CHAPTER 1

Concept of Systems Approach to Safety Management

1.1 INTRODUCTION

Construction work occupies a large part of economic activities in the housing sector, the industrial sector, the infrastructural sector and to a lesser degree in the agricultural sector also. Construction projects in all these sectors may be classified broadly in the following groups depending on the type of construction:

- Buildings: These vary from small residential buildings to large multistoried office buildings, housing complex, educational institutions, hospitals, recreation centers, factory sheds, warehouses. Under this category may be included the utility and service buildings also.
- Industrial structures: They include the supporting structures for heavy machinery, plants, equipments, material handling plants, oil and gas pipe lines etc.
- Tall structures: They include cooling towers, chimneys, transmission towers, silos and overhead water tanks.
- Liquid retaining structures
- Marine civil engineering structures
- Hydraulic structures: They include dams, barrages, canals etc.
- Sewage and industrial effluent treatment plants
- Special structures: They include off-shore platforms, nuclear plants etc.

Many of the above construction projects are complex, multi-disciplinary in nature and are executed in a highly competitive environment deploying modern technology and sophisticated equipments to bring down costs and also to ensure completion of the projects within the scheduled time-frame. Moreover in the construction industry the work environment changes all the time from one site to another. All these aspects coupled with the engagement of different types of sub-contractors with their practice of deploying ill-trained semi-skilled and unskilled persons in large numbers pose a serious impediment to a safe working practice, thus pushing the construction industry in the high-risk category. This is manifested in the high rate of accidents resulting in injuries and casualties of human beings with damage to property.

1.2 FREQUENCY OF ACCIDENTS AND SAFETY HAZARDS

From available data it is revealed that more than 10 million workers engaged in construction work receive injuries in the course of one year throughout the world. It is also a more or less established fact that the accident rate in construction is about 3 times the rate in the manufacturing sector and, approximately, one out of 6 workers engaged in the construction industry suffers injury at one time or other in a year. Some of the injuries, of course, are minor in nature and not so serious, though the victims are incapacitated for some time. But in many other cases the victims succumb to the injuries or are permanently disabled.

Records of fatal accidents reveal that about 70 to 80% of all fatalities at site are due to fall from a height or due to collapse of structures on them. Besides this, vehicular accidents, failure of erection cranes, electric shocks, fire, sudden collapse of shuttering during concreting etc. cause fatal injuries at many sites.

Finished projects are also vulnerable to safety hazards and damages in the post-construction service period due to faulty design, failure of foundations due to machinery vibration, failure of bridge foundations due to scour, environmental degradation and unforeseen natural calamities like earthquake, storm, flood, landslide etc. Safety is also compromised when there is lack or absence of maintenance for a prolonged period causing gradual deterioration of strength in the structural components due to fatigue, corrosion or exposure to harmful chemicals.

1.3 CAUSES OF STRUCTURAL FAILURES

Case studies indicate to the fact that major structural failures are caused by one or more of the following factors:

- Design errors
- Construction errors

- Material deficiency
- Lack of maintenance
- Misuse of finished structures
- Failure due to unforeseen external forces

1.3.1 Design Error

Design errors may occur from adaptation of designs not conforming to construction methods, lack of understanding of critical load combinations, selecting inadequate safety margins and lack of attention to functional requirements. Design errors may be committed either during performance of known tasks, such as standard design and detailing or, performing new tasks, not previously experienced by the designer. The designer's ignorance or oversight regarding fundamental structural behaviour is also responsible for many faulty designs. Design errors increase the probability of failure of a structure. As such, the designer should have a clear idea in building physics, likely behaviour of structural components under the influence of critical loads and the effectiveness of the materials specified.

1.3.2 Construction Error

Construction errors occur in many forms during the whole process of construction. Construction errors are also the source of many safety hazards during the maintenance period and many a times, during a rehabilitation process. Human errors in demolition work may trigger catastrophic failures and unintended collapse of the existing structure.

Construction errors generally originate from misinterpretation of drawings, working in contravention of details shown, sudden change in construction methods, lack of attention to safe working condition at site, building inadequate and risky temporary structures and platforms, flouting of standard safety norms, complacency on the part of the workmen, deployment of semi-skilled and unskilled persons on critical jobs, mishandling of cranes and equipments, flouting of electricity safety norms, poor workmanship because of lack of regular checking and supervision at site, misinterpretation of specifications and many other errors during construction.

1.3.3 Material Deficiencies

Material deficiencies originate from providing and using materials not conforming to specifications resulting in construction of defective and weak structures. Use of below-grade aggregates, fine sand in place of coarse sand, use of ordinary bolts in place of high tension bolts of same diameter, use of cement from very old stock are some of the examples of material deficiencies. Safety of the structures is affected seriously, when structures consisting of defective materials are exposed to extreme weather conditions, corrosion and face natural calamities. Many structural failures have roots in the use of defective materials when it is exposed to even mild tremors or a wind much below the design value.

