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Free Discussion – Second Part

In the free discussion to the preceding 9 contributions and the two concluding remarks the following persons (listed in alphabetical order) participated:

Prof. G. Ballio, Pavia, Italy
Dr. C. Bøe, Oslo, Norway
Prof. O. Ditlevsen, Copenhagen, Denmark
J. Ferry Borges, Lisbon, Portugal
Prof. H. Iemura, Kyoto, Japan
M. Kersken-Bradley, Berlin, German Federal Republic
Dr. F. Knoll, Montreal, Canada
Prof. G. König, Darmstadt, German Federal Republic
Prof. H. Kupfer, Munich, German Federal Republic
N.O. Larsson, Stockholm, Sweden
J.A.P. Laurie, Pretoria, South Africa
M. Matousek, Zurich, Switzerland
Dr. R. Rackwitz, Munich, German Federal Republic
Prof. J. Schneider, Zurich, Switzerland
K. Sriskandan, London, Great Britain
Prof. C. Turkstra, Montreal, Canada
Dr. L.P.C. Yam, London, Great Britain

Their statements are given below in chronological order:

Ferry Borges: I am most interested in the presentation of Dr. Knoll. However, it was not clear to me what is the position of Dr. Knoll concerning the implementation of his ideas. Is he optimistic or pessimistic about the practical application of the concepts presented?

Knoll: My reply is simple: I came to the session actually looking for help for the undertaking of our research. I have been able to obtain a number of useful suggestions. The task seems quite formidable to me but we have hope to come up with a suitable arrangement to set-up a research group.

Kersken-Bradley: A question to Mr. Bøe: In your concluding remarks you referred to safety as a "limitation of business opportunities". I do not quite agree. Within a framework of clearly defined responsibilities and liabilities - including appropriate sanctions and legal prosecution - business decisions based on the consideration of possible consequences of the decisions should yield a level of safety not differing very much from a prescribed level. Thus, business and safety requirements should not be contradictory; if they are contradictory, then either the framework, mentioned above, or the safety requirements are not adequately balanced and need to be rechecked.

Bøe: To make it clear, I said it is the attitude that most demands for safety are considered as limits to business opportunities. I don't think there is a constant conflict between safety and economy. It is more like a constant trade-off situation where economy always comes first and forces safety into the background. This is why codes are so important because they represent limits to risk which are not negotiable, i.e. not dependent on individual trade-off between safety and economy.

Yam: While agreeing with Dr. Bøe that safety and cost are somehow related, I am uncertain about the degree of this relation. The recent British study on failures has indicated that increases in resources would not have significant effects on failures. Perhaps only investment at a national level could have helped. Let us take another look at this relation from practical observations. One tends to assume that building is a business in which construction quality is in conflict with profit. But when we examined failure incidents in some Eastern European countries, in which the element of profit did not predominate, we found the same familiar patterns and causes of failure. For example, human errors occurred to a similar extent, some due to pressure to meet deadlines though financial pressures were absent. Let us turn to industries with relatively abundant resources, such as offshore, nuclear and construction for defence. They are highly safety conscious but, in spite of vast investment on quality assurance, have to admit that money alone cannot buy safety. We need to do more work to understand human nature.

Matousek: I have a question to Professors Kupfer, Ditlevsen and Baratta: What is the definition of "gross error" you introduced into your papers?

Kupfer: To answer the question of Mr. Matousek about the difference between deviations from target values due to natural variations and due to human error, I would like to point out that large deviations caused by natural variations generally occur with extreme low probabilities. On the contrary, the same deviations if they are caused by human error have much higher exceedance probabilities, e.g. 10^{-2} or 10^{-3}.

Of course, there is also a philosophical aspect because it is not easy to distinguish whether a large deviation was caused by natural variations or human error. In particular, it is necessary to look at the process generating the quantity under consideration. E.g. in concrete production extreme low strength values can not totally be excluded even if the relevant codes of practice have been observed. However, a large deviation of the location of the reinforcement in concrete members from its intended position can hardly be viewed as the result of random influences since the men at the job reexamine the result of their work. Also, the functioning of the distance pieces can be controlled before concreting. In this case one might consider to define a deviation being the result of an error if it exceeds a certain value.

Schneider: Could we hear the definition Mr. Matousek would like to have in this context?

Matousek: I think the notion "tolerances" should be used in this context. All human activities or results beyond stated tolerances would then be defined as gross errors.

