ORIGINAL RESEARCH PAPER

Architecture

DESIGN FOR PEOPLE'S SAFETY IN CONSTRUCTION PRACTICES

KEY WORDS: Safe Design, Design for People, Construction, Safety Management.

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ABSTRACT

A Design that is Safer to Construct, Operate and Maintain over the entire Life Cycle of the construction project is sustainable and should be a designer's choice for managing construction practices from initial to final phases. Prevention/ Safety through Design means "Addressing occupational safety and health needs in the design process to prevent or minimize the work-related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials, and equipment." Safe design is about integrating hazard identification and risk assessment methods early in the design process, to eliminate or minimise risks of injury throughout the life of a product. This applies to buildings, structures, equipment and vehicles. Safety-in-design checklist is important while managing any design project. Designers can play a role in making construction sites safer. There are many keys to designing for safety like: collaboration between all project team members, inputs from people, designers knowledgeable of: design for safety concept, construction site safety, construction practices, safe designs etc. Life Cycle Safety (LCS) can reduce overall project costs through reduced redesign and rework in the field and earlier planning for efficiencies. eg: A safe design approach results in many benefits including: • Prevent injury and disease • Improve useability of products, systems and facilities • Improve productivity • Reduce costs • Comply with legislation • Innovate, in that safe design demands new thinking.

INTRODUCTION

The construction industry is considered one of the highest contributors to work-related accidents and ill-health in most economies around the world (Hadikusumo and Rowlinson, 2002, Sousa et al., 2014, Yuan et al., 2018). For example, in the UK, 0the construction industry accounted for 30% of work-related fatalities in the 2018/2019 reporting year (HSE, 2019a). Construction Industry in India is highly prone to hazards related to site activities and construction projects engage large number of contractual workers. These workers come from varied trades especially from rural areas and agricultural background who do not have proper training in construction safety also are not literate enough to forecast the unknown dangers.

Construction workers' health and safety (CWHS) research in India has not gained much attention among researchers. It **helps the reader to identify hazards and control risks** and explains how to plan, organise, control, monitor and review health and safety throughout the life of a project. Every year, about 1,000 construction workers are killed on the job. Everyone is familiar with the Focus Four – **falls, electrocutions, struck-bys and caught-in/betweens** – the four hazards that kill about 90 percent of construction workers.[1]

Ii. The Concept Of Occupational Safety And Health (OSH)

OSH is a concern in all countries of the world and across all economic sectors. Hence, it is susceptible to a wide range of conceptualisations. A proper and a general understanding of OSH is therefore required to ensure its effective management. The International Labour Organisation (ILO) (2011) defines OSH as a discipline dealing with the prevention of work-related injuries and diseases including the protection and promotion of the health of workers.

This notion has informed a new research agenda in the area of "**Design for Occupational Health and Safety" (DfOSH)** [also referred to as "Design for Safety" (DfS), "Prevention through Design" (PtD), "Safety in Design" (SiD), "Construction Hazard Prevention through Design" (CHPtD), "Safe Design" (SD)], all in an attempt to effectively deal with the challenge of OSH risks on construction projects. Traditionally, the responsibility for managing OSH risks had been left with main contractors, especially at the project implementation or construction phase of projects (Hare et al., 2006). However, this new way of managing OSH risks advocates for a shared responsibility among project stakeholders.

The **Australian Safety and Compensation Council (2006)** defines **DfOSH** as a process of "the integration of hazard identification and risk assessment methods early in the design process to eliminate or minimise the risks of injury throughout the life of the product being designed." This definition corroborates and extends an earlier understanding provided by Gambatese et al. (2005) who indicated that "designing for construction safety entails addressing the safety of construction workers in the design features of a project".[2]

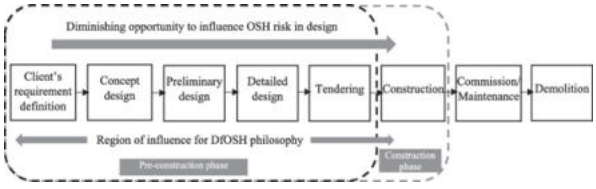

Fig. 1. Region of influence for DfOSH philosophy in the project development process.

