Safety in the Construction Industry

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Abstract

Structures used to facilitate construction, such as framework and scaffolding, are often not given the importance they deserve, because of their temporary nature and because their cost is not recoverable from a single construction as a line item. Consequently, in many countries, the accident and failure rate for temporary structures are higher than those in permanent structures.

Every accident leads to tragedies such as injury or death to persons, and damage to property and the environment, with all the associated direct and indirect costs and effort. Economically and professionally more important is the fact that accidents also lead to delays in the construction process. All these add up to undesirable repercussions, not only on the workers and the organizations involved, but also on the entire construction industry, the community, and, if the accidents and failures are sufficiently large or frequent, on the government itself.

Most of the accidents and failures in temporary structures may be traced mainly to minor mistakes in fabrication, to relatively inexpensive items of materials or equipment, and to oversight or negligence in the implementation of applicable codes and regulations.

Author discusses these vital factors in relation to health and safety in the construction industry, with the aim of minimization of injury to personnel and damage to property. Paper highlights characteristics of temporary structures, causes of accidents and failures, and measures for their prevention and remedy, with special emphasis on health and safety in the construction industry. Presentation will include case studies of code violations and failures of temporary structures.

1 Temporary Structures

Temporary structures, by definition, are erected and used only for the purpose and for the duration of the task for which they were intended. In the construction industry, the main purpose of temporary structures is the erection of a new permanent structure, or the renovation, modification, repair, painting, cleaning, or other operation on an existing permanent structure. The temporary structures are removed immediately after the objective has been accomplished, for future reuse.

1.1 Characteristics of Temporary Structures

For temporary structures, the materials, designs, construction technologies, and uses are different from those for permanent structures.

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They are more susceptible to risk than permanent structures because of the following:

(a) Their "temporary" nature psychologically induces a tendency to neglect or overlook deficiencies and hazards.

(b) The general public rarely gets to see them close up or use them, and thus catch any flaws.

(c) Workers erecting and using them are uneducated, and may not appreciate safety rules.

(d) Organizations erecting and using them are generally not the main contractors or owners of the permanent structure, and hence have no long-term vested interest in them.

(e) They have no direct benefit to the users after the construction.

(f) Their cost is not a main line item to the client, and must be absorbed by the contractor.

(g) They are dismantled and reused many times, and in the process, tend to get damaged at critical locations such as joints and supports.

(h) They are considered to be so simple that they do not need too much attention.

1.2 Special Features of Construction Industry

In the construction industry, difficulties of temporary structures are compounded by the fact that compared to most other industries, the construction industry is unique in many ways, as follows:

- It is a large but diverse and fragmented industry
- Every job is unique with numerous complex tasks
- It is labour intensive work involving many materials and heavy loads
- The work force is transient which is difficult to train, especially if the labour is imported
- The contractual arrangements are complex, leading to multi-employer projects

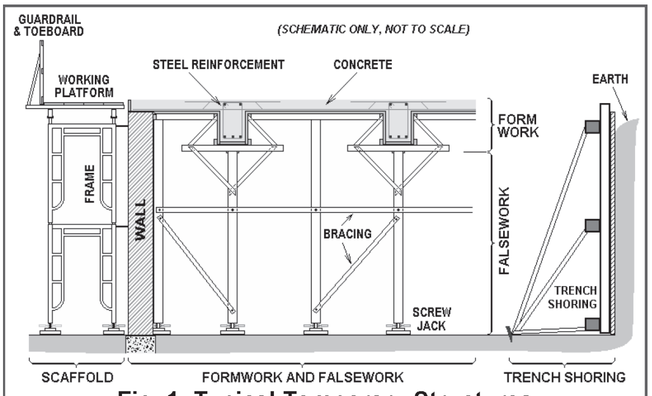

Fig. 1. Typical Temporary Structures

1.3 Examples of Temporary Structures in Construction

1. Signboards and fencing around the site
2. Guard house, site office, site canteen, workers' quarters, etc.
3. Temporary piling which will be extracted at a later stage
4. Excavated trench shoring system (Fig. 1)
5. Formwork, to cast the concrete for permanent structure (Fig. 1)
6. Falsework, the support structure for formwork (Fig. 1)
7. Scaffolding, the structure around or within the permanent structure which enables the workers to carry out their construction tasks (Fig. 1)
8. Metal or plastic rubbish chutes
9. Overhead shelters ("fans") around the periphery of the external scaffolds (Fig. 1)
10. Overlay nettings at external scaffolds (Fig. 1)
11. Overhead shelters at the designated entry or exit points of construction site
12. Cantilevered material receiving platforms at upper levels of the construction

