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Problem of More Effective Feedback to Learn from Success and Failure

Nécessité de mieux tenir compte des expériences

Erfahrungen besser ausnützen

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SUMMARY

Feedback from experience is essential because engineering is still basically empirical. Failures continue to occur. No one has the same understanding of a structure as its designer, and he should maintain long-term contact with it. When the designer dies, it is not fanciful to say that something is lost to the structure.

RÉSUMÉ

Il est essentiel de tenir compte des expériences car l'activité de l'ingénieur reste essentiellement basée sur des notions empiriques. Les accidents et ruptures continuent de se produire. Le projeteur est la personne qui possède la meilleure connaissance d'une structure et il devrait garder un contact suivi avec elle. Il n'est pas exagéré de dire que, avec la mort du projeteur, une construction de génie civil perd une partie d'elle-même.

ZUSAMMENFASSUNG

Der konstruktive Ingenieurbau ist keine reine Wissenschaft. Die Erfahrungen sind dabei besonders wichtig. Unfälle werden immer wieder geschehen. Niemand hat ein so grosses Verständnis für ein Bauwerk wie sein Entwerfer, und er sollte einen regelmässigen Kontakt pflegen. Es ist nicht übertrieben zu behaupten, dass ein Bauwerk mit dem Tod seines Entwerfers einen Teil seiner selbst verliert.

1. Introduction

> "At first, the people of the whole world had only one language and used the same words. As they wandered about in the East, they came to a plain in Babylonia and settled there. They said to one another, "Come on ! Let's make bricks and bake them hard." So they had bricks to build with and tar to hold them together. They said, "Now let's build a city with a tower that reaches the sky, so that we can make a name for ourselves and not be scattered all over the earth."
> Then the Lord came down to see the city and the tower which those men had built, and he said, "Now then, these are all one people and they speak one language ; this is just the beginning of what they are going to do. Soon they will be able to do anything they want !" Let us go down and mix up their language so that they will not understand one another." So the Lord scattered them all over the earth, and they stopped building the city."
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> Genesis 11

I have no intention of taking the story of the Tower of Babel as the text of a sermon on structural design, but this must surely be one of the earliest illustrations of the fact that the design and construction process is critically dependent for its success upon effective communication - one of the pervasive themes of this colloquium.

The particular aspect of communication with which this short paper is concerned is the achievement of more effective feedback to learn from the success and failure of design under the acid test of construction and post-construction experience.

2. The Need for Feedback

Although firmly rooted in mathematics and physical science, structural engineering design is essentially an empirical exercise, requiring experience, insight and judgement. In these days, when the electronic computer makes available to the everyday designer an array of sophisticated analytical tools that the experienced engineer of twenty-five years ago would not have dreamed possible, it is easy to overlook the fact that some of the apparently simple decisions that have to be taken in the design process may be the most important ; also that non-technical factors may have a decisive effect upon the success or failure of a design.

Despite scientific and engineering progress, which has steadily reduced the uncertainties of all kinds that affect structural design and has paved the way for some spectacular engineering success, failures continue to occur.

It is axiomatic that there is a strong need for effective and continuing feedback so that established design principles and methods may be modified and improved where required in the light of empirical evidence of success and failure. For most practising designers, this feedback falls into two distinct areas, both of vital importance.

a) Feedback from the vicarious experience of others, gained from an ongoing study of past and contemporary technical literature.

b) Feedback from personal experience.

3. Feedback from Vicarious Experience

"Experience teaches slowly, and at the cost of mistakes." (J.A. Froude)

In the engineering world of today, there is a bewildering array, almost a surfeit of technical literature. (In passing, one may note that this has had the paradoxical effect that, although we have the means to be better informed than our predecessors, it is questionable whether we have truly become so, perhaps because of the sheer volume of paper with which we are daily bombarded !)

Certainly there is no lack of material describing engineering successes by way of current projects under construction or recently completed. It would seem that the feedback of vicarious experience to designers in the context of "success" is adequate. Turning to the importance of feedback from the experience of others on "failure", it is first necessary to provide a definition. Feld in his book, "Construction Failure", defines failure as behaviour not in agreement with the expected conditions of stability, or as lacking freedom from necessary repair, or as non-compliance with the desired use and occupancy of the completed structure. A more succinct definition provided by Melchers is that failure is "the premature rendering of a project unfit for its purpose as currently defined". This definition is considered to be a good one, and will be adopted for the purposes of this paper. It is interesting that it implies that a project should not necessarily be regarded as having an indefinite life - a consideration sometimes overlooked by owners and the public.

