But the subject itself is not necessarily new to engineers.

G. NAWAR, Australia
It seems to me that the objective of the quantification of acceptable risks is a very contingent issue and is something that could do with an exhaustive study from different countries. Whether we can quantify an acceptable level of risk for the different construction processes and if we can agree on such levels or at least have some common approach perhaps at this stage we will be able to have some influence on the legal and the political circles and get more people to accept that nothing is 100% safe. So, at least the objective can be better defined in all the construction and design processes.

LEON GRILL, Australia
I will comment on the statements of Mr. Knoll and Mr. Hillemeier. For 15 years I have been involved in quality controls related to the design stage, checking of projects. Therefore, I will refer to "when, what and who". It has been mentioned that about 50% of the mistakes and errors which cause structures to fail, have occurred in design. Perhaps the percentage is far higher than this. Other sources state that 70% or 80% of the errors have started in the design process. Thus perhaps the largest number of errors could be discovered at this stage. I also believe that checking should be based on more than having greater knowledge than the design engineer. An additional feature of "who" is checking, is that which has been mentioned by Mr. Hillemeier, the human factor. In thorough checking one should not waste time in following calculations, but rather be concentrating on concepts and structural behaviour, with very good attention to details which are the most repeated sources of failures. A keeping in touch progressively with the designer and offering training, I think, is a very good step in the direction of achieving quality assurance.

I have also one question to the panel: I noticed that in relation to quality assurance, a lot of time is dedicated to reliability theory. I will read only one sentence here from the "Journal of Structural Engineering" from June 85 which says: "The actual rates of structural failures have been estimated to be about 1 to 2 orders of magnitude higher than the failure probability calculated from the theories of structural reliability". That means, if I understand correctly, that the figures given by these theories can be up to 100 times away from reality. So, is it necessary to waste time in speculation, or better to go down to practical work of checking in both stages, design and the execution?

R. MELCHERS, Australia
I think I can answer your question. The statistics you cite are correct and generally agreed. And that is why you see reliability people at conferences such as this.

R.A. DORTON, Canada
I want to follow up the comment from Professor Nishino made about designers in the past concentrating on new structures and not taking too much notice of durability and maintenance. Most people go into engineering, I think, because they are attracted to the mathematical certainty they think is required in the profession. Later on they realise the inaccuracy of that. But we are all happy at calculating stresses and that's what we do in our early days and that's all the design codes require us to do. They say very little about maintenance and durability. And although we talk now about the necessity of life-time cost, and we all agree with it, I think if we have to define what needs to be done in the future it covers this whole area. We are trying to find out what is the rate of deterioration, what is the effect of cracking on the life-time and the strength of the structure. These are all really new questions that we have never faced in our codes and they still do not exist in our codes. I think we are perhaps kidding ourselves if we think this is going to improve rapidly, it is only going to happen when - as Mr. Wex said - the politicians are aware of the necessity of it and, secondly, that it is built into some sort of a code format so that the designers are forced to consider it. As professionals you might say we should do it anyway, but under the pressure of cost and time in the design office, very frequently these items in fact do not get addressed and the client often is not sophisticated enough to know the right questions to ask at the design stage.

J. WILLENBROCK, USA
At the risk of getting back to the point of definitions that Mr. Baker made, I would suggest at the beginning of this conference that we clarify the differences between quality control and quality assurance. In the United States the nuclear industry is probably the most sophisticated industry with regard to quality. They provide a very clear separation between quality control on the one hand and quality assurance on the other. Quality control encompasses the technical activities that we, as engineers, perform when we attempt to determine the variance between the standard of performance and the actual performance. Quality assurance on the other hand is a much more pervading concept, it is more an auditing function, a detective function of trying to determine if the overall quality system is working correctly of if something went wrong with the system. I think that is what Mr. Meseguer was driving at. I would like to get a reaction from Mr. Hillemeier and some of the others on the panel. Is there a difference between quality control and quality assurance?

MODERATOR
Thank you. Again I would like to hold off answering the questions in the hope that we get as many comments from the floor as possible. Are there more?

L. VU HONG, France
I was very impressed by the presentation of Professor Meseguer but I would like to add a comment on the comparisons he made between the traditional approach and the new approach. In the traditional

approach he said that the engineer controls the contractor and in the new approach the engineer only supervises the contractor and the contractor controls himself. While I think that even at the time that we did not even hear the word "quality assurance", a responsible contractor did control himself. I think that checking is a part of every activity. Even in our daily activities we perform checking on everything we make. I think, what is new with quality assurance is that the contractor is able with quality assurance to demonstrate at any time that he performed the contract under the controlled condition and that is why the engineer just performs supervision and not control or inspection. That is why I would like to add one definition of quality assurance: "the quality assurance system provides a means of establishing confidence in everybody, in every party concerned, that quality can be achieved as required".

A. NOWAK, USA
I would like to address the issue of selection of the optimum quality assurance levels. This refers to the comments made by Professor Melchers. If we look at the whole profession, definitely the objectives are different than those of the code writers', they are different than those of the consulting engineers'. For example, a consulting engineer usually operates with limited funds and it is a question of the right allocation of the available funds.

P. MTENGA, Tanzania
Whereas the objective is to minimize the total cost of a structure, there may be some specific problems related to some countries. And this is the problem of inputs that may be required in the maintenance of the structure. This counts when foreign inputs come into the picture. You have to hire some companies to maintain a structure and so forth and you find in some countries the balance of payment is so difficult that you may somehow not be able to allocate the necessary funds. The designers should take into consideration the fact that it may be difficult for some countries to maintain the structure, so he should actually try to look at what is available, what is the best way to maintain this structure rather than plan to just taking what has been applied very successfully in the First World. I have some practical examples in my own country.

MODERATOR
Thank you very much.

I would like to ask two or three people on the panel to comment on the themes that came up several times. Generally there is agreement on the importance of checking procedures. One controversial question seems to be the marketing of the concept of life-time costing. Also I think, there is the question of marketing the cost of quality assurance to owners with the suggestion that owners tend to be rather short-sighted, looking only at first at cost for design and construction and not being far-sighted enough to look a little bit more into the future. We have on the panel people in the construction industry and one representative of a government agency and I wonder if these people in construction would comment on this problem - if there is a problem - of being paid for quality assurance and the possibility of life-time costing approaches.

Dr. Hillemeier, would you comment on that first theme?

B. HILLEMEIER, FR Germany
Nowadays the client tends to accept the lowest bid. Durability and low maintenance costs are seldom taken into consideration. The contractors are aware of this and thus are forced to calculate with minimum prices. Consequently, the general contractor assigns tasks to cheaper subcontractors which results in a lot of interfaces endangering good quality. Quality assurance measures help to minimize technical risks by safeguarding interfaces between general- and subcontractors for those works and services which are not performed by the general contractor itself.

I would like to answer Mr. Willenbrock because he asked me directly concerning quality assurance and quality control. I think quality assurance is the framework of all we do and quality control is one part of it.

MODERATOR
Mr. Yokoyama, could you comment on recovering the cost of quality assurance? From a business point of view?

Y. YOKOYAMA, Japan
It is very difficult to find a good basis for the selection of the contractor by the owner. I will give some information at this symposium.

MODERATOR
Thank you. And finally, would you Mr. Sriskandan, as an agent of the government, would you accept a costing criterion which was life cycle costing?

K. SRISKANDAN, UK
I think we do try to make our decisions based on whole life-costs. At the preliminary design stage we look at alternative designs in both, in all kinds of materials and also look at maintenance costs; when it comes to alternative tenders, we look at the actual capital cost plus cost for maintenance discounted back to the present day. And the costs of maintenance will also include, on highway works, costs of delays to traffic during the maintenance operations. Therefore, I agree that we should consider complete life-time costs, which should include not only initial costs, but the "total" cost of maintenance.

MODERATOR
Thank you. It seems we can be a little optimistic in at least some areas that this concept is economically feasible.

That brings this session to a close. On behalf of the audience I would like to thank the panelists and on behalf of the panelists I would like to thank the audience. You have been very patient and I thank you for your very interesting questions. Thank you very much.

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Project and Decision Making

Moderator: Jack H. Willenbrock, Prof. Dr.
Pennsylvania Univ.; University Park, PA, USA

Panelists: Roger A. Dorton, Mgr. Structural Office
Minist. of Transp. and Communic.; Downsview, ON, Canada

Hans Knöpfel, Lecturer
Swiss Fed. Inst. of Technology; Zürich, Switzerland

Niilo Kurvinen, Vice President
YIT OY; Helsinki, Finland

Ryoji Nishihara, Gen. Mgr.
Shimizu Constr. Co.; Tokyo, Japan

T.N. Subba Rao, Managing Dir.
Gammon India Ltd.; Bombay, India

Taking part in the discussion from the floor:
L. Vu Hong, France
B.P. Wex, UK

J. WILLENBROCK, USA, MODERATOR
I would like to begin this panel discussion by introducing the panel members. The first one is Mr. Kurvinen, who is the Vice-President of YIT Limited General Engineering and Contracting Company in Helsinki, Finland. The next panelist is Mr. Subba Rao, who is the Managing Director of the Gammon India Limited Contracting and Consulting Company in Bombay, India. The third panelist is Hans Knöpfel who is with the Swiss Federal Institute of Technology in Zurich, Switzerland. The fourth person on the panel is Mr. Nishihara, who is the General Manager of the Quality Assurance Management Department, Shmizu Construction Company Limited, Tokyo, Japan (with his interpreter Mr. Takahashi). The final panelist is Mr. Dorton who is the Manager of the Structural Office, Ministry of Transportation and Communication in Ontario, Canada.

