NorthWest Occupational Health & Safety

Engineering Design: The Key to Safety in Confined Spaces

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Introduction

We live and work in structures designed by engineers or influenced by engineering design through codes of practice and consensus standards. These contribute to the infrastructure that exists behind the scenes that creates the many benefits that accrue from living in an advanced society. Engineering design produces the safety and security and reliability of structures and the equipment that operates in them. Design considerations for structures as they relate to interaction with humans are not identical or consistent. This discrepancy reflects obligations imposed by occupancy. Some structures are designed for occupancy, infrequent or continuous, while occupancy is not a consideration in the design of other structures.

Design for occupancy affects the strength of horizontal and vertical surfaces and location and size of openings in these surfaces and obstructions located on them; provision of light, control of air and surface temperature and humidity, control of emissions from processes and residual materials and particulate load; and exchange of the internal atmosphere with outdoor air. Design for occupancy also imposes requirements to control safety hazards. These include energized electrical conductors, hot and cold surfaces, moving parts of equipment and machinery, fall hazards, unstable materials and surfaces, and implosive and explosive surfaces Conditions that are perfectly acceptable during normal operation within the confines of a suitably designed structure may pose a life-threatening situation during occupancy.

Engineering design that does not recognize the need for and accommodate to the implications of occupancy that occurs during the life-cycle of a structure, regardless of how infrequent and unpredictable, can pose conditions that threaten safety. Engineering design, therefore, has a critical role in the safe performance of work at all stages in the life-cycle of a structure.

Engineering design is complex and reflects many inputs. These include requirements for process optimization, safety and efficiency; requirements for structural integrity that address challenges of chemical incompatibility, corrosion, erosion; and requirements for environmental safety and control of emissions. As well, there are requirements of the building code, the fire code, the plumbing code, the electrical code, the fuel gas code, codes for pressure vessels, and so on. These requirements focus attention onto many specific aspects of the structure as a functioning entity. The safety of the people who must work in structures not designed for occupancy following shutdown is not a high priority in considerations at the design stage.

Confined spaces, as a class of work environments, bring these considerations into much sharper focus. Confined spaces have the general distinction of being places in which people do not normally work. As a result, they do not receive consideration about access and egress and conditions of habitation accorded to other workspaces.

Confined spaces pose especial challenges regarding management of hazardous condition. Accidents that happen in confined spaces are rare events. They are difficult to predict and very expensive to prevent. In addition, the same rare event is highly unlikely to reoccur. Otherwise, we would read about them in the news media and they would receive corrective action. Another characteristic of these workspaces is that minor mistakes committed during the conduct of work can produce major consequences.

Characteristic of structures that fit the definition for confined spaces is the boundary surface. The boundary surface surrounds the confined space and defines the location of the of access/egress. A boundary surface need not be substantive or contiguous. Depending on geometry relative to the location of the access/egress, the boundary surface can considerably hamper rescue and provision of emergency medical services.

In a world of scarce resources and strict requirements for justification of present cost against vaguely perceived future benefit, the logic for not providing extensive infrastructure oriented toward rescue at the time of initial construction of the structure and at the time of undertaking the work is quite persuasive. Preventing serious and fatal injury firstly through preventive preparatory measures and secondarily through provision of suitable infrastructure to accommodate emergency response workers requires considerable commitment of resources. Yet, given this reality, the other reality is that accidents involving these workspaces do occur and that they are usually preventable or at least able to be mitigated through recognized measures.

The critical reality regarding serious accidents at work is the ‘golden hour’. Studies of trauma in wartime situations indicated that survival of the victim depended on response time. Survival declined dramatically for response time greater than one hour. Applying this finding to workplaces in urban environments, difficulties posed by geometry regarding extrication and traffic congestion are the major causes of the delay involved in accessing advanced medical support.

Workspaces not designed for easy access and egress or prepared with the necessary infrastructure prior to the start of work exacerbate the situation In situations where access and egress to the workspace is complex and difficult, life support for the victim must occur *in situ*. This outcome certainly is not desirable and considerably increases the risk of serious permanent injury and loss of life.

The Foreward in ANSI Z117.1-1995 provides a succinct summary of the issue and the frustration and concern about personal safety during work in confined spaces (ANSI 1995). The ANSI Z117.1 Committee is one of the few consensus groups world-wide that focus specifically on safety during performance of work in confined spaces.

The Foreward commented about access/egress portals that are too small, that are improperly located, and that complicate or inhibit escape. Configurations are convoluted, unnecessarily obstructed and haphazardly configured. Additional comments mentioned internal clearances that are too tight for safe passage and penetration distances that are excessive and provide no alternative means of access or escape. There is often lack of consideration for features that could enhance ventilation effectiveness. Other major concerns include structural weaknesses in walls, floors and ceilings, and proximity to pipes containing gases, liquids or steam. These increase risk to entrants through unintended contact with them. The Foreward also commented on the absence of appropriate devices to isolate all energy sources from the space and absence of provision for mechanisms to prevent bridging, compacting, and hang-ups of loose material.