Iii. Health And Safety Issues For Construction Workers

Some key health issues that construction industry workers are facing today are, a) Pain or injury from physical overexertion. b) Repetitive manual tasks, or working in awkward postures. c) Exposure to moulds, fungi or rodent droppings. d) Exposure to lead, wood dust, asbestos, paints, solvents, and other toxic chemicals or materials. e) Working in extreme temperatures and UV radiations. f) Working with hand tools, powered tools and heavy powered equipment. g) Excess vibration of hands, arms or body from powered tools or equipment. h) Stress, shift work or extended work days. i) Working in low illumination or at night without proper lightning arrangement. The best way to protect workers against hazards is to control problems at the source. Occupational Safety and Health Administration (OSHA) stated that workers must have Personal Protective equipment (PPE) that fits properly.

Iv. Occupational Safety And Health Risks Of Fracking Operations (Construction Accidents: Reasons)

The categories used for classifying fatal accidents were:
a) Falls
b) Falling material and objects
c) Electrical hazards
d) Transport and mobile plants
e) Other

Examples:
Safety Hazards[3]
- **Falls:** OSHA requires fall prevention for any work over four feet high. Falls occur due to:
- Unguarded sides of a rig
- Holes for the drill pipe prior to installation
- Ladder use
- Climbing the derrick
- Working from truck beds while unloading equipment
- Access and egress to mobile equipment

Slips and falls over hoses or materials or on slippery surfaces can be prevented by covering floor openings, guarding platforms, using fall protection and maintaining an orderly worksite.
- **Struck-by:** Workers can be injured or killed if struck by:
- Trees while clearing the site
- Pipe while moving it on and off the site
- Tongs or spinning chain while tripping in and out
- High pressure hoses
- Hand tools
- Rigging cable
- Falling objects

- **Caught-between:**

Workers can be crushed or caught between:
- Rigs
- Spinning chains
- Equipment
- Unguarded machinery

These injuries are preventable by machine guarding and the lockout of equipment during maintenance.
- **Remote sites:** Extraction operations are often in rural areas and must be fully capable to handle emergencies such as fires, blowouts and hydrogen sulfide exposures.
- **Other hazards:** Frayed cords, unsafe/ungrounded equipment and contact with overhead power lines can pose problems. Crane safety must be an integral part of rigging up and down. Confined spaces may be present. Welding poses a safety risk due to the use of compressed gases. Trenching collapse risks can be prevented with appropriate shoring.

Health Hazards
- **Silica:** Large amounts of sand are used to help fracture shale and keep the fractures open. Studies by NIOSH show the potential for high exposures to silica which is known to cause silicosis and lung cancer. Controls such as wetting the sand and enclosing the transport operations are recommended.
- **Noise:** Noise is a major problem on fracking sites. Much of the noise is from heavy equipment and can be reduced by engineering solutions (noise absorbing materials, "buy quiet" programs).
- **Heat/Cold:** Temperature extremes pose a risk to workers for heat and cold stress. Appropriate clothing, liquids (hot and cold), rest breaks, shade/warming areas and readiness for treating affected employees are important precautionary procedures.
- **Sunlight:** Solar exposure can cause skin cancer, and workers need to be protected from exposure with clothing and sunblock.

V. A Safe Design Approach: Design For All[4]

Safe design is about integrating hazard identification and risk assessment methods early in the design process, to eliminate or minimise risks of injury throughout the life of a product. This applies to buildings, structures, equipment and vehicles.
- Of 639 work-related fatalities from 2006 to 2011, one-third (188) were caused by unsafe design or design-related factors contributed to the fatality.
- Of all fatalities where safe design was identified as an issue, one fifth (21%) was caused by inadequate protective guarding for workers.

Safe design begins at the concept development phase of a structure when you're making decisions about:
- the design and its intended purpose
- materials to be used
- possible methods of construction, maintenance, operation, demolition or dismantling and disposal
- what legislation, codes of practice and standards need to be considered and complied with.

Designers need to consider how safety can best be achieved in each of the lifecycle phases, for example:
- Designing a machine with protective guarding that will allow it to be operated safely, while also ensuring it can be installed, maintained and disposed of safely.
- Designing a building with a lift for occupants, where the design also includes sufficient space and safe access to the lift well or machine room for maintenance work.

The Concept: What is Safety in Design? [7]
- **What is Safety by Design?**

The process of considering construction site safety and health in the design of a project and designing for safety constructability.