As I was developing a theme for this panel, I decided to provide each of the speakers with an assignment. The assignment was transmitted to them several months ago. It dealt with my feeling that within the area of quality there are some procedures that are culturally dependent. They apply only to the country in which they are practiced. There are other quality characteristics and procedures, however, that are universal. I asked each of the panelists to review a specific paper that had been presented and to identify those quality practices and procedures that are culturally dependent and can, therefore, not be applied in other countries as well as the quality practices and procedures that are universal and can be applied in other countries. What I would like to do at this time is give each of the panelists about four minutes to present their findings and then we will open it up to a discussion from the floor to perhaps expand upon those comments. We will begin with Mr. Kurvinen.

N. KURVINEN, Finland
There are four aspects which are different in different countries, First, the manner of inspection by authorities. There are a numbers of laws, codes, licences clearly different in different countries. In selecting contractors, the type of prequalification is very different, too.

Further, the way to execute projects is different. In some countries it is quite normal to employ many sub-contractors and the general contractors' staff is small. In other countries one organization will do the whole work.

Third, labourers, labour staff, and labour unions are different. The influence of the unions on the work is unfortunately very essential. The skill of labourers is of course different and in some projects you cannot use local staff. In the Soviet Union, for instance, you have to take your own staff. In Middle East projects it is better to look for labour staff in third countries.

The fourth area, where differences may occur, is the handing in or taking over of the completed work. On Soviet projects there is a special committee that very often has not been involved in the project. It comes at the end and reads the documents and decides if it is OK or not. In the Middle East it very often turns out to be a commercial discussion which may take a very long time. It is often a question of responsibility: who will be responsible and possibly feels scared to take the responsibility.

There are some aspects which are more similar in different countries. I mention for instance basic materials. If you buy reinforcement steel from India, France, Scandinavia or the Soviet Union, you do not take very big risks. There are differences, but basically the quality of steel, cement and timber are similar. It is the same with equipment. You only need to know which type you need and where.

Nowadays the project management systems and the control systems using computers in many countries, will also have the same logic.

In general, I would finally say that work planning and the degree of planning are very important. With good planning you can reach something or you can avoid something. Still it is usually not the technique, it is not the machine which goes wrong, it is the man - it is the human being - and that is why it is necessary everywhere to keep the organization well informed of what is going on, what is the problem, what are the targets, what is the meaning of quality in order to keep all the people, including labour staff, well motivated and proud of their work. Only in this way you can have the best possibilities to succeed.

MODERATOR
Thank you very much. As the second panelist I would like to ask Mr. Nishihara to comment on the paper of Mr. Dorton.

R. NISHIHARA, Japan
My assignment is to review the presentation made by Mr. Dorton of Canada, entitled "Safety Considerations for the Burlington Skyway Project" (and published in the Symposium Preliminary Report, pp. 39-46) and to identify some points concerning his presentation.

First, the points that do not apply in Japan:

In Japan we do not have alternative design bidding in which a bidder can select any one design out of the four designs offered by the ministry. We do not have such a system in Japan. For smaller projects, however, the contractors may propose an alternative design with minor modifications or improvements but the basic design remains unchanged. We do not use the value engineering approach or alternative designs, or optional bidding in this country, particularly in the public work sector.

In the private sector there is a growing tendency for contractors to propose an alternative design or engineering method. When it comes to negotiations between two parties, however, it is still practiced on a unilateral or onesided basis. In other words, the client still dictates to the contractor what to do and the contractor can only listen and agree.

At each stage everyone does his best in terms of quality assurance and then passes it to the next party or the next stage, where the person in charge again does his best in terms of quality assurance. As a consequence, we are all, particularly the client, rewarded with the quality required.

Now about quality practices and procedures that we do have in common: the specific quality required for any structure is completely laid out on the drawings. Sometimes even the methods to achieve that will also be specified in the contract documents.

We do have competitive bidding practice in Japan, in which case qualified bidders are selected and invited to bid. The bid prices are evaluated against estimated prices or the budget, although there are some different ways of implementing this evaluation. We also have the low price limit within the predetermined price range to evaluate the bid prices. A contractor will also be evaluated to determine if he is qualified for the work, by checking the quality of his work or his ability to complete the work in time or within the terms of payment etc.

Finally, the client, or owner, provides supervision over the project based on his engineering standards.

MODERATOR
Thank you. The third panelist is Dr. Knöpfel who will review and report on the paper of Mr. Yamane and Mr. Nishihara.

H. KNÖPFEL, Switzerland
I have arranged my comments to the papers of Mr. Yamane, Mr. Yoshida and Mr. Nishihara into three sections.

First, concepts that have not been used so much in my range of experience are

- competitive bidding by nominated bidders and nominations made by prequalification,

- supplying materials purchased by the owner, and lending large items of equipment to the contractors by the owner,

- to do the business of contracting for construction works only if you have a license, under the construction business act for example. Licensing for contractors is not common,

- at the time of concluding the contract, the method of execution of works and the control method are provided as a requirement. Often we just define the result and not the method of working, the contractor is completely responsible for the way of achieving certain results, and

- the lump sum is used almost always as a method of fixing the construction price. That is not the case in Switzerland. We have, for the works referred to here, mostly unit prices.

Second, concepts that have been used very frequently in my range of experience are -

- the basic concept of Mr. Yamane's paper, including integrated consideration at all phases of the project - the planning, design, construction, maintenance and operation,

- the establishment of standards and specifications for design, construction and maintenance is also quite common, incorporating a wide range and multi-disciplinary knowledge,

- careful design of construction methods and, if newly developed, testing using experimental constructions,

- design of the structures by good consultants. The contractor is held responsible for quality control of construction. Confirmation of the performance by inspection from the owner's side, and

- the sliding scale clause for compensation of inflation. After a lapse, for example, of 12 months from the date of the contract basis.

Let me emphasize that "not frequently used in my range of experience" does not mean "poor"; and "frequently used" does not equal "good". Project organization depends on local conditions and contracting has not been investigated and compared well enough internationally to propose an optimal solution.

Third, I turn to two concepts that did not come up in the above-mentioned paper. I put them as questions here -

- is the fast track concept an ingredient of the actual state of the art or has it a deteriorating effect on quality as a rule? Is the traditional approach the expression of modest project management knowledge, is it out-dated?

- should the public owner be allowed to give the work not to the lowest bidder under certain conditions, and should he have to show evidence that these conditions apply?

MODERATOR
Thank you. The fourth panelist is Mr. Subba Rao who will comment on the papers of Mr. Dorton and Mr. Sriskandan.

T.N. SUBBA RAO, India
I turn to the paper by Mr. Sriskandan first. His report on tendering practices with a view to providing a measure of quality assurance at the very outset of a contract brings out the present state of the art in Great Britain and to a great extent the Commonwealth countries.

Of particular interest is the observation that all design and construction should be independently checked. Consultancy is contracted out to consulting engineers and the consultant so appointed is responsible to the owner only but he has also responsibility to society.

A very important aspect Mr. Sriskandan has highlighted and which is indeed a very important factor - insofar as developing countries are concerned, where the hunger for shelter with low cost housing schemes is paramount - is the responsibility of the developer to the ultimate user. The developers invariably put up the least at as minimum costs as possible and at as fast a pace as possible. Finally, the wanting population purchases it to gain a measure of shelter but find, after a period of time, that what they bought has already started providing tremendous problems for their living and that the comfort they purchased is not there. For this, who is responsible, and, what kind of independent checks are required?

Now, I would like to get back to Mr. Dorton's paper to the extent it has not been covered by Mr. Nishihara. His proposition that in his country no alternative design will be allowed is also the Japanese

practice and which Mr. Dorton defends in his paper as contributing, eventually, to safety, i.e. no claims from the contractor, cost savings and the like. Is it a procedure in the right direction? Does this not inhibit creative thinking, does this not prohibit development of new technologies?

But the most important message which I take home with me, is the message given by Mr. Meseguer about the triangle of balance between the user, the ideas which should manifest themselves, and ultimately, the persons involved. They form, in my opinion, the trinity of tot for quality assurance. It is my attitude that the training you receive inhouse, the traditions that you want to maintain in the company, these are the basic modulations. They could surface themselves in several ways but eventually it boils down to the basic component - the human being and his attitude. So long as that is not right, the eventual result can never be right. What shall be your specifications, what shall be your quality assurance programs?

One word to prequalification: when you prequalify a contractor as you normally prequalify a consultant, you should ask the contractor what kind of works he has performed before, obtain credentials of his past works from the authorities concerned, find out what kind of manpower and resources, financial and material and plant resources, he has or can lay his hands on. If he does not have any technology inhouse, which sub-contractors is he going to employ - all to give the client the desired quality assurance. Much of it has been practiced on the Burlington Skyway Bridge and Mr. Dorton's reference to it is indeed very revealing.

MODERATOR
As the last panelist I would like to ask Mr. Dorton to comment on the paper of Mr. Colenbrander on the Eastern Scheldt Project (published in the Symposium Preliminary Report, pp. 31-38).

R.A. DORTON, Canada
The paper falls quite well into the categories the Chairman had asked us to consider of those procedures that are culturally dependent and those that can have universal application. I have expanded a little on the term "culturally dependent" to include, say, project dependent because of the complexity or sheer size of the project that Mr. Colenbrander indicated. There is one such item, being a multi-billion Dollar contract, each project manager (5 of them) was responsible for developing the quality assurance requirements for his own field. I think this is a concept that was applicable to this project but is not likely to come up on the general projects we are involved in.

One item that was unique to my knowledge was the idea of audit days. This was applied to very complicated procedures. They in fact invited outside experts to come and witness the actual project implementation and to provide their expert advice right on the site. Finally, there was an element of quality assurance that, I hope, was peculiar to this project and which I would suggest should not be implemented elsewhere, namely involving the Parliament in the quality assurance program.

