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Concluding Remarks

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PURSUING HUMAN ERRORS

It appears that the problem of human errors and their effects is finally coming to life after having been pushed off for a long while as the research community was looking at other, seemingly more rewarding tasks.

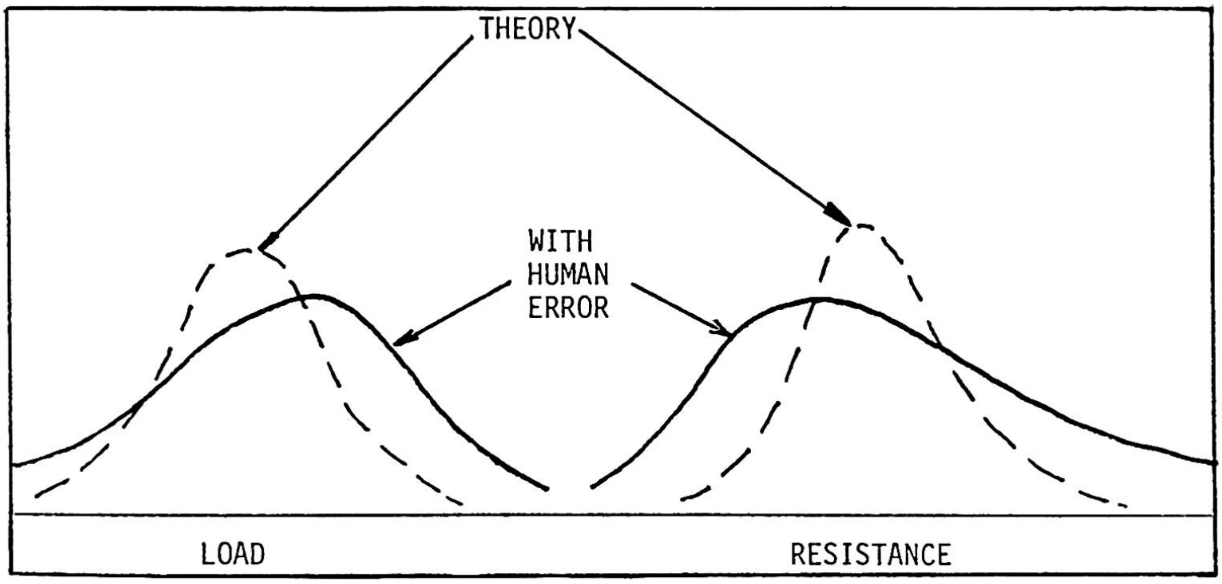
In the meantime methods of structural analysis were brought to all but perfection, making programmes and tools available, taylored to just about every conceivable type of structure. Also the analysis of statistics and probabilistics in the field of structures has been pushed perhaps to the limit of what can sensibly be used in today's construction industry, its application being limited only by the hypothesis that in construction everything is going the way it should go "weil nicht sein kann was nicht sein darf" (because that which must not be, cannot be).

Voices have been heard rarely until recent years who tried to focus attention to the fact that things do go wrong in spite of statistics and probabilistics, giving the lie to those disciplines when it comes to close the gap between reality as it happens every day and the perception of such in theory.

The fact of that discrepancy has now been widely recognized and a number of attempts can be listed that were undertaken in the last few years to clarify the reasons and conditions for the gap to exist. The general name of "human error" or "gross error", was found to suggest concisely the source of the discrepancy and two roads of attack to deal with the problem can be discerned so far, as documented by today's papers and many other recent contributions. Let us consider for a little while what these two lines of attack really are and perhaps the prospects of success may become foreseeable.

1. The a priori model :

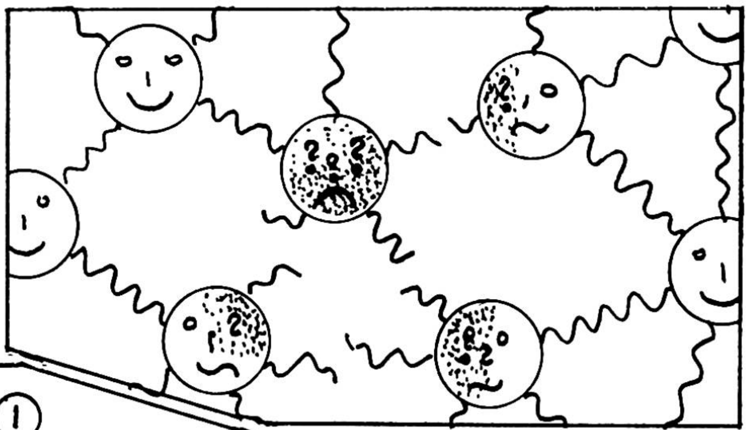
Human error has been perceived by some researches as just another source of variation of building parameters such as for example the so called stochastic variation of climatic phenomena. Distributions have been proposed for this particular source of deviation and, for a number of trivial cases, the algebra has been worked out including it, and with the purpose of fitting it in with the previously found probabilistic models of the building parameters. Results of this have been quite predictable, shifting and flattening the humps of loading and resistance distribution.