- **Prevention through Design :** "Addressing occupational safety and health needs in the design process to prevent or minimize the work-related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials, and equipment."

The consideration of worker safety in the design of a facility includes:
- A focus on construction worker safety
- "Safety Constructability"
- Formal consideration of construction worker safety not a traditional aspect of design
- Design professionals traditionally focus on the safety of the "end-user", such as the building occupant, motorist, or facility operator.

Fig. 2. Parameters which impacts a project's design

Why has construction worker safety traditionally not been addressed in project designs?
- Designer education and training.
- Lack of Safety in Design tools, guidelines, and procedures.
- Designer's limited role on the project team.
- Designer's traditional viewpoint on construction worker safety.
- Lack of understanding of the associated liability.

But Designs Do Influence Construction Worker Safety:
- Design influences construction means and methods
- European research: 60% of construction accidents could

have been avoided or had their impact reduced by design alterations or other pre-construction measures
- Examples of designing in safety and health measures:
- Anchorage points for fall protection
- Parapet walls
- Substitution of less hazardous materials

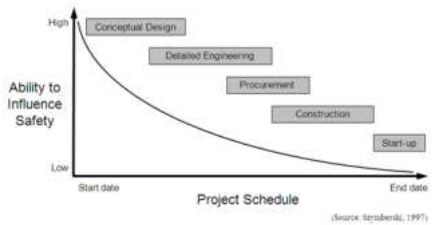

Fig. 3. Ability to influence safety on a project

What Safety by Design is NOT:
- Having designers take a role in construction safety DURING construction.
- An endorsement of future legislation mandating that designers design for construction safety.
- An endorsement of the principle that designers can or should be held partially responsible for construction accidents.

Keys to Implementation:
1. A change in designer mindset toward safety.
2. A motivational force to promote designing for safety.
3. Designers knowledgeable of the concept.
4. Incorporation of construction safety knowledge in the design phase.
5. Designers knowledgeable about specific design for safety modifications.
6. Design for safety tools and guidelines available for use and reference.
7. Mitigation of designer liability exposure.

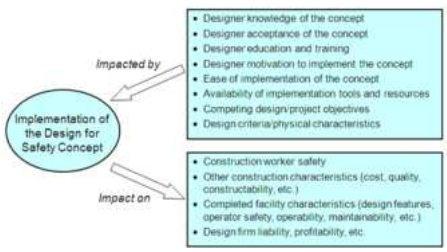

Fig. 4. Factos affecting implementation for Safe Design

Vision for Safety in Design:
Getting the Right People at the Right Time will result in:
- Reduced
- Incidents and injuries
- Changes in design
- Costs associated with late changes
- Rework
- Schedule duration
- Coordination issues associated with late changes
- Increased
- Upfront costs but decreased overall project costs
- Streamlining of project execution and communication
- Improved design
- Increase collaboration on all other areas of the project

Barriers to Safety in Design
How do we
- Get the right people involved at the right time?
- Capture their input?
- Address the paradigm that Safety in Design costs money.
- Influence the behaviors of the designers, constructors, and end users providing input?
- Motivate those managing the design and scope to include input at the right time?
- Not overburden the design delivery so we can maintain the project schedule?

Viability of Designing for Safety

1. Barrier: Increased Designer Costs
- **Potential solution:** Educate owners that total project costs and total project life cycle costs will decrease.

2. Barrier: Designers' Fear of Liability (Fear of undeserved liability for worker safety).
- **Potential solution:** Clearly communicate we are not suggesting designers should be held responsible for construction accidents. And develop revised model contract language.

Impacts:
1. Improved safety through reduced worker exposure to safety hazards
2. Improved quality and productivity
3. Lower cost over project lifecycle
4. Reduced site hazards fewer injuries and fatalities
5. Reduced workers compensation premiums
6. Increased productivity
7. Fewer delays due to accidents during construction allow continued focus on quality
8. Encourages designer-constructor collaboration

Life cycle Safety (LCS): The term Life Cycle Safety describes the need to comprehensively address building-related occupational safety and health risks for all affected worker groups across all life cycle stages.[6]

Fig. 5. The Life Cycle stages [8]

Programming Phase - The Right Input:[8]
- Designer (Architect-A/Engineer-E)
- Develop options from owner requirements
- Technical experts, code requirements
- Owner Representatives
- Engineering, Operations, Maintenance, EHS
- Provide input on operation and maintenance issues
- Contractor
- Provide input on how facility would be constructed
- Reviewed impacts to schedule, sequencing, cost, logistics
- Trade Contractors
- Provide input on constructability and safety issues impacting their specific trade