1.3.4 Lack of Maintenance and Misuse of Finished Structures

Any safety hazard due to either or both of the above factors can be attributed to wrong handling or negligent use on the part of the users during the service period. It is the responsibility of the owner or the users to maintain a building structure, an installation or a bridge handed over to them after construction. But, it is common knowledge that, very often, wrong handling and overloading are done without thinking of the consequences. Using a bottom chord of an ordinary tubular truss for lifting loads are one of the many examples in this matter. Sometimes, owners neglect maintenance of important structures citing paucity of funds. They also sometimes remain complacent for a long period after completion of a project, neglecting any necessity of maintenance, thinking that the structure will remain intact and safe for all times to come.

Reliability is seldom assessed during the service period, except in the case of important structures. Environmental degradation, local damages, corrosion effects and fatigue failures are often ignored at initial stages, resulting in a serious multiplier effect in creating safety hazards at a later stage, involving enormous cost in rehabilitation and repairs or closure of the facility in many cases. Many structural failures have occurred due to complete absence of any maintenance and repair, even though the structure has performed well during the initial period of its service life.

1.3.5 Failure Due to Natural Calamities

Natural hazards like earthquake, storm, flood, landslide etc., are primary causes of many catastrophic structural failures with loss of human lives all over the world. The loss can at least be minimized, if not avoided altogether, if the intensity and harmful effects of these external forces are estimated in a rational way during the planning and design stage and structures are proportioned and designed accordingly. Every country has its own national codes of practices, which give excellent guidelines to the designer in this matter.

1.4 SYSTEMS APPROACH IN SAFETY MANAGEMENT

The brief enumeration regarding the causes of structural failures stated earlier, reveals that the safety of a structure along with human safety can be reasonably assured if proper attention is given to the safety problems right from the planning and design stage and is extended to the construction and even to the post-construction service period, when the structure is likely to be subjected to the aggressive forces of the environment and natural calamities. In view of the complexity of the problem of maintaining safety of a structure for such a long time under the action of different types and combinations of safety hazards, a systems approach is considered to be logical in safety management. The operation research, system analysis, reliability analysis and all decision-making processes are integral part of this system approach. In this matter the main thrust of safety management is directed to the following aspects:

(*a*) A quantitative approach to find out solutions to safety problems

(*b*) Development of deductive and inductive logical approach in the process of collection of relevant data from the problem area, formation of justifiable theories and mathematical models, application of theses models to the specific problems to get optimized solutions.

The methods adopted by this system of safety management consist of the following steps:

(*a*) Structuring a problem by collecting all relevant data from site and old records and identifying the objectives

(*b*) Construction of the design process or developing a mathematical model (for ill-structured problems) to eliminate or mitigate the safety hazards

(*c*) To find out optimized solutions by applying standard mathematical tools, following the provisions of codes and local safety regulations.

(*d*) Implementing the solution in the specific problem area.

(*e*) Monitoring and controlling all operations at site to achieve the desired objectives.

(*f*) To assess periodically during the service period the reliability of the structure and its components and connections and finding out solutions through an effective maintenance strategy and/or rehabilitation/repair/strengthening or replacement of components, as required.

In the systems approach, the management models may be either deterministic or probabilistic depending on whether the safety problem is well-defined or ill-structured. The models may be static or dynamic (*i.e.*, changing with time), depending on whether the constraints remain unchanged or change with time. For example, a simple repair strategy adopted at a particular time may have to be changed to a strategy of component replacement if a number of vital structural components are found to be seriously damaged beyond repair at a later date.

For complex problems involving a number of variables with various types of constraints, having either predictable or random nature of relationship between the variables, linear programmings are often done and computers are used now-a-days for evaluation of safety problems for important structures, to get optimum cost-effective solutions in the quickest time.

In very complex and ill-structured problems like building safety models against flood and scour damages, it becomes sometimes impossible to frame any deterministic mathematical solution covering all the basic parameters of the problem. Simulation techniques are usually applied in such cases along with help of existing knowledge-based expert systems available from recorded case reports.

After deriving a solution, it is applied with proper control (in the design process through peer review and at site through adequate on-site supervisions) adopting suitable methodology and systematic approach. Side by side, a system of continuous monitoring with regular feed-back should be developed. For this reason the systems approach is always dynamic. No ad-hoc decision-making should be entertained in safety management. In the systems approach there should be a definite objective or goal, which is to be achieved through a systematic approach in design considerations, material selection, implementation, control and feed-back for further scrutiny and improvement in quality.

The background fundamental principles and concepts necessary to develop a systems approach in safety management are discussed in the following chapters along with an introduction to the reliability of structures.

QUESTIONS

1. Explain how the stability of a structure may be compromised due to design errors.

2. In what circumstances serious errors may creep in a structural system during the construction period. What may be the likely adverse effect of such errors during the service life of the structure?

3. As it is not possible to eliminate fully the safety hazards due to natural calamities, what should be the rational approach in the design?
4. What is meant by systems approach? Explain how the principles of systems approach may be gainfully applied to ill-structured problems in safety management.
5. What are the ill effects of material deficiency and lack of maintenance on the serviceability of structures?

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