13. Mobile work platforms (usually found in upgrading projects)

14. Passenger-cum-material lifts, hoists, gondolas, tower cranes, overhead or gantry cranes, etc.

Only the major items 4,5,6 and 7 as shown in Fig. 1, will be discussed in this paper.

2 Importance of Safety in Construction Industry

In any profession, the need for safety is paramount, because of the following:

- Humanitarian concerns
- Professional, institutional, and social concerns
- legal and regulatory concerns
- Economic concerns

In construction industry, safety is even more critical than in other industries. Every nation must take construction health and safety quite seriously, because the accident and fatality (death) rates in this industry are among the highest in most countries around the world, including the advanced nations.

Figure 2 depicts the number of fatalities in various Singapore industries between 1992 and 2001. It may be seen that the construction industry accounts for 50% to 70% of the deaths. However, the numbers are decreasing in recent years.

The situation is similar in large and developed nations also. Figure 3 shows a comparison of Japan's construction fatalities in relation to all industries, for the years 1958-2000. Construction is seen to account for 40% to 45% of all industrial accident deaths in recent years. Here again, the total number of deaths has been steadily brought down from earlier decades, by improved safety.

It is also not true that a larger workforce attracts more accidents. Accident and fatality rates depend more on the safety culture of the nation and the safety management system of the organisation.

Figure 4 shows the number of workers, and the rate

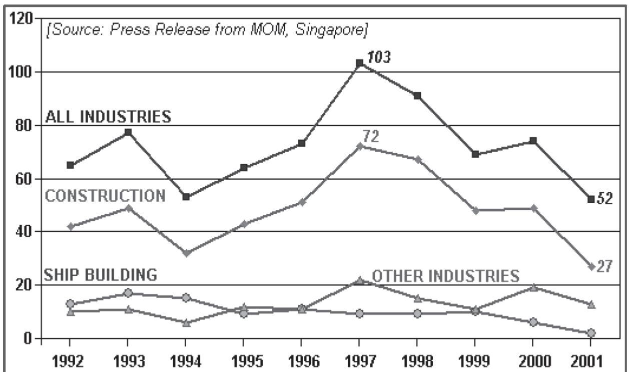

Fig. 2. Fatalities in Singapore Industries, 1992-2001

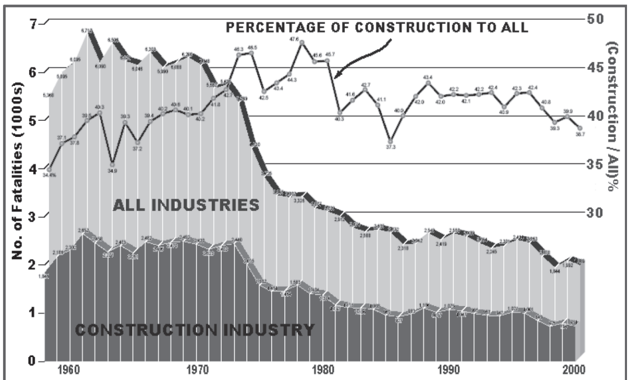

Fig. 3. Fatality Rates in Japan Construction Industry and All Industries, 1958-2000
[Source: Japan Construction Health and Safety Association]

