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Autor: Turkstra, Carl J.
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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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