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Excerpts from…

HUMAN FACTORS UNDERLYING BUILDING FAILURES

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EXECUTIVE SUMMARY

This study of human-factors underlying building failures includes: a review of the literature over the last twenty years; a taxonomy of human-factors contributing to design errors in the building process; a methodological critique of the AEPIC accident report form; an interview study of ten design professionals in the building industry compared to ten in the (mostly nuclear) power plant design industry; and a set of recommendations to reduce human errors in the building design process.

The key findings of the literature review are that human errors in design and construction are by far the major cause of structural collapse. Human errors are caused by lack of knowledge, negligence, inadequate supervision, poor communication, lack of thorough checking, and lack of adequate design references. Building failures due to human error may be controlled through supervision of staff, education and motivation of staff, careful specification of responsibilities, project planning, personnel selection, and principally, a good quality assurance plan. Quality assurance is a matter of setting quality standards, evaluating conformance to these standards, and acting when these standards are violated.

Human-factors leading to design errors in the building process are of three major types: factors related to technical procedures, such as errors in design calculations; factors related to organization and management, such as poor teamwork; and factors related to behaviour of an individual, such as insufficient knowledge or skills

The goals of the interviews with the designers were as follows:

1. To assess the extent to which design errors led to (or could have led to) failures.

[1] Please see the disclaimer notice in the original report.

2. To assess the seriousness of the above problem and the consequences in terms of financial cost, losses, and/or injuries.

3. To assess the role of human-factors in the above errors.

4. To establish whether control procedures (such as quality assurance) are used to catch errors in the work of the respondent's firm.

5. To identify measures for the reduction of design errors and measures for improvement in safety.

The main criteria in selection of the sample was the respondent's professional involvement in, or familiarity with, design practices in their respective firms and that they were professional engineers or architects, or worked in an engineering capacity. Also, we selected firms following into the main categories given below.

The key findings of the interview study with design professionals in the building and power plant industries are as follows: design errors are a somewhat serious problem and to an equal degree for both industries. Errors are serious when they occur, but they occur infrequently. Thirty case studies of design errors were described by each group of respondents for a total of 60; on the average, they were rated as "somewhat serious" by both industries. Financial loss represents the major consequence. The overriding cause of design errors was human error, including inadequate design checks, errors in design drawings, and poor communication. The major way of preventing errors is by better checking and review.

The major recommendations to reduce human error in the building industry are: good teamwork; adequate supervisory control; frequent checking, inspection, and review; extra care with new or unusual design features; clearly defined responsibilities; complete project documentation; collection of feedback from past failures; better training of staff; improved communication; adequate motivation of staff; and adequate quality assurance strategies and procedures, especially external and internal checking and regular design reviews.

The consequences of the thirty design errors in the building industry were 15 cases of financial loss, accounting for 50% of all cases; three cases of inconvenience; three cases of deterioration of the building; two cases of a life safety problem; two cases of personal injury or sickness; and four cases of no consequences at all since the errors were caught in time.

For the thirty design errors in the power plant industry, there were 11 cases of financial loss, accounting for 33% of all cases; 8 instances of production loss; 8 time delays; two cases of damaged equipment; and one instance of no consequences.

RECOMMENDATIONS

Based on the literature review and the twenty interviews, the following recommendations to reduce human error in the design process are offered:

1. Teamwork
There should be improved teamwork, with peers checking the work of their co-workers as a matter of standard procedure. Each person in the building process should be aware of how his task fits in with the successful completion of the project. There should be self control and self-checking for small or less complex structures.

2. Supervisory Control
Precautionary measures against unintentional or deliberate human errors and negligence include peer review (as above) and careful and regular supervisory control should be instituted.

3. Checking, Inspection, and Review Procedures
New or unusual features should be reviewed externally by qualified experts. Checking and inspection procedures should be incorporated into each stage of planning, design, and construction for the presence of errors. There should also be an independent (external) assessment of the building design, as for example by the municipal authority. Checking and design reviews were the ways most commonly cited by our interview respondents to prevent design errors.

4. New or Unusual Features- Extra Care
Additional precautions are required in the case of new design or construction methods for which little prior experience exists. In such cases, it is wise to have only one very experienced, senior engineer or architect in charge of the design of the structure.