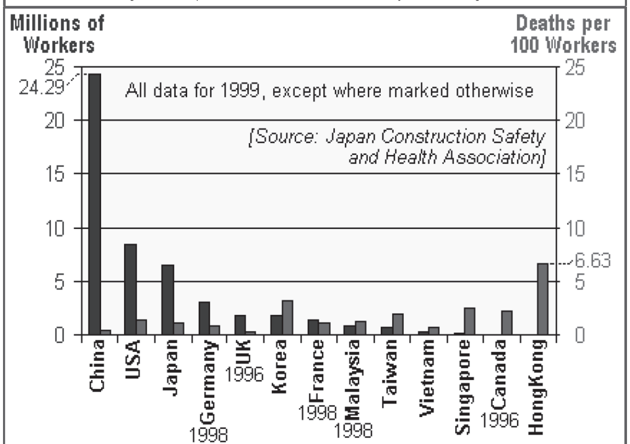

Fig. 4. No. of Workers and Fatality Rates, 1996-1999

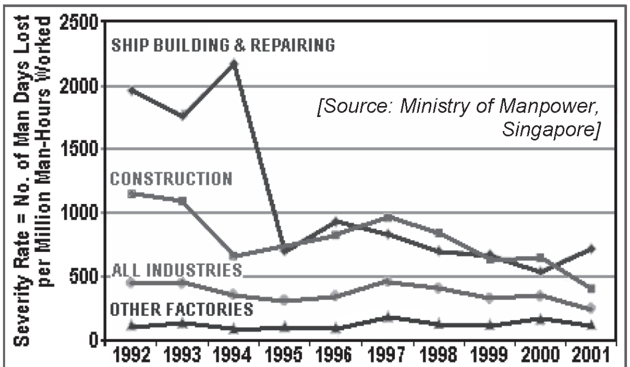

Fig. 5. Accident Severity Rates in Singapore Industries

of deaths per ~~100~~ workers in various countries in the west and the Asia-Pacific region for various years between 1996 and 1999. It appears that the fatality rates are higher in most countries of the Asia-Pacific region with the exception of Japan, and lower in the West with the exception of Canada.

Apart from the frequency of accidents, the severity of accidents is another measure of the seriousness of accidents in the construction industry. Severity is measured by the number of man days lost for a certain number of man-hours worked. Even in this regard, construction fares badly, as may be seen from Fig. 5, depicting the severity of accidents in Singapore, showing construction fatalities to be the worst of all industries. However, the severity is also being reduced in recent years.

These statistics should be of great concern to the nations presently under high risk in the construction industry. Apart from loss of limb and life, damage to property and waste of time, the reputation of the profession and of the country itself are at stake.

3 Economic Impact of Accidents

Many owners and contractors still believe the myth that safety concerns will lead to greater cost and reduced productivity. The reality is that safety evaluation and control save money. The delays and total expenses following an accident are usually much higher than the original cost of establishing and maintaining safety standards. The costs associated with accidents and fatalities are as follows:

(a) Direct Costs (Insured):

- Human ill-health, injury, death
- Transportation for first aid, and for medical treatment
- Liability insurance costs (after workers compensation)
- Medical and hospital expenses
- Property damage, destruction
- Repair and replacement expenses

(b) Administrative Costs:

- Budget allocations must be made for:
- Equipment and supplies
- Safety director / coordinator
- Time (meetings, inspections, etc.)

(c) Indirect Costs (Uninsured):

- Impact on public, neighbourhood
- Wages to injured worker for time not worked
- Training new/substitute worker
- Rescheduling work
- Construction authority and civil fines
- Impact on profession, industry
- Delay due to accidents, investigations
- Loss of crew efficiency
- Clean-up, equipment repair, stand-by
- Post-accident extra safety supervision
- Legal fees
- Reputation of government

4 Modes of Failure

Temporary structures may fail and cause accidents in various modes, as follows:

4.1 Material Failure

Material failure is the most basic mode of failure, and is involved in all other modes of failure. It refers to crushing or tearing of wood fibres, yielding or cracking of metal, snapping of rope or wire.

When a material fails in tension, there is usually a reduction in cross-sectional area, and the particles separate. When a material fails in compression, there is some increase in cross-sectional area, and the particles crush against one another, sliding along “shear planes”. Shear failure is very rare in members, but is likely at connections, as in the lugs at bracings with frame members.

