Major construction and other failures: lessons for project teams

Major Construction and Other Failures — Lessons for Project Teams

Dommages majeurs — Leçons pour les groupes de projet

Bedeutende Schadenfälle — Lehren für die Projektierenden

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SUMMARY
Amongst the many successful achievements of construction around the world there have been some serious failures during the erection of structures. The incidence of failures is generally decreasing but the concentration of energy which may be released in any one failure is increasing. There is therefore a growing need to anticipate potential failures as well as learn from those that do occur. The evidence referred to in this paper indicates that major construction failures are rarely caused by novel technological problems but always involve two or more organizations. Attention is therefore needed to the organizational and contractual lessons of these and analogous failures.

RESUME
A côté des nombreuses réalisations couronnées de succès, il y a aussi des accidents majeurs lors de la réalisation de constructions. Le nombre de ces accidents a tendance à décroître, mais la concentration d'énergie qui peut être libérée lors d'un accident est en train de croître. Il est nécessaire de prévenir les accidents et de tirer les leçons de ceux qui se produisent. Les exemples cités dans cet article indiquent que les principales déficiences sont rarement créées par des problèmes technologiques nouveaux, mais résultent toujours de la présence de deux organismes ou plus. Il est, donc, important de tirer un enseignement de ces déficiences et d'autres déficiences similaires pour l'organisation des travaux et l'élaboration des contrats.

ZUSAMMENFASSUNG
Neben den vielen grossen Bauerfolgen in der ganzen Welt sind auch einige schwerwiegende Fehlleistungen bei der Errichtung von Bauten zu beobachten. Die Häufigkeit der Bauschäden nimmt allgemein ab, im Gegensatz zur Energiekonzentration, die bei jedem einzelnen Fehlschlag freigesetzt werden kann. Es wird deshalb immer nötiger, sowohl potentielle Defekte vorauszusehen als auch aus den bereits vorgekommenen Fehlleistungen eine Lehre zu ziehen. Das in dieser Arbeit angesprochene Beweismaterial deutet darauf hin, dass grosse Baudefekte selten durch neuartige technologische Probleme verursacht werden, sondern dass sie stets an den Nahtstellen zwischen beteiligten Partnern entstehen. Besonders zu beachten sind aus diesem Grunde die sich für Organisation und Auftragsvergabe ergebenden Lehren, die aus diesen ähnlichen Fehlleistungen gezogen werden müssen.

1. FAILURE

Dictionaries define failure as non-performance or an unacceptable want of success.

The adjective "unacceptable" is important. Success and safety in engineering are matters of probabilities, as in life generally. Controversial as it may seem when stated publicly, there is no certainty that anything is safe or that any one decision will lead to one predictable result.

A failure is therefore a result that falls outside an acceptable range. So is luck, but that word implies that the result is welcome. Failure is unwelcome, to society, an organization, or to individuals. Use of the words 'major failure' implies that the result is serious and should have been avoided.

What is serious is relative. Risks at work vary from job to job, and are usually different to the risks when not at work (Most jobs in Western countries are safer than being at home - construction is an exception). A definition of seriousness is that a major failure increases the chances of damage to people or things by an order of magnitude or more. It is these failures that attract public attention.

2. SIGNIFICANCE OF FAILURES

References cited in an earlier paper indicated that there is continuing improvement in the incidence of failures of engineering products. [1] The frequency and seriousness of failures are irregular, but in products as different as aircraft, bridges and process plant it is clear that the probabilities of failure have reduced. This is to the credit of engineers, their education and professional societies, leading employers, inspecting authorities and all who have paid the costs of higher standards.

On the other hand the failures that do now occur tend to be more serious, to the people affected at work, and to society. The reasons lie in two trends in the evolution of all sectors of industry:

- The pursuit of economy of scale. Larger plant and structures promise economy of scale in production and in the use of services. There is a diminishing return from greater scale, but the trend continues though irregularly. The consequence is greater concentration of physical and financial risks.
- The pursuit of optimization in design. Greater technological expertise has led to many advances in project performance and construction safety, but also has led to more 'economic' use of structural and other materials. [2] The physical consequences are to reduce structural redundancies with the result that the failures that do occur tend to be more rapid and less likely to show prior warning signs. The organizational consequences are that people and organizations are more specialized and their work is more interdependant.

The potential effects of a failure are therefore greater, which is presumably why there has been public pressure and legislation in Western countries for better anticipation and prevention of industrial hazards, but less and less can any one person be expert about all of a project and there are fewer directly relevant failures from which to learn. We therefore need to study those that occur in construction and any analogous failures in other industries.

3. REPORTS OF FAILURES

As might be expected, the most serious failures are investigated systematically and reported publicly. Many others are not reported, and near misses may go unnoticed. The evidence available is therefore not comprehensive, and ideally evidence of the causes of failures should be considered together with evidence of the causes of successes. Expenditure on the latter is regretably rare. Action to remedy what appears to be a fault considered in isolation could damage what were predominantly satisfactory ways of engineering and managing projects. The published reports of serious failures show that many of the decisions made were satisfactory. We therefore have to learn from faults but be cautious about producing new rules.