Rackwitz: From a modelling point of view it appears useful to define errors independent of their size or their effect on structural safety as marked events belonging to a certain error generating point process. This implies that jurisdicial definitions do not apply in the strict sense. An error is present if a faulty action or omission takes place which is in conflict of what should have been done according to given professional rules, codes, regulations, etc. valid for the activity under consideration. Thus, an error which increases structural safety also is an error as this is the case if it has no effect on structural safety at all. Natural variations can then be taken within their entire physical or geometrical domain of definition. This definition of errors necessarily excludes faulty actions due to general professional ignorance for which no rational remedy appears possible.

Ditlevsen: Mr. Matousek directed his question to me also. As it can be seen from my paper, theoretical reliability is related to a mathematical model which may, according to the engineer's own choice, contain errors described in probabilistic terms. Some of these errors may, in fact, be denoted as gross errors which are parametrizable and therefore accessible to statistical analysis, and, consequently, accessible to rational control. In this view it is, perhaps, not very important or even useful to set up a general definition of what is a gross error. However, relative to a specific structural design including its mathematical model it may be useful to consider as a gross error any gross deviation of the realized structure and its environment from what was intended in the mathematical design model, and this whether or not the deviation has damaging consequences. This concept includes gross deviations caused by nature itself due to unsuitable choice of mathematical model. That claim in this case is to be put on the engineer and not on nature is not essential. The term "gross deviation" is imprecise and is to my opinion, as paradoxial as it seems, only practically operational as such. For the design process and the construction process a "fuzzy" perception of what are gross errors suffices. Quite another question is the legal one of claiming somebody in the court if damage has occurred.

Turkstra: Technically one can define a gross error as any condition in which design parameters are chosen from populations not envisaged in the design process. Personally, I do not like the term because it is too gross.

Errors in construction are of many kinds, may be made by various actors in the process, and can be prevented in different ways. They should not be lumped into a single category.

Nor do I believe that we should model errors and accept them in design. This penalizes the careful and responsible engineer and removes the incentive to improve practice. It is our responsibility to see that human errors are avoided.

Laurie: Figure 3 of Yam's paper indicates that in nearly 50 % of failures, checking of design concepts would have minimized recurrence of this type of failure. This appears to contradict his comment that responses to the survey questions had disclosed that increased budgets (more money) would not have avoided the failures - surely checking costs money?

This in turn suggests that engineers instinctively think in terms of investing more money in the structure or perhaps in more refined analyses when searching for improved safety rather than in the procedural or organisational aspect of design and construction (such as checking) which have been shown to be more critical when it comes to failures.

Yam: Mr. Laurie is quite right in pointing out that some remedial measures in Figure 3 involve spending money. Of course, money has to be spent on implementation and is in this respect related to safety. When I said money alone can't buy safety, I was warning against over-simplifying the relation. The simple relation holds up to a point. For example, improvement at a project level is quite impossible in many instances and has to be considered on a national scale.

König: I want to point out and underline that the amount of money spent on a structure can indirectly influence safety to a great extent.

The Civil Engineer is forced by competition to build new structural systems, use new construction methods, new materials and in the extreme to reduce the dimensions of structures from those used in previous structures. If the designer works far beyond the limits of general experience it is possible that he may not fully understand the overall behaviour of the structure, or he may not realize that there could be some new aspects of behaviour which were not known before. In such cases there is a greater likelihood of structural accidents.

Errors in estimating the price of a structure may also influence safety to a great extent. In such a case the contractor, in an effort to keep within his price, is forced to design and to build a weaker structure. Even with a high effort of control it is very difficult to avoid failures under these conditions.

The above statement is similar to that made in Prof. Kupfer's presentation and I would like to add the following to his list of causes of failure:

a. Bad estimating by the contractor especially in design and build contracts.

b. The engineering climate, e.g. time pressures on engineers to complete schemes quickly.

Also Sriskandan must have found that the higher effort of control reduces the failure rate of bridges in UK.

Skriskandan: I would like first to add to what Dr. Yam has said in answer to Mr. Laurie's question. In the UK we have been following procedures for quality control of design since 1973. Prior to that there were no formal procedures and there were errors which cost money to put right. However, since 1973, there has been only one known case of an error that slipped through the checking system.

The cost of the checking has varied from 5%-20% of the cost of design with an overall average of about 10%. We consider that we are getting good value for this money.

Professor König has suggested that there might be a difference in risks between structures that are fully designed before inviting tenders and those that are submitted in competition to design and build. I think that even in the latter case it would be possible to prescribe the safety requirements and independently check the design before it is constructed. However, what is more difficult to prescribe are the requirements for durability and adequate inspection and maintenance.

In my view, this is where competitive designs may prove to be troublesome. The client should try and prescribe these requirements very fully or be prepared to pay extra for modifications to improve these aspects of the design.

Ferry Borges: I call the attention of Prof. Turkstra to the need of considering duration when dealing with several types of serviceability limit states.