Before moving on, there is another highly important area to consider, intermediate between success as it is commonly understood and failure as defined by Melchers. In speaking of structural failures, Feld has this to say : "If we define failure as observed collapse, there are few failures. But if non-conformity with design expectation is defined as failure, and this is the more logical and honest approach, and one takes the trouble to measure the shape, position and condition of completed structures, there are many failures - far more than the list of incidents that are covered by the news media, both technical and public." Clearly, in the context of this paper, "failure" is the wrong word to apply to the phenomena described here by Feld. A better term is, perhaps, "structural aberrancy", and this will be used to describe the type of non-conformity with design expectation that falls short of "failure" as defined by Melcher.

Most experienced designers have encountered structural aberrancy, particularly where creep or consolidation play a part, or where there is an unforeseen reaction between construction materials and the

environment. However, except in significant cases, approaching failure, papers on such phenomena are comparatively rare. This is a pity, since the long-term behaviour of structures, good or bad, is of considerable interest to the profession.

Perhaps a designer who has written a paper on a major project at the time of its completion may be diffident about writing a follow-up to describe aberrancies in performance years later, but in fact, the provision of such feedback should be strongly encouraged. (Perhaps IABSE could give this consideration, if it has not already done so ?)

When it comes to outright failure as defined by Melchers, particularly if structural collapse has occurred, feedback is sometimes not easily forthcoming, although the information may be of much value to the profession. Failures may lead to adverse publicity, loss of reputation, loss of money, arbitration, lawsuits and unfortunately even loss of life. It is not surprising that, at least in the early stages following any significant failure, feedback is difficult, if not impossible, to procure, if only because of the clampdown on information by those with a commercial interest. Sir Bruce White, in his Foreword to Hammond's "Engineering Structural Failures", remarked that,

> "It is one hundred years since Robert Stephenson, when President of the Institution of Civil Engineers, in summing up a paper said that "he hoped that all the casualties and accidents which had occurred during their progress would be noticed in revising the Paper ; for nothing was so instructive to the younger Members of the Profession as records of accidents in large works, and of the means employed in repairing the damage. A faithful account of those accidents, and of the means by which the consequences were met, was really more valuable than a description of the most successful works ..... "
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> With our increasing advances in engineering skill and knowledge and in the magnitude of our works, the need for the frank recording of "casualties and accidents" is of even greater importance than in Stephenson's time. Yet how rarely, in the papers read before professional societies, do we find a frank analysis of errors of design and execution. We can fully understand the desire of an engineer to conceal careless mistakes ; with these we are not really concerned. It is in the genuine errors of judgement in design and execution, in the failure fully to understand site conditions and to foresee consequences that we are so vitally interested. Engineers do not serve their profession well if, in a desire to impress, they conceal their disasters."

Notwithstanding these observations, there is a substantial amount of information in technical literature on the general subject of engineering safety and failure, and a number of detailed accounts of specific failures.

Melchers in his review and classification of civil engineering failures published in 1976 lists seventy-nine references from the technical press.

In addition to publications of writings by individuals, valuable contributions to the study of safety and/or failure have been made by the American Society of Civil Engineers, the International Commission of Large Dams and the Institution of Civil Engineers, which set up a committee to report on structural safety.

Several attempts have been made to classify project failures, to analyse the various elements that can contribute to failure, and even to rate the proneness of any given project to failure taking account of such parameters as new or unusual materials and methods of construction, experience and organisation of design and construction teams, research and development background, industrial, financial and political considerations.

Melchers, whose paper I would commend to any who wish to read further, has prepared a "Comprehensive Conceptual Model of Civil Engineering Project Implementation Factors" that takes account of the total civil engineering process, giving due importance to non-technical elements that may affect success or failure.

It seems to the writer that the major difficulty in setting up any overall philosophy or conceptual model to attempt to predict or control failures is the "rogue" event - the gross error that may be made almost anywhere in the engineering process due to lack of knowledge, oversight or unforeseen circumstance. Thus I believe that the greatest benefit of feedback on the successes or failures of others may lie not in systematic analysis of failures but rather in the responsive chord that is sometimes triggered by memory when similar or parallel circumstances arise in one's own projects.