Since engineers control the design, construction, modification, and maintenance of structures in which people work, the choices and decisions that they make during design influence the comfort and safety of workers during work activity. Hence, engineers have the ability and ultimately the obligation to ensure that their designs minimize the risk of performing work in these environments. The most desirable outcome is to optimize safety during all phases of the life cycle of a structure. This requires design for maintenance. A well-known truism is that retrofitting to correct deficiencies is costly versus correction during design prior to construction.

An effective means to optimize the design for entry to perform maintenance and repair is to create a panel to review the design. Suggested participants include representatives from operations and maintenance and individuals having specialized knowledge concerning fire and occupational health and safety. Given the nature of the work to be performed, this group should be able to provide input about conditions during work, possible accident situations and conditions likely to be encountered by emergency responders (assuming adherence to all control measures). Unhindered performance of work by emergency responders because of implementation of control measures should minimize the consequences of the accident.

So, what changes can engineers make in their designs to reduce and minimize the risks created by entry into structures for which this was not considered or intended?

The first consideration is to ensure that the structure internally and externally is robust enough not to require repair in future, because entry is inevitable. This consideration can lead to selection of more robust components in vulnerable and critical areas of activity.

The next consideration is to design to eliminate the need for entry. Attention to this consideration ensures that equipment known to require service is readily removable from the structure from the exterior. As well, externalizing controls, such as valve wheels, and displays of information can eliminate the need for entry. Video inspection units eliminate the need for human presence. These are especially useful in sewer inspections.

Robotic equipment can perform some of the tasks that otherwise would require a human presence. This is especially true for cleaning and removing residual materials, and improving flow of flowable solid materials. Note that equipment that substitutes for the human presence must be compatible with the environment in which use occurs. This is critical in environments that are ignitable, corrosive and erosive, and capable of causing contamination by chemical and radioactive substances.

Previous discussion considered actions to eliminate entry. If entry and work activity in the structure must occur, minimization of the risk usually occurs through consideration about the layout and location of external access/egress and internal layout and configuration. Minor change sometimes can eliminate or at least considerably reduce and control risk, especially that posed by fall..

Among the most readily addressed of the concerns identified in the Foreward in ANSI Z117.1-1995 during the design stage are the location and accessibility provided by access openings. Location and accessibility provided by external access/egress openings are major contributors to the risk of work in confined spaces. This results from impeding removal of the victim from the space for transport to hospital. This concern is readily amenable to attention at the design stage.

Some examples of difficult access on the outside surfaces of structures include hatches and manways on side walls, and underside and top surfaces that are isolated in space from access platforms and ladders. Other situations include accesses located in geometries that pose a risk of fall. Snow and ice present during winter weather can considerably increase the slipperiness of walking surfaces and the risk of strike-by injury from icicles.

Entry into the space from the exterior requires adequate access. When the opening is not at located at grade, adequate access can require a platform large enough to set up extrication equipment and enable activity by emergency responders to extricate an injured worker. Four rescuers are required to pass a body through a small opening in the wall of a structure. In the absence of a built-on platform, the design must provide access for temporary solutions, including use mobile powered work platforms and/or scaffold.

Small access openings in interconnected spaces and especially situations where the opening is located in a side wall above the level of the floor considerably complicate the handling of injured individuals. Some examples of difficult access within structures include spaces accessed from adjoining spaces. These include double-bottom structures on ships, baffled structures in tanks, and crawlspaces and attic spaces where the internal structure impedes movement. These situations require as many as six individuals to effect the body mechanics needed for rescue where simultaneous vertical lift and horizontal movement of the victim by human power are required. In constraining geometries, this type of movement is very difficult to perform.

A complicating factor is the need for openings in both the external shell and internal structures to enable ventilation. Ventilation in confined spaces usually occurs through use of portable equipment containing duct for supply or exhaust. Movement of the entrants and supplies and duct and unducted flow of air compete for the available surface area in an access/egress opening. In an emergency, the victim must pass through the same opening. The level of preparation for this event governs the likelihood of severity of outcome to the injured individual. This situation constitutes conditions that are considerably less than ideal.

Safeguarding to protect against contact with readily accessible moving machinery, hot and cold surfaces, energized electrical conductors, fall hazards, and hazards posed by unstable structures are additional considerations.

Unfortunately, considerations needed to optimize safety during entry and work often conflict directly with codes to ensure structural integrity of pressure vessels, for example, and design requirements for processing efficiency. Design is the art of integrating choices and requirements into a functional whole. Successful design is a difficult endeavor.

This reality brings the discussion full circle. Engineers control the design, construction, modification, and maintenance of structures in which people work. The choices and decisions engineers make during design influence the comfort and safety of workers during work activity. Hence, the most desirable outcome in order to optimize safety during all components of the life cycle of a structure is to design for maintenance as a consideration in designing for performance.

References

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