Programming Phase – LCS:
- Option Evaluations
- Life Cycle Safety was evaluated along with other goals:
- Cost, energy, emissions, etc.
- Relative risk of various options were evaluated against the Plan of Record (POR) or against one another
- Safety in Design Checklist used helped identify potential Risks

Design Phase - The Right Time
- Basic Design Delivery steps can include
- Schematic, Design Development, Construction Documents
- Design Team begins to fully engage and begin detailed

design
- Equipment sizing, selection, and layout
- Detailed routing and coordination
- Design Changes and Value Engineering
- Multiple design reviews internal and external
- Issue the design packages for construction

Focused LCS Review: Right Input, Right People, Right Time
- Designer identifies scope of design and package content
- Contractor primarily responsible for construction and retrofit
- Owner (Sustaining) primarily responsible for Operations and Maintenance
- Safety-in-design checklist
- Identified potential risks and mitigation
- Comments captured on review form

Examples of safe design:
Positioning air-conditioners for maintenance
Split system and other air-conditioning systems require maintenance access. Air-conditioning systems are sometimes located on roofs or attached to upper story walls creating fall risks for maintenance workers.
Air-conditioning systems should ideally be placed at ground level. If this is not practicable then fall protection can be provided through guard railing.
- The person with control over the decision of locating the system may be the architect, building owner, builder or air-conditioning installer.
- The benefits of ground level location include reducing falls and awkward conditions for manual handling as well as reducing maintenance costs.


Air-conditioning system high on a wall in a commercial setting.
Photo: J.Culvenor


Air-conditioning systems located at ground level with good access.
Photo: J.Culvenor

Access for lighting maintenance.
Maintenance of a lighting system can involve difficult access and work at heights. This means maintenance can be hazardous and expensive. A solution can be to install lighting systems on sliding tracks.
- The person with control over the decision to install this system may be the architect, engineer, building owner, electrical contractor or builder. Maintenance personnel need to know the lighting system can be accessed via the sliding rails and how to operate the system. Although this may be evident such as in the photo above, notices should be placed where they can be easily seen.
- The benefits of a sliding track system include minimising falls and reduced cost of maintenance work such as cleaning and changing bulbs and tubes, due to efficiencies achieved from using the existing walkways. The people that would benefit from this kind of installation include maintenance workers, cleaners and installing electricians.


Sliding lighting systems.
Photo: J.Culvenor, thanks to Fosters/CUB

Rollover protection for tractors.
Many farmers, farm workers and other people who use tractors have been killed when tractors have rolled. ROPS provide protection for the operator in this event.

It should be noted that ROPS do nothing to prevent a rollover and the operator needs to remain within the boundary of the structure. This means seat belts and a cabin are associated solutions.

Falling object protection structures are also useful on tractors when working in areas where falling objects can be a risk, such as construction, forestry and mining.
- It is the tractor designer and manufacturer who determine what ROPS should be fitted and users who determine where a retrofit ROPS is being added.
- Those that benefit from this safety feature are farmers and construction workers. When a ROPS is fitted, information about the need for use of seat belts to maximise rollover protection effectiveness is essential. The best location of this notice would be on the tractor. An alternative approach would be installation of ignition or motion interlocks on seatbelts or other forms of restraint.


Loader without roll over protection.
Photo: J.Culvenor


Cab and integrated roll over protection.
Photo: J.Culvenor

Vi. Safety Rules And Regulation: Efforts In India
Efforts are taken by government by setting up, National Safety Council (NSC) which generates, develops and sustains a voluntary movement on Safety, Health and Environment (SHE) at the national level. Apart from this, the BIS (Bureau of Indian Standards) have taken intensive researches and studies to publish many SP and IS codes, for bringing standardization, marking and quality certification of goods and for matters connected therewith or incidental thereto, acting as guidelines for construction, manufacturing, processing etc. Gammon India holds the record of Twelve Million hours of accident-free work at Kalpakkam.[1]

Vii. Safety Principles
Five Principles Of Safe Design[4]
- Principle 1: Persons with control—those who make decisions affecting the design of products, facilities or processes are able to promote health and safety at the source.
- **Principle 2:** Product lifecycle—safe design applies to every stage in the lifecycle from conception through to disposal. It involves eliminating hazards or minimising risks as early in the lifecycle as possible.
- **Principle 3:** Systematic risk management—apply hazard identification, risk assessment and risk control processes to achieve safe design.
- **Principle 4:** Safe design knowledge and capability—should be either demonstrated or acquired by those who control design.
- **Principle 5:** Information transfer—effective communication and documentation of design and risk control information amongst everyone involved in the phases of the lifecycle is essential for the safe design approach.