4. Feedback from Personal Experience

Many designers may never have the privilege of responsibility for a major structure, nor the misfortune to be involved in a major failure. It is certain that even those who are thus privileged or unfortunate will also have had to do with many lesser structures, which have roused little or no publicity.

The writer was once sitting at an airport in the company of an eminent designer, responsible for some of the most important bridge structures built in our time. The topic of discussion was the high remuneration paid to first-line pilots, and as we spoke, we watched such a pilot climb out of his aircraft. My colleague remarked that he considered them worth every penny that they were paid, because they were there to know what to do when something went wrong. He added, however, that there was a significant difference between their responsibility and ours. "That pilot's responsibility has ceased, and he will not carry any further responsibility until he climbs up those stairs again. You and I, however, go on accumulating more structures behind us that might go wrong, the longer we live". I make no apology for this digression, for there is a profound truth in these words.

The importance of feedback on the success or failure of a designer's personal efforts cannot be too strongly emphasised. Such feedback is important both during the construction phase, and in the longer term, after construction is complete.

The point that design is essentially an empirical exercise was made at the beginning of this paper. It is highly desirable that the designer should be intimately involved in supervision of construction of his work, for important changes of detail may need to be made to his original designs. These may come about as a result of available construction techniques, construction errors, substitution of alternative materials, or improvement in original design detail as a result of feedback from the construction process. In the writer's opinion it is vital that the designer should at least participate in, and preferably control, the supervision of his work, which should be entirely independent of the supervision provided by the constructor. The tendency of some owners to employ a designer to prepare plans and specifications and then hand the work over to others to supervise, giving the designer no effective participation, is strongly deprecated.

The second area where feedback on the success or failure of a designer's personal endeavour is important is in the long-term behaviour of the structures that he has designed. Every structure is an artificial intrusion into the natural environment. The structure and nature must come to terms with each other, and often this cannot happen overnight. An experienced engineer responsible for the maintenance of structures for a large public authority once remarked that all structures need a period of "bedding in", during which they may display unexpected behaviour. Perhaps this is another way of saying that many structures display structural aberrancy as previously defined, which may be a far cry from failure.

However this may be, there is no doubt that the ongoing observations of the behaviour of structures for which he or his close associates have been responsible, can teach small but vital pieces of wisdom to a designer in a manner that vicarious experience is not capable of. Any experienced designer will bear testimony to this. The late Dr. F.E. Kanthack, under whom I trained, was wont to remark that, "all concrete cracks, and it cracks at 15 ft. centres", an obvious generality and over-simplification, but it is remarkable in how many parts of the world I have paced off cracks and found them to be at 5m centres. From my personal experience, and those of my mentors and close associates I could cite : the pitfalls of using high alumina cement (long before the occurrence of the grave difficulties experienced in the U.K.); the merits of using a large number of small diameter bars at relatively high stress in water-retaining structures (before the advent of crack control theory); the absolute need for adequate cover to reinforcement and a high quality concrete mix in aggressive environments (given good cover and good concrete I have yet to see evidence of corrosion of reinforcement, even in the presence of significant transverse cracks). The list could be expanded to include more significant data relating to specialist aspects of design, and every experienced designer could no doubt provide a like series of observations from his own experience.

Such feedback might be regarded as trivial, but I do not believe that it is so. In the absence of gross error, the quality of the performance of a structure is to a large extent dependent upon good detailing, knowledge of which can only be gained from experience.

When the designer of a structure re-visits it long after construction is complete, he will see the structure as no other viewer will do, and he may look critically at areas that others will ignore. He alone knows the uncertainties that he had to consider and resolve during the design ; he alone knows those areas which checking may have shown to be uncomfortably highly stressed, but still within limits ; only he may remember areas where workmanship fell short of specified standards, and a compromise had to be reached. In most cases the designer is the person best qualified to notice and advise on the need for maintenance on his own structures.

It may be regarded as fanciful, but I believe that when the designer dies, something essential is lost to the structure, for no-one is ever again likely to have the same understanding of it, or personal feeling for it.

Perhaps herein lies professionalism.

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