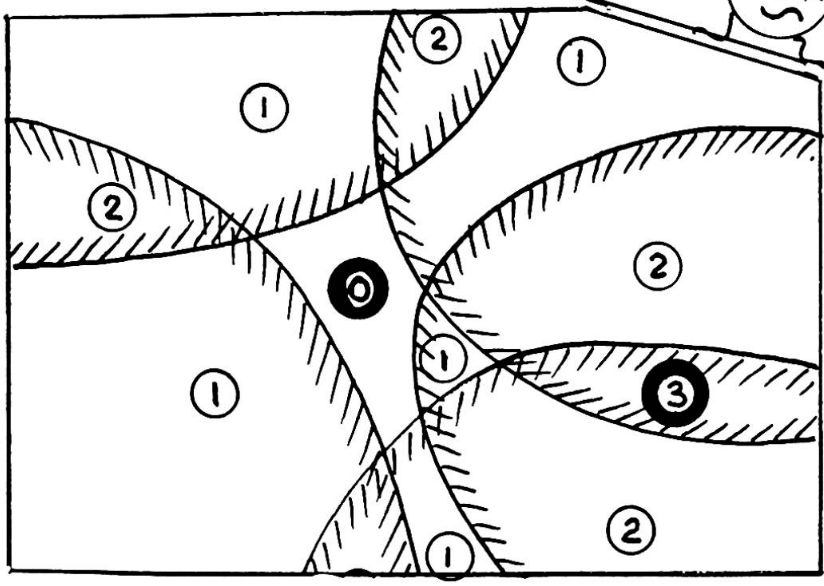


Nobody though, to this author's knowledge, has been able to prove sofar to any degree of certainty that such distributions really apply or even, whether or not this is an appropriate way to treat the problem.

When one diverts for a moment from the civilized although trivial model cases and looks at reality, one cannot but notice that its complexity is so great that to this date, it has defied any rational analysis of its parameters. It is quite easy to enumerate fifty or so factors that relevantly influence the creation and well-being of a structure, some of which are of a character which makes them altogether inaccessible to the classic statistical approach. Let us just recite a few of the more difficult ones, such as :

The information flow among the participants of a project whose interruption or malfunction can be traced as a cause of many mishaps.





The mapping of responsibility. Gaps exists where things fall between chairs, nobody feeling responsible for them; or the contrary where too many people or bodies do share in the responsibility for one particular portion and therefore spend their time and effort stepping on each other's toes.

The disposition of incentives, positive or negative. Often people can be found in a position having to make important decisions concerning events that are not related at all to any of their interests, financial or legal, or whose weight is out of all proportion to what the person can perceive as an incentive for himself. Or : Who causes the problem,

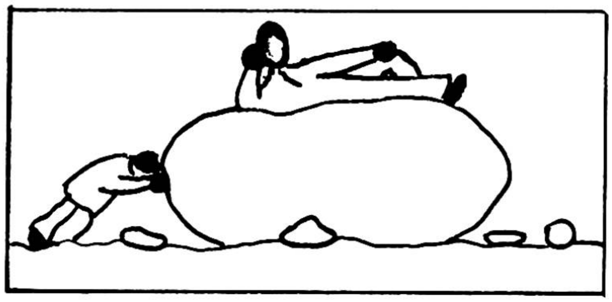
Is it the highly paid and pampered big boss

or

the poorly rewarded underling who will goof?

The qualifications and abilities of people assigned to a task :

Is it the little guy who is given a task beyond his abilities or the highly qualified who gets bored and goes to sleep because his work is not enough of a challenge to him ? Who will cause the blunder ?