5. Responsibilities
The responsibilities of all members of the planning, design, and construction teams should be clearly defined orally and in writing. Tasks, responsibilities, and duties of the owner, project manager, site manager, and specialists must be clearly defined and the names of different persons fulfilling different functions should be drawn up on an organizational chart for easy reference.

6. Project Documentation
All documents, plans, and drawings should be regularly updated throughout the entire life of the building project from the planning stage to final construction.

7. Feedback from Failures
Failure reports on causes, types, and consequences of building failure should be collected for categorization and analysis. This information would be used to identify problem areas and to improve quality assurance procedures. Such information on building failures could be obtained from engineers in consulting firms, government departments, insurance companies, building inspectors, and large holding corporations.

8. Training of Staff

There should be better education and training of staff through technical upgrading seminars. All staff, especially supervisory staff, should be trained in interpersonal skills to improve effective communication and working relations.

9. Communication

Communication should be improved by ensuring that all phases of the project are fully and clearly documented. Special care should be taken to communicate clearly at the interfaces of the project where information at one stage is passed on to staff at another stage. Effective communication is especially important when there is a change, apparent error, or disagreement.

10. Improved Supervision

Supervisors should be educated in interpersonal skills so that they will be better able to better handle instances of individual failure, and so they will be able to recognize signs of impending failure before they occur. Behavioural problems can be reduced by educating supervisors to make them aware of past incidents so they can recognize them if they occur again. They should also learn how to handle apparent errors or disagreements that arise. There should also be regular job performance reviews to highlight personnel problems.

11. Motivation

It is important that all those involved in the design and construction of the building have adequate motivation to do a good job. Motivation refers to an internal state of the worker, his attitudes and willingness to work well, in addition to external reinforcements such as pay which can activate the individual to do a good job. Adequate worker motivation can be maintained by ensuring that all staff are well paid according to their expertise and job performance, and that there is good working morale among employees, supported by good working conditions and teamwork.

12. Summary

The key to preventing human error resulting in building failure is quality assurance strategies and procedures. These include checking and regular design reviews, teamwork, effective communication between all members of the project team, responsibilities matched with qualifications, continuity of professional personnel, and no excessive time or cost pressures to cut corners.

TABLE

Respondents were asked to rate a list of common factors that can contribute to design errors as (1) somewhat common, (2) not common, or (3) entirely rare. The results were as follows:

	Building	Power Plant
inadequate checking by members of design team	1.3	1.9
errors in design drawings or specifications	1.4	2.0
inadequate oral communication	1.4	2.0
political (e.g. governmental) or finan. pressures	1.4	2.3
gaps in information (e.g. insufficient knowledge)	1.8	1.9
poor teamwork	1.8	2.1
inadequate documentation	1.9	2.3
errors in design assumptions	1.9	2.2
inadequate checking by others	2.0	1.7
errors in design concept	2.1	2.4
unclear definition of responsibilities	2.2	2.0
forgetfulness	2.2	2.3
errors in design calculations	2.3	1.9
lack of quality assurance plan	2.4	2.5
insufficient knowledge	2.4	2.3
negligence	2.6	2.9
impaired job performance	2.7	2.7
poor working conditions	3.0	2.8

THE SAMPLE FROM WHICH RESPONDENTS WERE DRAWN

A. POWER PLANT INDUSTRY

Nuclear Power Plants

Atomic Energy of Canada (one respondent in Reactivity)
Atomic Energy of Canada (one respondent in Electrical Control Systems Design)
Atomic Energy of Canada (one respondent in Process Design)
Ontario Hydro (one respondent in Electrical Power Systems Engineering)
Ontario Hydro (one respondent in Instrumentation and Control)
Ontario Hydro (one respondent in Quality Engineering)
Canatom (one respondent in Nuclear Engineering)

Conventional Power Plants

Foster Wheeler
Siemens (Control Systems)
Foxboro

B. BUILDING INDUSTRY

Structural Engineers

Proctor and Redfern
Carruthers and Wallace Ltd

Construction Engineers

Parkin Partnership (in their role as construction engineers)
Inducon Consulting of Canada

Architects

Bregman and Hamann
Webb, Zarafa, Menkes, Housden

Construction Management
Ellis-Don
Eastern Construction

Building Ownership
Cadillac Fairview
Olympia and York