Ergonomics and good work design
Safe design incorporates ergonomics principles as well as good work design.
- Good work design helps ensure workplace hazards and

risks are eliminated or minimised so all workers remain healthy and safe at work. It can involve the design of work, workstations, operational procedures, computer systems or manufacturing processes.

Responsibility for safe design

When it comes to achieving safe design, responsibility rests with those groups or individuals who control or manage design functions. This includes:

- Architects, industrial designers or draftspersons who carry out the design on behalf of a client or Anyone who alters a design.
- Individuals who make design decisions during any of the lifecycle phases such as engineers, manufacturers, suppliers, installers, builders, developers, project managers etc.
- Building service designers or others designing fixed plant such as ventilation and electrical systems.
- Buyers who specify the characteristics of products and materials such as masonry blocks and be default decide the weights bricklayers must handle.

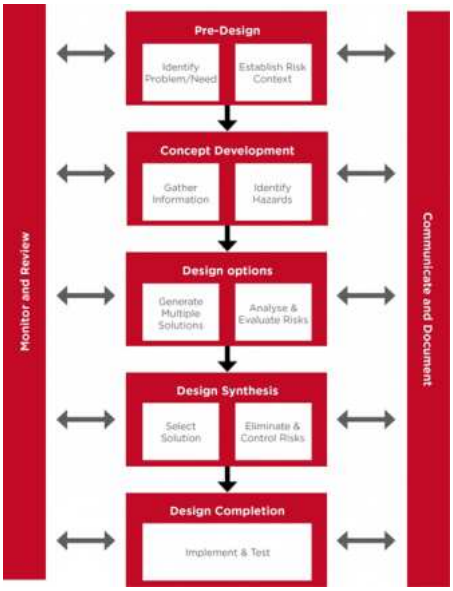

Figure 6: A model for safe design

VIII. CONCLUSION

- Sustainable construction occurs when design contributes to safety, therefore preventing excessive injury costs from reducing future construction projects in a local area.
- Having a lower accident rate on a construction project should be added to the list of universal project goals, such as low cost, high quality and fast completion time.[5]

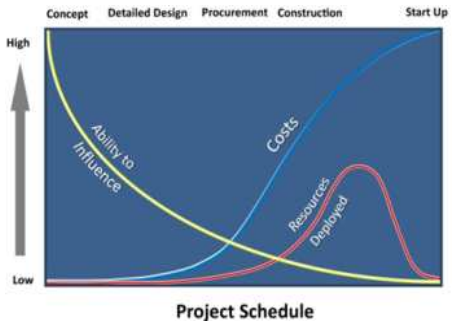

Fig.7: It illustrates the important concept that the ability to influence any project goal–cost, schedule, quality, AND SAFETY–is highest during the design phase.[5]

- Life Cycle Safety is a reminder that buildings also function as workplaces. The Leadership in Energy & Environmental Design (LEED) rating system already provides a partial foundation for Life Cycle Safety because improving health and well-being for building occupants is an explicit LEED objective. Green buildings offer significant benefits for building occupant workers compared to conventional buildings.[6]
- In the United States, government agencies such as Occupational Safety and Health Administration (OSHA) have done their part to promote a ZERO injury environment. However, in India effective safety construction management is not available.
- Construction organizations interested in maximizing safety and competitiveness must look to Total Quality Management (TQM) initiatives for inspiration.[1]

Summary: Benefits of Safety by Design

- Designers can play a role in making construction sites safer.
- Keys to designing for safety:
- Collaboration between all project team members
- Input from people who build
- Designers knowledgeable of:
- Design for safety concept
- Construction site safety
- Construction practices
- Safe designs
- Design for safety tools and guidelines available for use and reference.

Safety in Design is a Culture of Collaboration for Shared Ownership and Outcome!

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