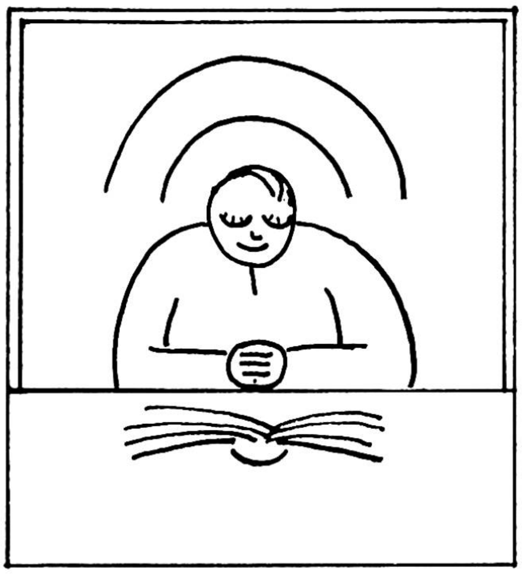


The general working condition of participants :

Is it better to keep people in key position under high stress

or

should they be shielded from anything that might be upsetting their peace of mind ?



Among many other things it is questions like this that need an answer, before we can start building theories about the probabilistics of human error and its effects. Of course, everything can eventually be expressed in terms of resistance or load, stirring it in with the all encompassing stochastic model we always apply unto events we are not able to analyse or understand. But is this ever going to teach us anything of value on the human errors that cause all the grief of structural failure ?

2. The common sense approach :

What then are all the engineers doing who build our reality while the researchers debate on the pros and cons of this or that model ? It is nothing more than the application of the best of their knowledge and the best of their experience, in other words, common sense.

Human errors do occur and means do exist to curb their frequency and effects. The uses of checking, verification, supervision and control were recognized since man began to build structures, and normally, resources are made available to perform it. We have today heard a number of contributions dealing with this common sense type of approach, and a number of others have been published in recent years. What they all have in common is that they try to formalize, on the basis of the logistics of the building process as perceived by the author or authority in charge, a system of verification and control of the building process in its phases. Some of these mechanisms have also been institutionalized, even for quite some time like the German "Prufingenieur", the French "bureau de contrôle", or more recently, in Great Britain. Only, in different countries different systems are applied and nobody has been able to prove one of them to be the best or merely superior to another. Not even the comparison with countries that do not have institutionalized procedures at all, has been made so far. This indicates two things :

- The common sense is entirely subjective and directly reflects the perception of circumstances by whoever applies it.
- There is no uniquely best or even better formalization of common sense measures against human errors, since every application works in its particular environment.

One can see immediately the limitation of this second approach to human errors. It is the bounds of what can be perceived at any one time and by any one person or perhaps group of persons in charge. It is therefore congruent to the limits of the human mind which we shall not probably change very much in the near future.

Serious impediments then exist for progress along both these lines of approach, the theoretical as well as the practical.

3. Data collecting :

Similar limitations have also become apparent in yet another area relating to the problem of gross errors: The collection of data. In several countries of Europe and North America, serious efforts have been started, and what has been recognized among many promising results is that we are not really certain what the relevant parameters of the problem are.

Looking back into my few illustrations as well as the questionaires I have been finding on my desk in recent years enquiring about past scenarios of structural failure, one thing is quite apparent : We do not know how and what to ask.

It is fine to find out that 60% or so of all failures occur during construction. But that is not really new since every experienced engineer will essentially know the same thing from his personal or indirect experience. And : This does not really tell us why the failure occurred. Perhaps we can pinpoint a person in a particular case but why was it that person and how can we go about preventing the same from happening again. Do we replace him with someone higher qualified, and in which respect, or do we increase the salary of his equivalent next time around ? Obviously, the trivial solution of the problem is to replace everybody who fails or is likely to fail with someone better qualified, and everything will be alright.

The only drawback is of course : Supermen do not occur in sufficient numbers to staff all vacant positions. We shall thus have to make do with whoever is available, i.e. ourselves, including the short-comings we may have been finding in each other. Therefore : Human short-comings do exist and will always lead to things being less than what they are supposed to be. All we can do is try and prevent them from taking effect. Either by eliminating conditions that are recognized to favor the generation of gross errors or by catching them in time. But how ? How do we set a building project up to make it less error prone, within the limitations imposed by the day. How do we assign resources available to the various possibilities of checking / verification / supervision / control in order to obtain the best possible results ? These are the real questions behind the problem of structural safety which we are facing today.