Turning to the items in that paper that are common and can be applied almost universally, the question of the feed-back loop principle was defined by Mr. Colanbrander. Critical parts were

subject to an independent outside design check, which most of us think is an important aspect and can be applied universally.

A training school was established at the start of the concrete construction for both skilled and unskilled staff. We may think that this is perhaps only justified on a large project. It is perhaps something that could be considered on smaller projects, too, in order to improve quality.

The design expertise was represented in the field as part of the quality assurance program. Often on other projects the design capability has been separated from the construction capabilities. This aspect is independent of size and could well be followed on all projects. Finally quality assurance extended to the operational phase with the issuing of a maintenance handbook, this has come up before here and I think this is a very important extension of the quality assurance principles.

MODERATOR
Thank you Mr. Dorton. Is there somebody in the audience who would like to react to one of the panelists?

B.P. WEX, UK
First of all to Mr. Subba Rao and his sound advice about prequalification of contractors. His advice was to the engineer: Look and see what the contractor has done before, get his record. That's fine. You put up your list of prequalified contractors and then the client, who is powerful, says to his engineer - and I am talking about not in the U.K. but in countries in the great wide world, where it can be rough - I want "so and so" included. I would like to know how Mr. Subba Rao proposes to get over that kind of arm twisting. Unfortunately, the engineer, in many countries, no longer has the power that he used to. This is not in the interest of the people at large and it is not in the interest of the client, but I do not know how to get over it. That is point 1.

Point 2 is, Mr. Subba Rao again, about alternative designs. I am sure we all agree, consultants, contractors, clients alike that, where the circumstances are appropriate, alternative designs are desirable. It keeps us all on our toes and if we are frightened of alternative designs that means we feel that we are not on our toes. So I absolutely agree that should be done where appropriate. But I think, I may have misunderstood Mr. Nishihara, and this is where I may be off track. I understood him to say that in Japan it is possible for the contractor to change parts of a design without further reference to the designer. That there would not be an overall change in concept but parts could be changed without reference to the designer. Now, if I am wrong, I withdraw the question. But if I am right, I would like to say that this must surely confuse responsibility enormously and I would come back to Mr. Sriskandan's point made in his paper, that any design change should be referred to the designer for his approval so that the responsibility for the design finally remains with the designer. That in my opinion is the only way to assure the quality of the design by avoiding splitting responsibility.

T.N. SUBBA RAO, India
Yes, Mr. Wex, regarding the point which I have to answer, when you have political pressures to include a non-qualified contractor. If

you have detailed the several requirements, I am sure, he will automatically not get included. But with the political interference, you still have a very strong position to prevail on the owner not to include him. But if the client still feels, well it's political, they must open his bid, I am afraid there is nothing in the world that you can do about it, but inform the client about the limits of your responsibility on the project in no uncertain terms. That is the only solution I can think of.

MODERATOR
Mr. Nishihara, would you like to comment on the question about the opportunity for a contractor to revise part of the design.

R. NISHIHARA, Japan
I am afraid, there is some misunderstanding that contractors are allowed to revise a part of the design without the consent of the designer. This is wrong. We still have to have the consent of the designer.

L. VU HONG, France
I would like the panelists to give their opinion on the conclusion made by Mr. Sriskandan. This conclusion is that the whole process of design and construction must be subject to independent control. So if possible, we could get one opinion from the people of the East and one from the West on what would be the degree of this independence. I am not sure that the completely independent check will contribute to achieve quality. In more than one occasion, we had encountered the situation where the man who performed the work says: "OK I am not responsible for the quality, because someone else will check it." You know what the result will be.

MODERATOR
I think this is a very good question with which to end this part of the panel discussion. Mr. Dorton, what is your reaction to the idea of independence and independent check for each party?

R.A. DORTON, Canada
I agree with the comment by Mr. Vu Hong and I have experienced that in my own government department, where we have to check all municipal designs as part of our mandate. We realize that we frequently get poor design because they know that their designs are going to be checked by our department. But I think, when we are dealing with major projects, there is a growing tendency to require an independent check. I think this is an essential part of the quality assurance, when we are dealing with either very unusual projects or projects where there is rather a large element of risk being involved or very large expenditures. I think it is really dependent on the size of the project.

MODERATOR
Mr. Nishihara, would you like to comment on your feeling of the need for independence and independent check.

R. NISHIHARA, Japan
I think it is necessary. Generally in Japan, within a company, there is an independent group of prestigious experts who conduct the checking. The kind of checking that they do is to see that the design criteria are in conformity with the required quality. The opinion expressed by this group of experts must be adhered to and

the data that this group provides is very important, because these data serve for improvement in the future so that faults or errors are not repeated. We call this work the "design review". This is common practice in Japan.

H. KNÖPFEL, Switzerland
I would recommend independent checking, but I would say that the result of the independent check is a recommendation. It should not be decided until the designer agrees.

T.N. SUBBA RAO, India
An independent check, whether it is at the stage of design or construction, should be welcomed. It is some kind of a technical audit. I am sure it will greatly improve the quality assurance program.

MODERATOR
OK - the moderator of the panel has the final say and I will now give you an assignment. You realize that I am a Professor of Civil Engineering at the Pennsylvannia State University. If you think back to your school days, a Professor always gives a homework assignment. One of the major benefits of a conference like this is not necessarily what you hear in this room, but the discussion that follows afterwards. If you leave this room and decide to think about many other things tonight, other than what was discussed here, you are not carrying out my assignment. I wish I could require you to discuss with some other people tonight some of these issues that have been raised. You will see some of the panelists at the reception tonight. You will also see some of the speakers. This is your opportunity to interact with those people. If you do not carry out some discussion related to these topics, I will give you a poor grade and you will fail this panel discussion.

Thank you very much for your attention.

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Planning and Design

Moderator: Robert E. Melchers, Senior Lecturer
Monash Univ.; Clayton, Vic., Australia

Panelists: Gerard F. Fox, Partner
Howard, Needles, Tammen&Bergendoff; New York, NY, USA

Franz Knoll, Dr. sc. tech.
Nicolet, Chartrand, Knoll + Associés; Montréal, PQ, Canada

Gerd König, Prof. Dr.
König&Heunisch Berat. Ing.; Frankfurt, Fed. Rep. of Germany

O. Damgaard Larsen, Civil Eng.
Cowiconsult; Copenhagen, Denmark

George Nawar, Special Projects Eng.
Dep. of Housing; Bexley, NSW, Australia

Rüdiger Rackwitz, Dr.-Ing.
Techn. Univ.; München, Fed. Rep. of Germany

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.

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Construction and Inspection

Moderator: K. Sriskandan, Chief Highway Eng.
Dep. of Transport; London, UK

Panelists: Robert Fechtig, Prof.
Swiss Fed. Inst. of Technology; Zürich, Switzerland

Bernd Hillemeier, Dr.-Ing.
Hochtief AG; Frankfurt, Fed. Rep. of Germany

Marita Kersken-Bradley, Dr.-Ing.
Consulting Engineer; München, Fed. Rep. of Germany

David W. Quinion, Company Chief Eng.
Tarmac Constr.; Wolverhampton, UK

S.A. Reddi, Chief Eng.-Projects
Gammon India Ltd.; Bombay, India

Ken Umeda, Senior Managing Dir.
Kajima Corp.; Tokyo, Japan

Taking part in the discussion from the floor:
G. Breitschaft, Berlin
A.G. Meseguer, Spain
S. Mino, Japan
P. Mtenga, Tanzania
J. O'Brien, Australia
S. Ono, Japan
J. Schneider, Switzerland
A.G. Simpson, UK
W. von Olnhausen, Sweden
L. Vu Hong, France
Y. Yokoyama, Japan
J.H. Willenbrock, USA

K. SRISKANDAN, UK, MODERATOR
The way we propose to run this panel discussion, is to have discussions under 6 or 7 themes. What we propose to do is to introduce each topic by a panelist, a short statement of about 2 minutes.

The first one is "How important is the control of materials in execution" to be introduced by Dr. Hillemeier.

B. HILLEMEIER, FR Germany
In Germany and other countries specific procedures for approval and testing of construction materials exist. These approval procedures normally do not require additional testing on a construction site. Nevertheless, for certain sites it is advisable to execute further testing especially when there are extreme conditions regarding shipping of materials and atmospheric conditions. The extent of further testing would be testing at random with the aim for the identification of the material and to check the relevant properties. In our company we usually take samples for additional material testing in accordance with a test program proposed by the QA department. On big sites in foreign countries these tests are performed in a local laboratory whereas in Germany these tests are performed in our central laboratories. This is, for instance, valid for cement whose quality may be impaired by humidity or for additives the quality of which might be impaired by high temperatures. Reinforcement bars should be tested at random especially with regard to brittleness.

MODERATOR
The floor is now open.

D. QUINION, UK
In the U.K. the adoption of quality assurance means that there is a requirement that quality assurance procedures apply to the manufacturers. This is done in a variety of ways, but the popular way which is extending to cement, to ready mixed concrete and is already evoked in the case of reinforcing steel and structural steel, is that the producers of the raw materials operate quality management systems. Those systems are assessed by a third party certification scheme which is representative of the manufacturers of the materials, the users of the materials, such as contractors and consulting engineers, and the clients, the principal government bodies and private companies who are concerned that the quality is right.

The third party certification scheme is very akin to an audit team which initially assesses the quality management system and goes round periodically and assesses what is going on. These means ensure that materials such as cement, ready mixed concrete and reinforcing steel come to the site already produced to a given standard.

There is an alternative way with a new material for which there is no great background of knowledge, and we have to encourage the adoption of new materials if, as an industry, we want to move forward. These materials have to get what is termed an "Agrément Board Certificate". The Agrément Board assesses a new material for the purposes for which it is being promoted and issues a certificate, when it is satisfied for the stated uses and stated compositions, that the material is fit for use for a given life. It might be 10 years, it might be 50 years.

