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4. Discussion of IABSE SURVEYS «Hazard Scenarios and Structural Design» J. Schneider, S-33/85, published in November 1985 in IABSE PERIODICA 4/1985

A Discussion by A. N. Beal, Leeds, UK

A good principle can have its sense destroyed if it is codified as a «rule»; engineering judgement can suffer greatly by being «rationalised» into rules with values determined by statistical calculations rather than careful thought. Unfortunately, although the proposals in this Paper are undoubtedly well-intended, they suffer seriously on both accounts.

The emphasis on «hazard scenario» jargon is particularly unfortunate as it obscures the fact that much of what is discussed is common in existing practice under different titles. Thus scenario thinking as described is (and always has been) the very essence of a practising engineer's work – only instead of saying «let us analyse this hazard scenario», he/she says «let's design for this load combination» or «let's think about what might happen». Only the proposed procedures and terminology are new and it is worth discussing how helpful these are. (It is worth noting that the same comments apply equally to «Quality Assurance» [2: para. 1]).

I agree completely with Professor Schneider's warnings (3:2 para 5) that paper work cannot replace engineering thinking and that it is this creative thinking which is essential. However some of the specific proposed rules are very difficult to reconcile with engineering thinking. «Turkstra's rule» that in any one load combination (or hazard scenario) one load (or hazard) should be taken at its maximum value with the others at reduced «most probable» values seems to be favoured here – but it is open to serious objections. The idea that, for example, it may be appropriate to consider a reduced wind load when designing for live loads is sensible but it is not new and long predates Turkstra's 1970 paper (e.g. BS153: Part 3A: 1954 Cl. 12b[1]). However Turkstra's version of this idea as quoted here replaces a sensible engineering judgement with a rule could easily produce nonsense. Thus if we apply it to a bridge subjected to only «dead load» and «imposed load» it suggests that we consider either the dead or imposed load at its maximum value with the other at its most probable value. However there is no reason why the loading should not be subdivided into a greater number of categories; as only one would be at a maximum at a time, increasing the number of categories would tend to reduce the design loading. Thus Turkstra's rule has the interesting property that the design loading is inversely proportional to the number of loading categories selected; imposed load on a bridge could be reduced at a stroke simply be subdividing it into «lorries», «buses», «cars» etc. The other fundamental objection to Turkstra's rule is that it is based on the assumption that loads (or hazards) are statistically independent, whereas they are often linked in practice, e.g. high winds and snow are both more likely in winter as are high floor loadings in department stores (because of Christmas). Surely adopting such a rule is contrary to the thinking advanced by the Author?

The structural failure examined in 3.5 appears to have been caused by underestimation of the snow and wind load which can combine on a station roof; if recommendations on snow and wind loads are revised, this would resolve the problem without the need to rewrite all our Codes. Perhaps what the example does illustrate is the need for engineers to think independently and to realise that there is more to engineering design than just following approved procedures and complying with codes of practice.

In section 5 it is suggested that hazard scenario thinking should be applied separately to applied stress and structural strength; this looks suspiciously similar to the partial factor format of the limit state codes and, sadly, seems to share much of their usage of probability theory. The theory used in the limit state codes has clearly established errors in its treatment of loads[2], material strengths[3] and the combination of these[4]. If limit state theory is to be replaced by a new approach, it would be very unfortunate if the new approach repeated the old mistakes.

References:

1. «Specification for Steel Girder Bridges, Part 3A: Loads», BS153: Part 3A: 1954, BSI, London.
2. «Secondary Dead Load and the Limit State Approach», A. N. Beal, 'Concrete', Sept. 1981, the Concrete Society, London.
3. «Concrete Cube Strengths – What use are Statistics?», A. N. Beal, 'Proceedings Part 2', Dec. 1981, ICE, London.
4. «What's Wrong with Load Factor Design?», A. N. Beal, 'Proceedings Part 1', Nov. 1979, ICE, London.