Timber is strong along the grain, and weak perpendicular to the grain. Other problems with timber are knots, cracks and other natural interruptions to the grain that can make it unserviceable. If the grade of the timber is not marked, there is the risk that it may be of lower strength than assumed in the design, and hence liable to fail.

4.2 Component or Member Failure

Failure of even simple accessories such as wire binding between reinforcement bars and support chairs can result in progressive collapse. Every component of temporary structures deserves care.

Compression members or components can fail by buckling, even under low stress levels. In fact, most falsework and scaffolding failures have been attributed to buckling of compression members due to insufficient bracing. If scaffolding is not tied to external supports, or if long metal beams of angle, channel, or ‘I’ section do not have intermediate web/flange stiffeners, buckling will occur.

4.3 Structural Failure

In a temporary structure, the material may be stressed well below the limiting value, and the compression components individually may be well braced against buckling. However, if the entire structure or a main segment of it has high slenderness ratio, that will fail by buckling.

Likewise, if a rectangular panel has pinned ends or weak corner joints and no diagonals, the panel will collapse into a parallelogram under lateral or eccentric vertical loads, leading to structural failure.

In a properly erected temporary structure, workmen may remove a diagonal member from a panel to allow a passage. This, if left uncorrected, would make the frame vulnerable to collapse.

4.4 Connection Failure

The strength and stability of the temporary structure are highly dependent on the connections between its components

Connections in temporary structures must be assumed at their most basic configuration. If the designer has assumed a special connection such as fixed in his design, special components and fabrication methods (such as welding) would have to be used.

Spigot and socket joints attaching frames to one another, may be tight fitting to start with, but will become loose and shaky after a few uses. Rosettes which are expected to provide firm pinned connections will also allow some play for the connected members with use.

The lugs at the corners of rectangular panels on to which cross bracings fit neatly while new, will get bent, and the bracings will have to be forced onto them, sometimes distorting the panel. Occasionally, when the bar holes do not fit over the lugs, ad hoc measures such as wire ties are used. It is not unknown for the cleats or retaining nuts on the lugs to be missing or inoperative.

Wire bindings between reinforcement bars, between them and bar chairs that support them, between intermediate bracings and vertical posts, etc., have been known to be missing or ineffective.

Connections in temporary structures may be nails holding a wooden plank to another wooden piece, or by bolted clamps. During use, nails may pull off if the plank, instead of pressing down, tends to lift up from the wooden piece. Clamps may permit relative rotation and/or shifting of the connected members, and cause eccentric loading, swaying and collapse of the structure.

All these problems with connections will compromise the load bearing capacity of the temporary structure. Because of the difficulty of providing fixity at the joints at site, and due to the loosening of tight fits with repeated use, connections in temporary structures can be expected to develop positional restraint only and not directional restraint.

Often, in temporary structures, connection failures may not be of the connections themselves as designed, but failure on the part of erectors to check and/or install the connections properly. A case in a point is when horizontal members are fixed to the vertical posts by means of clamps, which depend mainly on friction to transfer the loads down.

4.5 Support Failure

As temporary structures are made to rest on temporary supports, their bases must be wide enough and rigid enough to prevent settlement into the underlying soil or other medium. Otherwise, the structure will tilt, or sink locally, causing further problems.

Support conditions of temporary structures are difficult to control. If settlement occurs at isolated supports, it may result in the overloading of other members around the supported components and adverse consequences.

If bases of posts and screw jacks are not fixed to sole plates, they will slide if the ground is sloping, especially when wet, or they will slip off under some transmitted vibration.