This enables new materials to be put forward and adopted by industry. So, in the U.K., we recognize the importance of materials control and we are expecting the supply industry to set up their own systems to supply sites with materials of stated and proven properties.

MODERATOR
Thank you David. Can we now put that question to the panel. Is there a similar quality assurance scheme for materials in other countries? Do suppliers get together and have quality assurance schemes in other countries?

G. BREITSCHAFT, Berlin
We have in our country a very similar system as mentioned before by Mr. Quinion. It is a system subdivided into a standardized area and in a non-standardized area. The standardized area will be covered by our DIN standards and there is a very similar certification procedure showing that the products are in accordance with the requirements of the standards. And for new materials and new systems, we also have a procedure on a legal basis, we call this - what is in the U.K. the Agreement - in our country "Zulassung". These performance qualifications will be standardized by the "Institut für Bautechnik, Berlin" after all the necessary tests have been carried out. Also questions of durability, lifetime etc. are included in this technical review. Maybe, in the near future, we will have in Western Europe, within the borders of the European Community, in the near future a common system for all the countries.

M. KERSKEN-BRADLEY, FR Germany
I want to ask Dr. Hillemeier if he was suggesting that the means, methods or objectives of testing are not sufficient as they are employed at the present time. Should testing put more emphasis on assessing suitability or identification, rather than on assessing compliance or non-compliance?

B. HILLEMEIER, FR Germany
In Germany the situation is like Mr. Breitschaft explained. Because building materials are procured on the basis of standards and approval certificates describing the properties of the materials, no additional tests have to be performed. As I already mentioned before, additional testing is advisable when special conditions are given. Identification and compliance testing helped us in several cases to avoid damage.

MODERATOR
Anybody else on that? Mr. Reddi, would you like to say finally what you think about the discussion so far, as far as cement and concrete is concerned and how it compares?

S.A. REDDI, India
As far as cement goes all the earlier remarks are very appropriate, where the cement is used in the country of production.

We had a number of projects being executed in third world countries, where the cement has to be imported. In that event, there is a possibility of deterioration of quality, maybe during transport. We have noticed in a few cases that the quality of products for the export into third world countries, to be very frank, is not exactly the same as the one for use in their own home countries. In such

cases, I think, it is imperative that for medium and large projects in-house testing must be resorted to. In fact we have a number of case histories, where our own company had the problem both with respect to quality of cement and reinforcement steel. In fact, with the reinforcement steel we had problems about the conformity to the dimensional requirements. So maybe, even though it costs a little more, it is worth having on site testing facilities, except for very small projects.

MODERATOR
Thank you. We move on to the next subject now which is: "Control of Components", i.e. precast products, prefabricated steel, anything that is produced off site. Can I ask Mr. Reddi again to make a short statement about that.

S.A. REDDI, India
We have already dealt with cement and reinforcement. Before I go on to precast members I would like to make a few observations on certain other components, which are totally bought items. For instance in the case of precast concrete, anchorages are bought from specialist agencies. How far are we right in merely using these materials based on the trade literature supplied by the manufacturers? Should we think in terms of some independent test, I would like the audience to react on this.

Similar is the case of bridge bearings. We have metal bearings, bearings with neoprene and the like. At the moment all the quality assurance aspects of certain bought bearings are entirely dependent on the data furnished by the manufacturers and we have to accept them as such.

For some of the export contracts in the less developed countries, we are obliged to get some of these products tested at some independent established laboratory and we found, rather surprisingly, unsatisfactory results in a few cases, even though the products were supplied by some of the very well known international suppliers.

The next point related to this is the role of specialist sub-contractors and who is responsible for quality in such cases, prestressing for instance. It is not always the general contractor that carries out prestressing work, maybe prestressing of a precast member. Sometimes, the precast members are purchased from factories and if they are prestressed members, we have problems apart from the dimensional accuracy. There are problems related to deflections. When the deflections are not uniform, there are problems about matching the components.

Then there are items which are temporarily sub-contracted out, waterproofing for instance or, coming down to buildings, architectural railings, expansion joints for buildings. We did come across a large amount of conflict on interpretations as to who will be responsible for these qualities. Generally, the specifications are drafted by the specialist contractors or specialist suppliers. I would like you to react on this.

MODERATOR
Thank you Mr. Reddi. - First of all, manufactured products like anchorages, bridge bearings and the like. What is the audience's view on testing of these and quality control of these products?

Obviously, you are all very happy with the way the discussion is going on.

K. UMEDA, Japan
Let me talk about my own experience. Because of the recent very strong Yen some of the Japanese contractors are seriously thinking of structural steel fabricated outside Japan. For instance, if we could import fabricated steel from Korea, economically speaking this is very helpful. However, the problem is the welding. According to the building regulations of Japan, prior to the shop fabrication, when welding is associated in it, we have to submit details of the welding for approval by the relevant authorities. Now, whether that welding can be done in strict accordance with this specification or not, is a problem. That is one point.

The second point is: In the international operation of our business we sometimes have to transport fabricated steel a very long distance by ocean freight. Now our experience told us, even though the fabrication of steel was done properly in our country and it was inspected by a professional quality inspector, still there is a problem, that is transportation. The damage which may occur, damage to the rust protection coating for instance which may occur during the process of transportation. Now, this creates lots of problems.

An extreme case: When we constructed a thermal power plant in Cuba, some important pieces of fabricated steel were lost. They disappeared into thin air. So not only to the quality control at the shop, but also to the logistics, transportation and insurance we had to pay very much attention.

MODERATOR
Thank you.

Could we turn to the next subject please: "Construction and erection on site", including accuracy of site work.

D. QUINION, UK
There are several points which one has to take into account when considering the quality of performance on site. The first one is: What are the tolerable deviations which may be allowed on the accuracy of members and their position and on the composition of various materials. Tolerable deviations should be carefully specified and they should have been taken into account by the designer. The materials at the time of delivery to site must conform to the specification. They have got to be transported to the site safely. We need to check them at the time they arrive, make sure they are unloaded in a manner which is acceptable to the supplier and that they are carefully stored and carefully issued, so the right thing goes in the right place. A very clear example is when somebody employs a black, mild steel bolt, when a high tensile bolt should have been used and I know a tower crane collapsed for that reason.

Construction work should be carried out to consistent standards. This is so that the men who do the work know the accuracy that is normally required of them and the standard of finish that they have to provide. This means that they work with knowledge of what they have to do. If we are consistent from site to site, then we will produce the standard of work required much more cheaply.

The next point is: Check as you go. You need to check what is going on as it goes on. The consequences, for instance, of removing a pour of concrete which has hardened when you have perhaps continued work on the next pour above it, are very costly and they are very time consuming.

Take the instance of piles and foundations which are to be covered up. I know of no alternative to having somebody directly inspect every single pile after it has been formed, before it is covered up or concreted. Not only do you need somebody to inspect and make quite clear that things are as they should be, but you need some form of further inspector or auditor to keep him on his toes, to make him aware of the fact that his activities are subject to inspection and if the inspector gets it wrong, then you fire him immediately.

MODERATOR
Those are some of the points which Mr. Quinion thinks should be looked at, tolerances, check as you go, inspection of piling. What are things the audience thinks should be checked?

M. KERSKEN-BRADLEY, FR Germany
Looking at standards in our country, and I think it is similar in other countries, there is quite a discrepancy between the density of regulations in relation to control of materials as compared to the density of regulations regarding construction on site. Is this considered appropriate in view of the fact that site construction, works on site, cannot be controlled or are more difficult to control in terms of acceptance and rejection and thus are considered to be more appropriately supervised or monitored? Does this explain the difference completely, or do you also share the opinion that there may be some inappropriate preponderance in the densitiy of rules comparing material control and construction control?

MODERATOR
Any reaction on that one?

Well, in that case, we are going to the next topic: "Temporary Works and how they might affect Quality Assurance".

B. HILLEMEIER, FR Germany
On the site, in my experience, those construction details will be realized correctly which are described in the drawings. The drawings are important because they are actually present on the site, and that without alteration of information. Let us, therefore, put all relevant data into the drawings and not rely on doing the work like children at play: When the first child whispers a little story to his neighbour and then this child passes the story on to the next one and so on... Then we should not be astonished about the final results.

The details in the drawings must be the better the more the personnel lacks skill and experience. Quality Assurance can pick up here. This is an organizational step.

J. SCHNEIDER, Switzerland
What about site inspection, just looking whether the site is tidy or not? For me it is always a good indicator to look if things are left in the way of people, e.g. if someone could fall over some bar and

break a leg. Also if people wear their helmets, their ear shields, or wear their glasses if they are doing something on the machines gives useful information. I think, these are indicators of whether a site runs well and is run well. I think this is also a good indicator of the quality of the construction. I am not so concerned about concrete cube testing. This is just an alibi. We say, look here, we do a lot for quality. But we do the wrong things. So what about this: is a tidy site a good sign?

J. WILLENBROCK, USA
The title of the symposium is "Safety and quality assurance of civil engineering structures" and I have heard a lot so far about safety from the point of structural adequacy. I wonder whether under this topic of safe construction, it is not important also to think about the preplanning that is necessary for the safety of the workers on a construction site. It seems that nobody has really addressed that and I think that your point is probably the tip of the iceberg related to that whole area of construction safety.

I know, in the United States, over the last 10 or 15 years there has been a lot more emphasis in the area of construction safety. I think the preplanning for quality and the preplanning for safety often go hand in hand because those two elements run counter to cost and schedule, which are the primary areas we often tend to emphasize. I wonder if we would not want to expand that area of a clean site and look at the broader issue of what is required to guarantee that we have a safe site.