Schneider: I don't like the notion "serviceability limit state" at all. In my opinion serviceability basically is defined by an agreement between the client of the structure to be erected and the designer. Safety requirements, on the contrary, are to be stated in obligatory terms in codes. For serviceability, a limit state does not exist, as I see it.

Turkstra: Mr. Ferry Borges is quite right in his statement that our definition of serviceability is not quite right. We simplified the problem in order to make the general points.

In reality, unserviceability is associated with several types of load characteristics - some are reversible up-crossing problems, some are holding time problems and some are first passage problems. We consider these types of problems in our detailed studies which will be published later.

Kersken-Bradley: The following presentation I should like to make, is not to be regarded as a sincere contribution to the discussion on what is the appropriate objective in optimization techniques accompanying engineering decisions. You may take it as an absurd provocation:

For some structures losses in case of failure may be very large:

$$L \rightarrow \infty$$

(some people refer to e.g. nuclear power plants in this way).

Question: By which measures can expected losses be reduced to an acceptable level ?

Provocative answer: The probability of failure can never be reduced to precisely zero. Therefore, measures have to be employed, ensuring total destruction; i.e. total destruction of our globe.

Then, no human beings survive
no possibility to suffer from losses
thus, no losses at all (as nobody can suffer)

$$\rightarrow E(L) = 0$$

Obviously, something is wrong with this answer, but what ?

Schneider: One of possible contradictions could be that human instinct - at least in sudden incidents - forces the individual to adequately behave in order to avoid being killed.

Ditlevsen: This provocative example is not consistent with proper application of decision theory. The falacy is that costs should be assigned also to the act that carries out the decision (in this example, costs which ethics, or human instinct, would dictate to be infinite) and not just to the state following after the act. In short, utility should be assigned prior to the act and not posterior to the act.

Kupfer: Referring to Mrs. Kersken-Bradley's provocative exposition, I sincerely question whether the sufferings of those who remain are of any concern. Instead, human life should principally be protected as far as possible. This ought to be achieved via an overall optimization. In such an optimization, the total available working power corresponding to the state of technology and human way of life would have to be taken as a given quantity. Also the optimization process might be affected by the availability of resources. Excessively safe and thus uneconomical construction leads equally to losses of lives which then are caused by the lack of various other needs, e.g. nutrition, clothing, buildings.

Such global optimization studies are, nevertheless, as the initiating question very theoretical since with the obvious irrationality of humanity which primarily demonstrates this in the misuse of technology, presently optimization can only be done in very narrow fields.

Iemura: Acceptable risk depends on people and circumstances. For example, if people are told that a big earthquake which has a return period of 100 years may occur tomorrow, they suddenly decrease the "acceptable" risk to earthquakes.

Rackwitz: I feel that there is some kind of religion or ethic imperative in a number of the arguments just put forward. There is certainly not a unique number of an acceptable risk which unequivocally comprises those intangibles, it cannot be determined by looking at statistical failure rates and if it would exist, there are heavy technical difficulties in the use of such a number. At present, an acceptable risk to human life and limb cannot be defined without explicit reference to the overall probabilistic uncertainty model used for the calculation. Thus, structural failure probabilities should not be compared with failure rates in areas of human activities where statistics are available nor should two designs be compared on this basis unless the uncertainty model is the same. The acceptable risk rather is a conditional by-product in the process of minimizing the generalized cost of a structure. The concept of probability should only be viewed as a meaningful intellectual tool in a decision theoretic context. The structure finally is described by a very real set of dimensions, material grades, etc. and these are the natural descriptors of the state of a facility. Explicit optimization of utilities immediately reveals that the "acceptable" risk should be identical to the optimum risk under each particular circumstance. It depends on many factors which differ from structure to structure, material to material, one type of loading to the other, etc. Thus, in principle, there may be neither an acceptable nor an uniform risk .

Turkstra: I am glad that we have reached the "fun" part of the program. The answer to Kersken-Bradley's dilemma may be as follows: Utility involves the product of failure probability and costs of failure. If failure costs are infinite, utility losses need not be infinite so long as failure probabilities approach zero in the limit faster than failure costs go to infinity.

Failure probabilites become "effectively" zero relatively quickly as I tried to show in an ASCE paper in 1967. Who, for example, can tell the difference between probabilities of 10^{-10}, 10^{-20} or zero.

Larsson: The result of our design procedures should be studied and failures analyzed so that we can adjust our safety factors. As an example, we have no experience of some new structures. A prestressed ground-anchor could have been correctly designed in the limit state, but could have its corrosion protection destroyed after one single moderate overloading, causing collapse within a few years.