With this in mind we can now, I believe, conclude on the most promising approach we should take to deal with the problem of gross errors. It is not, at first, a direct approach with statistical methods but will have to consist of something one might call a parameter study, or a system analysis : We shall have to study the gross error at its source, namely the human individual, and along its history until it takes effect. Then and only then can we hope to be able to do something rational about it that will improve today's situation, by either reducing the results of human gross errors, or by reducing construction expenditure while maintaining the same level of safety (frequency of mishaps); only on the basis of an analysis of the genealogy of the human error shall we be able to conceive rational mechanisms for its prevention.

4. Modelling the building process :

Human error can be seen as something resembling a parasitic growth on the organism of a building process. It will, like any parasite worth its name, attack in particular the portions of the organism that are already weak or sick and there it will thrive. In order to keep the organism sound, one therefore has to find out where those weak and sick places are located, so that they can be healed, repaired or otherwise made good for. This kind of reasoning has recently been discussed rather extensively among a group of Canadian engineers, and I think I am in a position to submit some preliminary suggestions that I hope will fall on fertile ground and grow into something more concrete.

The building process seen in its totality is a very complex organism, being composed of many elements and aspects of great diversity. As we previously found, it can be perceived as a communication network, with human individuals forming stations linked together and information flow forming the currency. It can also be seen as a field of responsibility which one can map and determine, plan and change. Other aspects, or better projections as I should like to call them would be the field of incentives influencing the human elements;

positive incentives like financial reward or professional acknowledgement, or negative ones like getting fired, or the threat of legal consequences. Other properties of the building process include such features as the hierarchical organization, the selection of individuals in terms of their apparent qualifications, the general climate of personal relationship : Are we all in one boat or do we have the lawyers at the ready to be at each other's throat every minute. And last but not least, and obviously, control and checking mechanisms, regulations and institutions will constitute a major ingredient.

To put order into this cluster of parameters, elements and relationships, will require a major research effort of a rather interdisciplinary nature. The most promising approach appears to be the creation of a computer simulation or model of the building process which will then serve as a tool to do studies of various aspects and/or the problem in its totality.

The model will have to act as a receptacle for data gathered and yet to be collected : Let us not forget that the documentation on mishaps which we have begun to acquire, must be greatly expanded if ever we should hope to determine significant results in the statistical sense. If we have collected more or less complete data on perhaps 1000 cases or so, this must be measured against the number and complexity of the parameters it takes to describe a building process in all its relevant features. Mishaps on the other hand, are by no means the only source of data; what may prove to become an equal or even richer source could be the near-misses, i.e. records of cases where gross errors were caught in time and could be corrected. Fortunately in building the successes outnumber the failures by several orders of magnitude and although the latter can teach us much, we may eventually learn even more from the former. Data collecting may also be less difficult since people prefer to talk about things that went right rather than wrong.

The model will also, eventually, serve as a tool to study projected building processes, or in particular strategies for the prevention of the effects of gross errors. Once sufficient data has been absorbed and the model can itself apply formalized experience, we may be able to rationalize on how to assign resources into the places where they are having their best effect.

Or, in a wider frame, we may be able to adjust the set-up of the entire building process in order to make it function as a sounder organism.

5. Serviceability :

One aspect similar to the safety problem has been clearly recognized in the recent past : It is the serviceability criterion.

It is not always outright collapse that constitutes the most important concern but the failure of structures in general to fulfill the requirements they were designed for. States of unserviceability can generally be considered in the same fashion as the failure state itself, although some distinct differences exist. Mainly these are with the definition of the limit of serviceability which has to respond to conditions occurring together individually for each single case : The same degree of deflection or cracking may be acceptable in one case, but not in another.

One of the more difficult cases of unserviceability in terms of logic is for instance the lack of sufficient safety against failure. The question arises there: How is a structure to be classified that did not fail but is not in conformity with whatever safety rules apply ?

Research on serviceability criteria has been relatively rare and only recently the basic principles are being studied. This is perhaps a consequence of a different legal and social situation, when compared to the question of safety against failure. In the latter case it is of course mainly the public whose interests lie with the achievement of safe structures whereas in the case of serviceability, it is mostly the owner who in general, and in western countries, is a different entity.

This would be of practical advantage because where no correlation exists, the two problems can be treated separately. Unfortunately, a number of cases exist where both criteria are not orthogonal such as the abovementioned nonformity with safety criteria against failure, or like all cases of deterioration through accumulating damage through corrosion, cracking, settlement etc.

Let us also keep in mind that the cost of correcting all cases of unserviceability may well exceed the cost of making good for manifest failures.

And lastly, or course, human and gross errors have their influence on serviceability of structures as much as on the failure criteria.