MODERATOR
I think that is terribly important. Anybody who wants to comment on that from the audience?

G. BREITSCHAFT, Berlin
I want to contribute a second time to the question raised by Mrs. Kersken. I think this question was not covered up to now. The question was: Is it necessary to have the same density of regulations for control or supervision on site as in the production field?

If we look at the statistics about failure rates which are presented in a lot of papers at this symposium, we see that a lot of causes have to be seen in connection with the work on site. Therefore, I personally have the feeling, that we should do more in this field.

The other question is: Is it possible to do this in the same way as it can be done in the production field? The production field is a continuous process. In this area it is possible to make common regulations describing the procedure of control. The work on site differs from this process and, therefore, I would propose not to try to write detailed codes or detailed standards how the work or the control work should be performed on site. I think it is better to follow a proposal made for instance by Jörg Schneider, to require for each project a special control plan. Such a control plan can be elaborated by the designer, knowing where the possible weak points in the structure are. This control plan can then specify or identify the necessary steps of control on site and the way how to perform it.

MODERATOR
In a way that touches on the question raised by Professor Willenbrock, which is preplanning for construction safety which is related to site organization.

D. QUINION, UK
If I could come back to the question of safety. Safety like quality is required in the U.K. to be a particular responsibility of the man who runs the company. So, the Managing Director, Vice President or whoever you may call him, is held responsible in the U.K. for the operation both of the quality management system and the safety management system within the company. On a large site we will have a safety officer and for smaller sites we have a series of travelling safety officers and it is their duty to draw the attention of the project management to any practice which they consider is unsafe or one which is going to be carried out which involves risk and hazard. If they are not satisfied that the proper standards are going to be achieved, then they can report the matter and it is put right by the highest level of management.

A recent investigation into falsework collapses 10 years ago and and observation of what was going on around the world showed that an unreasonable number of accidents were taking place, far too many people were being killed and lots of people were being injured. As a result, in the United Kingdom, we instituted a specific investigation. The report of that investigation was partly technical, it was partly concerned with the organization of work, it was partly concerned with the training of people in safety and it also addressed the question of "how can we make it better?". A code of practice was produced for falsework and in that document it was recommended that a coordinator be appointed for each and every site, who had to make sure that temporary works were carried out to designs and that somebody would be responsible for seeing that this was carried out and checked. It also indicated a checklist of items which should be given attention to in checking the design and in checking the work on site.

Now, when government safety inspectors tour sites - and they can go on any site at any time - they will examine whether these responsible actions have been taken, whether there is or is not a temporary works coordinator. If they are not satisfied they can issue a prohibition notice and from that moment work stops until they are satisfied that a safe method of working is to be used. The inspectors might be wrong, in which case the contractor can go to court to have the matter discussed and the prohibition removed, but normally they get it right and contractors have to conform.

MODERATOR
I think, Mr. Quinion was talking about temporary works and safety of temporary works and personnel, but there is one view that that does not contribute to quality assurance of the structure. Does anybody have a view on that?

J. SCHNEIDER, Switzerland
I am not so sure that the quality of the structure is the only thing we should look at. I think, we should really look at the safety of people at the site. This is, in Switzerland especially, but also in other countries, the most dangerous place you can find. We have to do something about this. What we have to do is not costly. It is in

fact cheap, much cheaper than doing nothing at all. A relatively simple site accident costs a lot of money. Assume, for example, somebody walks into a bar he does not see. He falls, possibly striking a nail with his hand and what do you think that costs? You can afford on a site half a man all day just to see that this bar and similar objects are not there. You can afford to pay that man by preventing this single accident. So why don't we do it? I am not saying that the quality of the structure is not important, but here we should remember the other aspects too.

S. ONO, Japan
The misuse of steel plate grade is nicely controlled in my company or generally in Japan. We have three types of steel plate grades and we use three identification paints for each steel plate.

MODERATOR
Does anybody else want to comment of safety on site as opposed to quality assurance of the structure?

R. FECHTIG, Switzerland
I will answer the question from Prof. Schneider. He asked about costs related to a small accident to a worker. We carried out a little research in our institute, looking at several sites and into several books of contractors. We have drawn from that research that a small accident costs a contractor between 500 and 2000 Swiss Francs per accident. So if you have 150 workers involved in 100 little accidents per year, you lose about 100'000 Swiss Francs per year. Your gain is that much lower. Think about it!

Y. YOKOYAMA, Japan
With regard to the labour safety problem, in Japan the government is very strict. To look after safety, we have in our company an independent department that is responsible for the safety control at sites. It has the authority independently to regulate the safety devices on the site. The reason why we have this organization in the company is confidence that safety pays anyway. That means, indirectly, safety improves the quality. For example, the government regulations request a very heavy scaffolding and protection net around the site. Our people follow those regulations. These improve not only safety records but also labour productivity. When we worked in the Middle East, our people used a similar system on the site. Our job sites have a very good safety record and the labourers from third world countries like to work with us. Many engineers from the U.K. or Switzerland study our sites and are very much impressed.

K. UMEDA, Japan
I have a few comments on safety. To be honest, I was not the advocate of company-wide quality control. I was against it. But now I accept the effect of it in terms of its result regarding the safety level. My company became a member of this nationwide quality control organization about 6 or 7 years ago. The largest effect resulting from the quality control concerned the safety level. The number of accidents in terms of safety decreased by 30% after we introduced company-wide quality control. In the companies who introduce this company-wide quality control, the definition of quality includes safety. The keyword "Q.C.D.S." reads as follows: Q means physical quality, C means cost, D means develivery time and lastly S means safety. I know many of our foreign friends are glad that we are including cost and safety and delivery time as very important

segments of quality.

L. VU HONG, France
As I understand, the Japanese way of quality management, what you call company-wide quality control, is just a kind of principle or philosophy and in all a kind of state of mind of everybody. Now, from the point of view of the organization, what is new that you have put in place, is what you call quality circle. Otherwise, you still have a Q.A. Department which performs some kind of monitoring of the system and secondly, you still have an independent quality control. And then what is new, in order to implement your policy of company-wide quality control, is just a quality circle.

K. UMEDA, Japan
We still have within the company quality control promotion sections, but this is mainly for guiding the company into the right direction in terms of quality control activities by making contact with other industries and other companies in the same line of business. And they never directly touch on the quality control at the production site and construction site.

On the other hand we have in our company a so called technology department and this is also responsible for guiding all the construction sites in the right direction of the quality control, but this department never does direct quality control at the site.

M. KERSKEN-BRADLEY, FR Germany
I am wondering whether the three contractors we are having here are truly representative, because the picture we receive from these companies is so perfect that I am not quite sure what we are talking about here. Do you consider yourselves really representative or are you first class contractors?

MODERATOR
We are not three contractors as I see it, we are five here. What does the audience think? Whether these are all perfect contractors and everything is fine?

A.G. SIMPSON, UK
Could I take up a comment of yours first, Mr. Chairman? When you said, "Does the quality of the temporary works affect the quality of the permanent design", I think the answer must be "yes, of course it does". Mr. Quinion, earlier this afternoon emphasized the need for care in the removal of temporary works. This is of vital importance, particularly where temporary works in a partially dismantled condition can impart unacceptable loads onto a very new permanent structure. Going on from that point, and the design of temporary works, our Chairman well knows that in his own Department in the U.K. it is a requirement that major temporary works should be checked and certified by an independent engineer.

But I would like to ask Dr. Hillemeier and Mr. Quinion how they assure the quality of the design of the temporary works in their own organizations. We have heard quite a lot this afternoon about materials and site activities, but very little about the assurance of quality in design.

MODERATOR
Thank you Mr. Simpson. - Before I answer this question, can I ask you please to give just one statement - do you check them or don't you?

B. HILLEMEIER, FR Germany
In general there are no problems with falsework because we have very efficient sub-contractors who are delivering good scaffolding and shuttering to our sites. With regard to scaffolding and shuttering only compliance with dimensional and structural requirements is of importance. In case of deviations these can be corrected with corresponding costs and no permanent damage in the sense of poor quality remains. So, in our company there is no need for the quality assurance department to check falsework except with extraordinary constructions.

MODERATOR
But the sub-contractor does check his work?

B. HILLEMEIER, FR Germany
I think he does.

D. QUINION, UK
As far as the U.K. is concerned and my company, it is a requirement that all temporary works are checked by an independent engineer on my staff.

MODERATOR
Thank you. - Can we now move on to "Competition in bidding". It was put there to be provocative. It was said that severe competition can lead to cut-price bidding with consequential effects on the quality of the structure. Does anybody have any comments on that?

A.G. MESEGUER, Spain
I have two points. In my country, formerly, the cost of quality control was included in the total cost and so the way in which the control organization was paid, was through the contractor. This produces many difficulties, because the contractor could put psychological pressure on the control organization. For several years now the costs for quality control appear separately and it is directly paid to the control organization without passing through the hands of the contractor. This system is operating very well. I wonder whether it is the same in other countries.

Now my second point is, that with our present system, if the contractor reduces the price by 20% in the tender, the cost of control is also reduced by 20% and this is very bad. Therefore, many times it has been proposed in my country, but up to now we have not changed yet, that the cost of quality control should be treated separately from the tender and not be submitted to rebates. And even there are some persons that ask for more money for control, when you are lower in price.

I would like to hear comments on this because for practical purposes we found that this is extremely important.

J. SCHNEIDER, Switzerland
I do not think that quality is achieved merely by control. So I am not so sure that your idea would work if any expenses for control

were paid separately and were not included in the bid. I have nothing against competition in bidding at all, but I think our system is wrong - at least in Switzerland - where almost every time, the lowest bid gets the job. I think this is wrong. We should, as a general rule maybe, give the job to the second lowest bidder, which would avoid this rather unsafe behaviour of contractors who need to be the cheapest within the competition. They should be motivated to not be the cheapest, but maybe the second cheapest and to deliver better quality instead.