The important general conclusion from reports of serious and lesser failures is that none were caused by hithertoo unknown physical phenomena that acted without warning. [3,4,5] All were caused by not knowing or using existing information. They were therefore due to problems of perception and communication.

4. SPECIFIC LESSONS

The problems of perception and communications observed in reports of failures seem obvious afterwards. With the advantage of hindsight it is relatively easy to say how something might have been avoided. The actions needed may not be so obvious amidst the pressures of cost, time, contractual and managerial pressures typical in construction. What appear to be the lessons of failures are therefore set out here in the form of a check list, for use as reminders of questions which may be important in planning, organizing and supervising construction.

4.1 Designers' requirements

- Are design requirements practicable ?

  Case: Box girder bridges, fabrication tolerances. [12]

- Have design requirements been implemented ?

  Case: Kings bridge, material testing. [13]

4.2 Site data

- Are all parties working to appropriate data ?

  Case: Ferrybridge cooling towers. [14]

4.3 Construction conditions

- Is the erection method compatible with design ?

  Case: West Gate bridge. [15]

- Are erection conditions known and checked ?

  Case: Cleddau and other box girders. [12,16]

- Are all temporary loads checked through to supports ?

  Cases: Barton bridge, stability of temporary towers. [6]
  Barton bridge, foundations for towers.

- Who looks for and who interprets warning signs ?

  Case: West Gate bridge.

  Analogous case: Sea Gem drilling rig. [17]

- Who checks that specified checks have been done ?

  Analogous case: Aberfan tip slide. [18]

- Would hazard analysis reduce the potential consequences of a failure ?

  Case: West Gate bridge, location of labour huts.

5. MORE GENERAL LESSONS

After a serious failure it is to be expected that investigations should lead to recommendations on how repetition of that type of failure should be avoided, a good UK example being the work of an advisory committee on the safety of false-work. [19] The problems of individual perceptions of risk and virility complexes are also the subject of investigations and conferences. [7,20] These are obviously necessary, it appears recurrently.

Less obvious from studies of particular failures and accidents in construction are the following more general questions:

5.1 Symmetry in design

- Are symmetrical components apparently more stable during construction than they are, even to experienced people ?

  Case: Barton bridge, plate girders.

- Should symmetrical components be erected whole ?

  Case: West Gate bridge.

- Can symmetrical components be erected wrongly ?

  Cases: Concrete beams used upside down.

  Analogous cases: Bravo field blow-out preventer and other directional valves with symmetrical connections. [21]

5.2 Alterations to existing structures

- Is an alteration or extention to a structure compatible with the first design ?

  Cases: Sea Gem drilling rig.
  Alexander Kielland platform. [22]

  Analogous case: Flixborough by-pass pipe. [23]

6. ORGANIZATIONAL RELATIONSHIPS

Failures of perception, communication and not using knowledge that exists are organizational problems, within organizations and in the contractual and other relationships between them in designing and constructing projects. The general problem is one of making information and ideas known to people who are not aware that they need them. A particular problem is the 'decoy' effect that individuals and organizations tend to concentrate on the first recognizable feature of a situation and neglect further information and questions. [8]

There is no evidence that the greater size or complexity of projects have been direct causes of failure. The larger a project the greater may be the physical and social risks, but the growth in size of projects typical of all industries has been accompanied by decrease in the incidence of failures. The organizational problem is in the greater number and variety of specialist individuals and organizations that have roles in design and construction. This trend continues regardless of size of project. The increasing risk is that no one person has the expertise, information, time, responsibility and authority to be in control of design and construction of a project as a whole. One such person in control of decisions might have been able to anticipate at least some of the failures reviewed here. [8,9] Appointing one person in control is clearly the lesson of studies of how to reduce or avoid delays and extra costs in construction, not only to improve safety. [24] It might therefore seem surprising that appointing a 'project director' is not common practice, to achieve satisfactory commercial results as well as reduce the risk of a serious physical failure.

Divided control is much more common, it appears in Europe and North America. One explanation may be that managers of client organizations accept that the above lesson is logical, but they also tend to see their project as unique and under the pressures of their jobs concentrate on problems as they arise rather than on general ideas on how to anticipate them.

One remedy may be that engineers and their clients should be more scientific about who makes decisions. We also need to know whether a tendency to error can be predicted in people or in new types of construction. [10,11] And we need to be trained to analyze our assumptions [8], for instance to question the common engineering assumption that checking a calculation, etc. reduces the chance of error. The tendency after failures or thoughts of potential failures is to add formal checks. The knowledge that work will be checked could lead to less care to do it well or behaviour to suit the checking system, coupled with greater but false confidence that the result will be safe. [7]

7. INVESTIGATIONS OF FAILURES

The primary purpose of investigations into failures is to detect their cause and recommend means of avoiding repeats. Such investigations properly begin with the physical evidence from the failed material, and then seek an explanation of the sequence of failure. Nearly all investigations succeed in achieving a complete physical explanation.

If the origins of these unhappy events are in the perception of problems and communication of information, the relationships between the people employed on a project prior to failure should be investigated as scientifically as are the physical events. For this purpose the teams that are appointed to investigate serious failures should include at least one person experienced in analyzing organizational and contractual relationships but not familiar with the particular industry and therefore likely to be innocent of its assumptions.

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