Reply of the Author to Mr. Beal's Discussion

The discussion by A. N. Beal is welcome. I heartily agree with some of his statements concerning the urgent need to apply mature engineering judgement. Expertise and having an overall view of things, however, is only obtained by experience and reaching a position of seniority. Mr. Beal should not forget that most engineers are still on the road to seniority and meanwhile are faced with problems that can hardly be dealt with by just stating the need for more engineering judgement and thinking.

As a teacher (and I claim to be an engineer as well) I have to teach the engineers of the future, who will certainly be faced with more difficult problems than we have had to face. I could cite many important examples, for instance the increasingly chemically aggressive environment attacking the structures we, the older generation of engineers, planned and erected. And here is my problem and that of all teachers: you cannot teach experience and mature judgement. But you can teach the basics and develop the necessary tools, models and some comprehensive concepts. The plea for tools and concepts should not be seen in a narrow sense only. We need broader concepts as for instance the Hazard Scenario Concept under discussion. This approach is obviously not sufficient to guide teaching and engineering thinking all the way, but it is helpful at least. I admit that it is scarcely more than new terminology in a field where experienced engineers make the right decisions, perhaps without discussing their methodologies. In fact, when asked for reasons and explanations many of these engineers would produce rather fuzzy statements, like «Look it's simply a matter of experience.»

I am inclined to think from Mr. Beal's discussion that he is one of those people who believe in a deterministic world and do not accept statistics and probability theory as useful tools for explaining many things that happen in the world around us. I looked up his references and detected in the papers a certain tendency to hide behind global factors (e.g. as included in any working stress design method or in the much simplified limit state design equations). As soon as these methods advance toward partial factor design formats (let alone reliability methods and the like) the discusser develops phobias. And here, in my opinion, Mr. Beal is wrong. These advanced methods and tools provide much more insight into the problem than all the global safety factor approaches. The latter have the serious flaw that factors can be regarded as covering everything in the sense: «Well, there may be some errors, but as we're covered by the safety factor we can safely ignore them.» I do not think that Mr. Beal himself supports such erroneous thinking. Introducing a factor-free safety concept, however, at least delivers us from the possibility of such pitfalls.

Most of Mr. Beal's discussion, however, is concerned with rather a small part of the paper, namely with Turkstra's rule. I asked Carl J. Turkstra to answer the objections raised himself. His answer is printed below.

Finally, I strongly support the following statement at the close of Mr. Beal's discussion: «It would be very unfortunate if a new approach repeated old mistakes.» As a matter of fact, though, capable people do not repeat old mistakes. They introduce new ones. This is not simply a joke. Experience has shown again and again that this is true.

Comment on the Discussion by Prof. C. J. Turkstra, New York, NY, USA

One of the primary objectives of modern load combination analysis is to deal in a rational way with the obvious and traditional fact that extreme loads rarely act simultaneously. To do this we must explictly evaluate of all design loads with time.

A first conclusion is that «dead» loads are different than «variable» loads. Rules for load combination only apply to variable loads – results must be added to permanent loads which are considered separately.

In an evaluation of any one type of variable load, a certain amount of common sense is required. Highway bridge loading for example, is not made up of separate categories of trucks, cars and buses – it is a multi-variant single process with its own stochastic character. When stochastic dependencies between loading types are important, they must be considered. Elementary rules can easily be modified.

What was proposed several years ago was a simple way of looking at complex random time-dependent processes. Subsequent experience suggests that this simple approach with slight modification often yields results that are sufficient for design purposes (1, 2, 3).

References

Larabee, R. D., «Approximate Stochastic Analysis of Combined Loads», Research Report R78-28, Department of Civil Engineering M.I.T., Cambridge, Mass, Sept 1978.

Turkstra, C. J., and Madsen, H. O., «Load Combinations in Codified Structural Design», J. St. Div., ASCE, Vol. 106, ST12, Dec 1980.

Wen, Y. K., «Methods for Reliability of Structures under Multiple Time Varying Loads», Nuclear Engineering and Design, 60 (1980).