S. MINO, Japan
I do not think that competition affects quality assurance. As long as the work is done according to the specifications, the owner will be satisfied. Most important is the selection of the contractors to participate in the bidding. The owner in Japan, usually selects the prospective bidders.

J. O'BRIEN, Australia
I would like to bring up the topic of the unscrupulous developer. We have quite a large number of problems in Australia arising from unscrupulous highrise development in resort areas. This is where somebody puts together a company, throws up a huge building, sells it when it is brand new. Ten years downstream the whole place is falling apart and the developer has vanished. I would like to ask particularly for a Japanese point of view: Do you have any unscrupulous developers? I have not heard of any. And with regard to the West, where I know there are unscrupulous developers, how do you stop it?

K. UMEDA, Japan
Well, this is a very touchy problem and many of the leading Japanese general contractors invest in real estate development business outside Japan, that is true. Some of them might have caused aggressive effect to the environment or by producing poor quality buildings. But in many cases Japanese contractors or investors in the development business outside Japan are led by the indigenous investors. So I do not think it is the Japanese investors only that must be blamed. However, when we undertake some major development business, not only in Japan but also outside Japan, good companies generally pay close attention to the quality of the product and its impact to the environment and I will keep it in mind that when my company undertakes any development outside Japan we will pay sincere attention to that.

MODERATOR
Thank you Mr. Umeda. - I think as far as Western countries are concerned, building regulations guard against that, because government building regulations require certification now. Anyway, can we now pass on to the last item please, which is "Inspection". - Could you say a few words please, Professor Fechtig?

R. FECHTIG, Switzerland
There is no doubt that inspection in quality assurance must be done. Who gives us the order for inspection. Is it the owner for periodical inspection, is it a handbook that has been worked out by a project team for a certain kind of construction, like bridges, tunnels, nuclear power plants. Or is it aimed at preventing damage that can affect a construction after a certain time of life? In the different countries over the world we really do not have the same standard

rules for inspection. What are the inspection systems of all those projects we have realised over the last 100 or 120 years? From my point of view there are some with quite a low standard. I am not thinking about nuclear plants, big bridge projects, skyscrapers, which have been erected during the last 20 years. But I refer to constructions between 1880 and 1910 when railway tunnels, or 1900 to 1930 when water power plants or smaller bridges were built. Has the owner of those objects a complete guideline to make a detailed inspection, so that he can be sure he knows when he has to start with bigger maintenance or perhaps with complete reconstruction?

I will remind you of the problem that we have on a lot of constructions which suffered from lack of maintenance because no periodical inspection by qualified teams had been made. How can all of us become more aware of this problem, so that we will include in our budget early enough the estimated costs for maintenance and for reconstruction. Inspections on an object like an old railway tunnel or highways, can force us to find new solutions to do reconstruction works under full traffic. I have been involved for several years with Swiss railway tunnel reconstruction work under full operation of the trains. That is really quite a problem of quality assurance and good planning.

MODERATOR
Professor Fechtig was talking about inspection after the structure is commissioned, in other words in service. There have been no papers on this subject, but I am sure it is a subject which deserves attention, because the quality assurance of a structure will depend on that.

P. MTENGA, Tanzania
I would like to refer my questions to the companies who are working in countries that have no well developed inspection and quality control procedures. How do these companies establish control procedures, control themselves and make sure that they keep to a certain standard (i.e. their prescribed level)? And, secondly, how do these companies help, say, by encouraging the indignant small contractor to keep to their standards, what measures do they take, what do they do to try to help the indignant small contractor to keep to their (1st world contractors') level of standard?

D. QUINION, UK
In England we have various organizations that have published documents which are used as operating documents and standards to control the way we operate: codes of practice and guides to good practice. These are available for anyone to buy and they are publicized in most cases fairly widely around the world.

S. MINO, Japan
Just a reaction to Professor Fechtig's comment. I do not know much about railway tunnels, but the Japan Highway Public Corporation has many highway tunnels and bridges. For the latter the inspection in service became very important. What is done now, is to facilitate the inspection during service by providing with easy accesses and inspection paths in the structures.

MODERATOR
Thank you. Is there any bridge owner or any owner of structures who has written down instructions of how regularly things should be

inspected and what shall be done about the inspection record?

W. VON OLNHAUSEN, Sweden
We are doing these things every day, we have in our Swedish Road Administration 12'000 bridges to inspect, to administrate and to rebuild and we have a lot of experience of the behaviour of the structures. And this experience should be the basis for design and construction and for our quality demands. I believe all of us aim in that direction.

We inspect at 3-years intervals - this can be discussed, but I will not do it here -. We have 3000 bridges which were built before 1940. And we know a lot about the older bridges too. But let me focus on just one point regarding their quality. I believe we have quite a good control in the construction phase. What we build is roughly OK. What we need is better durability. We have a safety factor on all the statical demands on the structure. We have no safety factors for the durability elements. And what can be done on this? We must study the durability factors more thoroughly, we must interpret them to measurable factors. Last but not least, all checking of quality should be done as close to the final product as possible, i.e. we should test drilled cores, not cubes, beside of the structure.

MODERATOR
Thank you. We have now reached the end of our time. Unfortunately the audience was warming up just as time was running out, so we have to close now. Thank you for at least trying to be patient with us here. Thank you all very much for coming and being with us.

Human and Organizational Aspects

Moderator: Franz Knoll, Dr. sc. tech.
Nicolet, Chartrand, Knoll + Associés; Montréal, PQ, Canada

Panelists: Aksel G. Frandsen, Techn. Dir.
Cowiconsult; Copenhagen, Denmark

Shigeo Hanayasu, Senior Research Officer
Res. Inst. of Industrial Safety; Tokyo, Japan

Robert E. Melchers, Senior Lecturer
Monash Univ.; Clayton, Vic., Australia

Andrzej S. Nowak, Assoc. Prof.
Univ. of Michigan; Ann Arbor, MI, USA

Carl J. Turkstra, Prof. Dr.
Polytechnic Inst. of New York; New York, NY, USA

Lac Vu Hong, Quality Assurance Mgr.
SPIE Batignolles; Puteaux, France

Taking part in the discussion from the floor:
J. Augustyn, Poland
T.K. Cheung, Hong Kong
D. Clyde, Australia
W. Colenbrander, Netherlands
R.A. Dorton, Canada
M. Kersken-Bradley, Fed. Rep. of Germany
D.J. Lee, UK
J. Menzies, UK
A.G. Meseguer, Spain
S. Ono, Japan
R. Rackwitz, Fed. Rep. of Germany
K. Sriskandan, UK
B.P. Wex, UK
J. Wynhoven, Australia

F. KNOLL, Canada, MODERATOR
We shall subdivide our discussion into two periods. The first few minutes I would like to spend with questions directed to the three lecturers that we have just heard: Then we shall proceed to a more general discussion on the theme of this Seminar, which is "human factors and their influence on quality assurance".

J. WYNHOVEN, Australia
My question is directed to Mr. Frandsen who has delivered an excellent paper very appropriate to my own practice. What was the reaction of the staff, particularly the junior staff, to a formal Q.A. document? Since its introduction, has there been a decrease in the number of problems?

A.G. FRANDSEN, Denmark
The staff reacted positively up to now. We have not had the system for very long but mainly it consists of well known procedures from the past, so it does not change very much. But they can now see it in a more systematic way. Whether we can notice a lower rate of mistakes since we have introduced the system? I must say that it is too early to state anything about that. The system has been functioning for a very short time until now, so we cannot tell if it improves the performance, but we hope so.

J. AUGUSTYN, Poland
Mr. Hanayasu stated that the number of accidents increases with the age of the workers and decreases with their experience. How should we understand this, since the oldest ones are also the most experienced ones?

S. HANAYASU, Japan
In this case, due to the shortage of workforces, many older workers with less experience participated in the projects and they were the main sources of the accidents, which resulted in the reported accident situation.

W. COLENBRANDER, The Netherlands
I was very pleased with the paper of Mr. Frandsen. I recognized a lot of it in my own experience. He mentioned audits and I would like to ask him: Do you think audits are possible within the company or is it necessary to go for external audits?

A.G. FRANDSEN, Denmark
We perform audits within the company and it is possible within the company if you have independent people to do it. I think it might have a reverse effect if you took people in from outside in order to make these audits. It might be necessary in very rare cases, but I would not recommend that.

R.A. DORTON, Canada
I also was very interested in Mr. Frandsen's paper and particularly the idea of moving the checking up front. I think this is very significant. We do a two phase checking in our bridge design office, we do the detailed computational checking, though many people think those checkings are not very important. But the most significant part is our preliminary review. We have the designer in the beginning of the project justify his selection of the structural type before a group of senior engineers, and also establish what analytical technique he is going to use and have it reviewed by senior

people. I think this is very important and I was wondering if Mr. Frandsen could indicate, within his organization, how he is moving up front this review process, because there seems to be one quality assurance engineer for a project.

A.G. FRANDSEN, Denmark
First of all we want the people responsible for the project to try to foresee all the possible difficulties they will encounter during the project phase. That is the most important thing. Very often you can imagine what will happen and you should put it into your planning and make precautions for taking up these difficulties. I agree with you that phase checking is a good thing because you can avoid the major mistakes on earlier stages and you can avoid checking too much before it is really necessary, when you have all the details. I think this is what we should do and not just to check the final result and then maybe have to redo much work. So I very much agree to the usefulness of checking in more phases, but I think the most important thing is to foresee the problems in the planning phase.

S. ONO, Japan
Mr. Vu Hong gave a lecture in which he referred to the decision making mainly by the top executive, going down to the bottom. I suppose this is a very customary or traditional method in Western society, but here in Japan we have another pyramid system, shortly expressed "bottom-up", that is the lowest level worker can produce any improvement proposal to be raised up to the top executive of the pyramid structure of any organization. This system may sound a bit time consuming to Western people, but this is something like the democracy, so it is very effective in another sense to gain the majority of the consent of the working people.

My question: Do you also have such a system in France? I suppose any recorder system is indispensable and in my company's experience, small gifts to the working circle has been very successful to inspire field workers to lead them to more profit oriented sides.

L. VU HONG, France
In our system the condition is that the decision should be pushed down to the lowest level, where the work is performed. What we require is that the project first be divided into sub-projects and into sub-sub-projects down to the responsibility of one single man. But we have also the obligation for all people from one level to report the performance back to the higher level. That is the feedback from the bottom to the top.

MODERATOR
What we have heard are some very important and interesting comments on how different systems, the Japanese system and the French system in this case, work with positive and also with negative incentives.

If perhaps somebody from the audience could shed some more light on this question - I think it is very important because it is very closely related to the human feelings that, after all, the workers must have towards their work.

D.J. LEE, UK
I could make a contribution, although I am a consulting engineer, on the basis of some research done in Britain on contracting. I think it bears on the point you were raising about decisions coming down

and feedback coming up. It appears that unless management imposes a safety procedure, very little happens. For example the wearing of safety equipment, even safety helmets, although that is an obligation. In fact, it is not always applied - it depends on the management of a contractor to impose this procedure. The problem is that a worker, particularly in Western Europe, can have a "macho" image. He does not need safety equipment, he is a tough Rambo type man. This image must be destroyed if safety is to be applied. The best contractors get better results if they rigorously apply a sensible procedure which is respected right through the organization.

MODERATOR
We have heard of imposing safety measures that need to be applied. Now could we have some enlightenment on how they are being imposed? We have heard our Japanese colleague say that small gifts are being offered to people who do the right thing. How does European management impose safety measures and make people do the things they are required to do?

L. VU HONG, France
I consider the safety aspect or safety measure to be implemented on site in our system as an aspect of personnel management. It is a requirement of the directive. This means that the responsibility for the personnel management in safety measures should be pushed down e.g. to a foreman, on the condition that we have all the requirements clearly defined. And then, the audit will go through the system periodically to verify in all aspects including safety, that the safety requirements have been respected and the procedure has been established and implemented by the foreman who is responsible for it.

M. KERSKEN-BRADLEY, FR Germany
If I understood Mr. Umeda's lecture yesterday correctly, the main procedure or the main philosophy in Japan is that quality assurance procedures are more or less integrated. I have the impression, that in Japanese companies there is actually no specific quality assurance officer and there is no quality assurance department in the sense which was brought forth by Mr. Frandsen and by Dr. Hillemeier yesterday for instance. However, this would imply that you actually cannot perform an internal auditing, or do you have other procedures? I can very well imagine internal quality control and quality assurance in an integrated manner. There are tendencies in our country to consider this approach. However, for the auditing function we need something separate from the normal routine operation.

S. ONO, Japan
In reality we have some auditing systems, some auditing sections, but they are not a positively acting group and they believe that quality must be made up during the fabrication process. So they only promote or encourage the people to adhere to the fabrication procedure. But they arrange for example, statistical data to encourage the foremen or workmen or managers to present them what are suitable procedures.

T.K. CHEUNG, Hong Kong
If I may make an observation on Mr. Knoll's question about implementation of safety measures among the labour force. I suppose you can only do that with regard to the cultural background of the society

in which you work and Mr. Lee has mentioned that question very well among the British as opposed to Continental workers. In Hong Kong there are similar attitudes. So one of the things the Hong Kong Government has tried to do in recent years is to try to change the public image by way of publicity campaigns through television, e.g. making people have the image that wearing safety helmets is a fashionable thing rather than something, you know, that destroys their manly image. I would like to know some more about that from other countries. Whether these campaigns in Hong Kong have been successful, I might be able to tell you that in a few years' time.

MODERATOR
We shall now go on to the second section of the discussion, where we are open to all subjects related to the theme of this Seminar. Thank you very much.

B.P. WEX, UK
I am delighted that so much attention is given to the question of human error in quality assurance. I am very pleased to see that statistics at last have borne out what practicing designers have been saying for years. Probabilistic theory is a very nice mathematical exercise, but for goodness sake, let's get down to the two really important matters in reliability; number one is correctness of engineering concept and number two, is human error.

S. ONO, Japan
To strengthen our successful example of the Japanese quality control system, I would like to introduce a famous book written by Dr. Ezra Bogerl some years ago, titled "Japan as No. 1" and in this book he takes up 3 or 4 tips for success. So try to read that book when you return to your country.

A.G. MESEGUER, Spain
This is a minor remark to Mr. Nowak's definition of error "a deviation of acceptable practice". I think that progress is based on deviations from acceptable practice. So I think that something should be added to this definition in order to separate what is an error and what is an innovative way of progressing, because both are deviations from acceptable practices.

A. NOWAK, USA
The question of the definition of human error has been the subject of extensive discussions and what I presented is definitely not the full definition. We tried to develop a comprehensive definition, but as I indicated, defining errors as a departure from acceptable practice immediately raises the question "what acceptable practice is"? By the way, we first had it as accepted practice, then the word acceptable was preferred. It is a definition which could and in the future probably will be modified to include some other aspects.

A.G. MESEGUER, Spain
May I suggest just to complete the definition this way: "A deviation of acceptable practice leading to an undesirable result".

K. SRISKANDAN, UK
Two short questions to Messrs. Melchers and Nowak.

Prof. Melchers had an equation for the total cost optimization, one item of which was on cost of control. I would like to know when this

work would be completed and if it comes up with some practical conclusions?

And to Mr. Nowak: One of his recommendations was to bring something about error control into codes. Could he expand on that?

R. MELCHERS, Australia
I am not really quite sure what you are driving at. Are you asking me to tell you when the whole of this work will be finished in the future? Is that what you are suggesting?

K. SRISKANDAN, UK
Yes, in a way in which practicing engineers could then use the results to decide how much resources to put into error control and how to divide that between error control in design, error control in construction and control in use.

R. MELCHERS, Australia
It is evident from my remarks that what we are doing and looking at is very elementary and we have a long way to go yet. Now the question, I think, we have to answer for ourselves is whether this line of research is a worthwhile task to pursue; if so then we can put some resources into it. If we decide it is not worthwhile, it will never be finished. I am sorry that is ducking the issue, but I cannot tell you that it is going to take 2 or 3 years or whatever, because it really depends on how much effort we put into it.

B.P. WEX, UK
To enlarge slightly on my last remark in the light of what Mr. Sriskandan said. I think they are both right. Prof. Melchers' work and his colleagues' has to go on. In the meantime, the checking system that Mr. Sriskandan's organization has set up to chase human errors also has to go on. His is the current practical solution, while Prof. Melchers is doing the research, which we hope will give us the necessary theoretical insight for the scientific solution.

A. NOWAK, USA
The issue of how should we handle human error in design codes is extremely important, delicate, involves a lot of politics too. The present codes are based on the assumption that the people will not make errors and you may say that safety factors or safety reserve in the code gives us some shield, some cover which covers some errors. Well, this is so. But there is no allowance for making errors there.

How should and could the errors be handled? This is the subject of the current research. I would like just to mention one option which is considered: If you have various contractors who have experience ranging from "very experienced" to "rather poor performance" you can have a certain ranking of those companies and depending on their experience in the past, they can use different safety factors. They can use different allowable stresses. The company with higher experience may save on material or may save on some other cost, while the one which has a bad record, has to go and provide the extra safety precautions. But this is just one option and all these various situations have to be considered.

R. RACKWITZ, FR Germany
Most of the discussion was concerned with finding out errors. What about avoiding them, for example by expert systems. Could you

comment on that?

R. MELCHERS, Australia
It seems that certain expert systems are a worthwhile thing to look at. The medical profession, with the limiting constraints of knowing what sort of diseases they are looking at and the sort of symptons that may arise, has done reasonably well in that area. I know there is some work going on in the mechanical engineering field for example, trying to use expert systems in design. There is also some work going on in the civil engineering industry and with the architects. I have not yet seen anything terribly successful in that area. But by all means, let it go on. I think, there is scope there. It would have been nice perhaps to have a contribution in that area.

J. MENZIES, UK
I would like to comment on the remark made by Mr. Nowak suggesting that more experienced contractors and designers be allowed to use different, i.e. lower, safety factors. Investigations of failures which we have made in the U.K. have indicated that if the safety factors in design had been higher, the failures would still have occurred.

R.A. DORTON, Canada
We have brought up again this question of the fallibility of professional engineers compared to students. There is an interesting aspect on the accuracy of work and it is very much a function of the organization from a human point of view. If work is being checked within a very small group, where the checker knows the designer, the designer is not very thorough. If the checking group is within the organization, but remote from the designing group, the engineer wants to be right, so he is more careful in his design. If the work is being done outside, being checked externally completely, the organization or the company, is very careful to see that they have got the job right before they are prepared to let it go out. So this whole question of how we are going to model human errors, is very much a function of the organization and the checking system that is being used.

J. WYNHOVEN, Australia
My question is directed to Mr. Hanayasu and it is to do with risk and safety. If one does not take risks, one does not achieve aims either and I noticed in the records here, that in constructing these two railway projects, deaths at the rate of 1 in every 8 km and 1 in every 4 km were achieved, but of course, there were probably remarkable engineering achievements. In Australia those sort of records would result in people just stopping work, but of course we do not achieve as much. What is the Japanese attitude to those deaths?

S. HANAYASU, Japan
In Japan we have every year more than 1000 deaths due to accidents in the construction industry. But today we are not thinking that such a large number of deaths as well as the high rate of accidents in the reported railway construction projects are acceptable to our society. Therefore, every party involved in construction works such as order initiators, contractors, labour inspectors and workers are very enthusiastic about preventing accidents from taking place. Hence, I think the attitude of people toward safety is positive.

J. WYNHOVEN, Australia
Perhaps, if I put the question slightly differently. When those accidents occurred, did it result in the workers stopping work and saying, until the safety is improved, we will not continue. In Australia that is what would happen. They would just stop work.

S. HANAYASU, Japan
It is up to the situation of accidents. If the appropriate amendment measures are taken in accordance with the accident situation, workers will be able to start their works. The contractors, in general, are serious about safety of construction sites, particularly in case of the accident, to improve the work places. Also labour inspectors have the right to order a contractor to stop his work if the work place was not improved properly. Therefore, it is very seldom that workers stop their work of their own will because of the remaining risks on the site.

D. CLYDE, Australia
As the father of a woman civil engineer, I would raise a social and cultural problem. I believe that engineering could be improved by having more women in the profession, particularly in relation to the macho image that Mr. Lee spoke about. My daughter is a construction engineer for a very large area in the South West of Western Australia for the Main Roads Department and she is totally accepted by the men. I believe women can improve the whole atmosphere of engineering and that women are much more reliable than men in a lot of tasks. - Perhaps Dr. Kersken-Bradley could comment on that.

M. KERSKEN-BRADLEY, FR Germany
I think you did more than I could ever do.

MODERATOR
We shall close this Seminar now and move on to the Prince Room to hear the final closing session. Thank you very much.

Closing Discussion

Moderator: Carl J. Turkstra, Prof. Dr.
Polytechnic Inst. of New York; New York, NY, USA

Panelists: Bernd Hillemeier, Dr.-Ing.
Hochtief AG, Frankfurt, Fed. Rep. of Germany

Franz Knoll, Dr. sc. tech.
Nicolet, Chartrand, Knoll + Associés; Montréal, PQ, Canada

Robert E. Melchers, Senior Lecturer
Monash Univ.; Clayton, Vic., Australia

K. Sriskandan, Chief Highway Eng.
Dep. of Transport; London, UK

Yoshio Yokoyama, Dir.
Ohbayashi Corp.; Tokyo, Japan

C.J. TURKSTRA, USA, MODERATOR
I would like to begin this discussion once again with a very brief comment from each of the panelists.

The theme of these quoting comments should be: What have we all learned in this conference, what are our impressions and what we think are the things that should be done and the best directions for future activities.

One curious aspect of this conference from my point of view was the rather surprising rebirth of a concept that I thought we had buried 15 years ago - the concept of absolute safety or the idea that could we build a building that has no probability of failure. Experience suggests that this is clearly false. Apparently there is still a residual apprehension concerning reliability analysis which I think is unfortunate because we have so much experience now. We know what reliability analysis can do for us. We also know what it cannot do for us and all of us in the business are aware of its limitations.

We have also learned that people are not optimizers. We are all try to do the jobs that we have as well as we can, working within the constraints that we have. We have learnt that we sometimes don't do as well as we would like, but we are not in a position to find optimal solutions to our problems because of very many uncertainties and a great lack of information. Personally I think that one of the greatest benefits of this conference has been to see how different organizations and different societies approach the problem of organizing the construction system.

Here I have a slide which represents the American system with the owners and designers and contractors fighting it out while the lawyers sit perched on our shoulders, ready to do what they have to do. It was very interesting to see how the Japanese seem to solve these problems of conflict by ensuring cooperation between components of conflictual situations. From a personal point of view, this international conference in Tokyo has been very educational.

F. KNOLL, Canada
I have two comments and they concern what I have been asked to look at and to say by one of my colleagues this morning: It is to look into the future for our academic and engineering endeavours. I would see two tasks for us to go on working, concerning quality assurance, one of them is analytical in a classical sense, it is to go on developing the models for the construction process and perhaps of the errors and their occurrence and make them ready for the study of practical cases, which, they are presently not, as we all learnt.

The second task would be quite related to the first one, but would be more of a synthetic or creative nature in the sense of design if one wishes: it is to develop strategies for the improvement of the quality of systems, it is the development of checking techniques, improvement of management systems and the human background that people are working in.

I was also asked to say something about what type of conferences should be held in the future on the theme and two distinct types are outstanding in my memory at the moment; that was the conference on the Rigi 3 years ago and the present conference in Tokyo and I believe both had their merits and both should be held and repeated,

maybe in a somewhat modified form. The conference on the Rigi was a gathering of people, of a high degree of information on the subject, where research opinions were exchanged. The meeting in Tokyo was perhaps more oriented towards dissemination of that knowledge. I think both are of the essence.

B. HILLEMEIER, FR Germany
In my opionion, IABSE can be the most effective international platform for gathering evaluation feedback of information in construction engineering. We, here as the delegates of our countries, companies and institutions, are the link for that feedback to our people at home.

Differences and similarities between the different countries in assuring safety and quality should be evaluated to improve one's own organizational and technical measures for ensuring quality.

We should also look for quality assurance measures to obtain more durable structures. Construction in my opinion means permanent struggle against water. Bad durability ruins the good reputation of construction works and of our profession. Durability is evidently one of those properties that cannot be obtained by checking only, as we all know. Here more must be done that goes into design, materials and maintenance and asks for quality assurance.

R. MELCHERS, Australia
I want to make two comments. The first is, that my impression is very much that the attitudes we take towards quality assurance are dominated by our legal systems or the legal framework, within which we work in each country and that reflects the cultural system of the country in which we operate. The experience in one country is not necessarily immediately useful for that in another, because we cannot easily change culture. But we ought to consider seriously whether to change the legal system as it affects engineers. It seems to me this is a political act and it is an extravert type of action, which is not the sort of thing which engineers generally tend to take. Of course we can also optimize within the existing legal situation and that is very much the sort of discussion which we have been having today and over the last few days.

As an academic I believe it is important to pursue the sort of comments that Carl Turkstra made in the beginning and that we ought to, as a profession, look more seriously at modern decision making tools, risk analysis, reliability theory, cost benefit analysis and so on, as that relates to risk and reliability. I have a suspicion that the message is not quite getting through to much of the engineering profession.

Y. YOKOYAMA, Japan
In the opening discussion I outlined the Japanese way of quality assurance by integration of people in the departments concerned. In the various sessions this has been explained from different points of view. After listening to various impressive reports and the discussions, I personally realised that there are some differences between the ways of quality assurance in various countries. For example, the checking systems for design and construction was one of the major topics in this Symposium. I learnt that most speakers, other than Japanese, seem to prefer checking by outside organizations. However, in the Japanese way, checking to prevent error is

made within the group which is responsible for the design and the construction. I got the strong impression that our system is only justifiable or acceptable in the Japanese climate under the present business circumstances. I believe that the Japanese engineers and contractors cannot be isolated from the rest of the world, and when working overseas, I think Japanese organizations should consider employing some checking system which the people under different traditions or different social structures can feel confident in. - In this sense I learnt a lot in this Symposium and I believe most fellow attendants from my country obtained a similar understanding from this conference.

K. SRISKANDAN, UK
I am here representing a public authority and in the opening panel discussion I stated that one of my concerns was to determine, how much resources should be devoted to the control of quality and how these should be divided between the various stages of the building process. From what has been said at this Symposium, I am led to conclude that it will be a considerable time before any reliable scientific information becomes available and, therefore, we will have to continue in the same pragmatic way as we are now.

In talking to colleagues in other governments, they were also asking the same question, and the only thing that seems to be different between the various countries is that we are all working within different legal, social and environmental constraints. But otherwise, I think, we have to continue as we have and learn as we go along.

MODERATOR
Thank you very much. Perhaps one or two members of the panel might react to some of these comments. I have been struck at this meeting by what I feel to be strong support for the concept of gathering data on errors and trying to deal with them in a more academic way, in a more organized scientific way and, as a Professor, I find that very encouraging. I would perhaps ask Dr. Knoll, who is a practicing engineer, if he thinks this line of research can be productive and if we can theorize and construct useful models of these problems.

F. KNOLL, Canada
Thank you Carl for throwing me the ball. I would like to say that I have seen a number of efforts that have already started in the field of gathering information about errors in their own ways. In the Western society these efforts are usually hampered by the implications of the legal system and the insurances etc. which make for some incentives to keep data secret. Recently this climate has improved a little and what I hear from people running AEPIC for instance, the US system of collecting data on accidents, is that they feel that they have easier access to the data, than they used to have. So there is some hope that we are going to have the data and then of course the data will have to be worked on and will have to be put into a presentable form so that the practice can profit from this effort.

MODERATOR
Specifically, is it an activity that lends itself to mathematical abstraction? Can it be modelled?

F. KNOLL, Canada
We have seen a number of tries to model it and I liked those efforts and every one of them, in my opinion, has its merits. What I think should be the end product we are hoping to get, is a unified approach of the scientific community towards the problem of human error and quality assurance, so that we will be able to talk in one common language on the theme, rather than having everybody doing his own thing.

MODERATOR
Would anyone else on the panel have another comment?

K. SRISKANDAN, UK
In the earlier discussions Prof. Melchers said that before we start to model this and get to scientific information, we must first find out whether it is worth doing it. What we should do is to determine the cost of the research and the incremental benefits that would come from it, and then decide, whether it is worth doing the research.

MODERATOR
Is there another comment?

Well in keeping with the wonderful tradition of this conference, we are finishing on time. I bring this panel discussion to a close and invite Professor Maeda, the Chairman of the Scientific Committee, to begin the Symposium Summary.

Thank you.

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