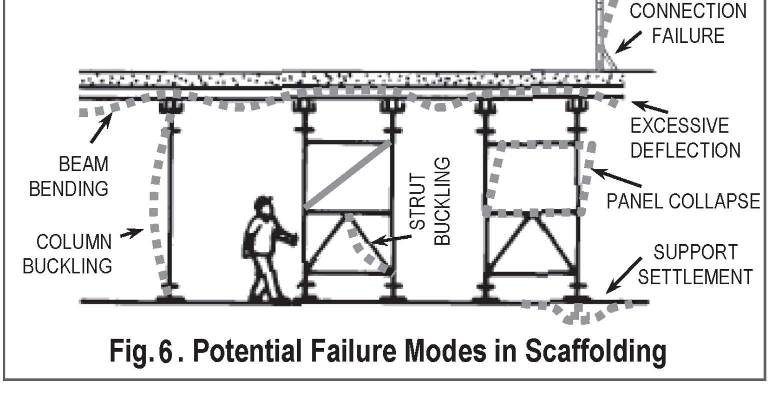

Fig. 6 . Potential Failure Modes in Scaffolding

Foundations of temporary structures are very susceptible to changing characteristics upon water-logging due to rain or run-off. Softening of underlying soil due to rain, after falsework has been checked and approved, is a very common cause of the base sinking under concrete placement or other heavy loading.

Some of the potential failure modes in temporary structures are illustrated in Fig. 6.

4.6 Overall Instability of Structure

Even when every component of a temporary structure has been carefully designed and fabricated, occasionally the loads on a temporary structure may be placed in bad locations, or natural forces may occur in a very adverse combination, in such a way as to destabilise the structure as a whole.

If the resultant of all the applied loads falls outside of the “core” of the cross-section of the base of the structure, part of the support will separate from its base. If the resultant falls outside the base, the structure will topple, as the overturning moment becomes larger than the stabilising moment. Examples are: Placement of a heavy load at one corner of a scaffold, or on a cantilever; very high wind on a crane or other tower; a worker climbing on the outside of a free-standing tower scaffold.

4.7 Soil Failure

Soils in and around a trench can fail by the following modes:

1. Vertical tension cracks
2. Sliding along a slope
3. Toppling beyond a tension crack
4. Subsidence and bulging of soil mass
5. Heaving or squeezing up into the trench
6. Boiling of slushy soil into the trench

Soil properties and behaviour can change drastically during or after trench cutting, because:

(a) Internal balancing pressures are released;
(b) Newly exposed surfaces become dry;
(c) Soil gets water-logged as under rain; or,
(d) Vicinity is subjected to vibration.

Trench side failure, called “cave-in” may be caused by a combination of these modes, and can also be progressively caused by different modes. A cave-in can bury workers even at shallow depths.

5 Causes and Characteristics of Accidents

5.1 Causes of Accidents

Apart from structural failure as such, other causes of accidents must be understood and evaluated. Accidents may be caused by (a) Unsafe acts, (b) Unsafe conditions, or, (c) Combination of the two.

(a) Unsafe Acts:

- Use of defective equipment
- Unsafe material handling
- Poor housekeeping
- Failure to use personal protective equipment
- Failure to follow safety procedures
- Attitude problems (horseplay, macho, etc.)

(b) Unsafe Conditions

- Improper guarding of equipment, platform
- Hazardous chemicals, explosives, etc.
- Poor site layout, housekeeping
- Poor tag-out and lock-out practices
- Unsanitary conditions
- Improper illumination, ventilation
- Improper dress
- Defective tools and equipment
- Poor maintenance
- Unsafe design and construction

5.2 Factors Contributing to Accidents

"Pure" (or "True") accidents, called "Acts of God", are those that could not have been predicted, avoided, or protected against in the normal course of events. An earthquake is a classical example. All other accidents are the result of many factors, as listed below and depicted in Fig. 7, singly or in combination (as denoted by the overlapping circles in the figure).

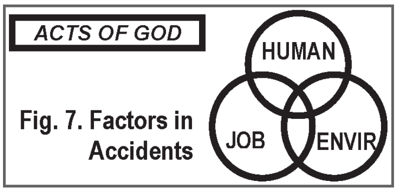

Fig. 7. Factors in Accidents

(a) Human Factors:

- Attitude (towards self, others)
- Limitations (medical, physical)
- Training

(b) Job Factors

- Task
- Tools and equipment
- Materials / structural safety

(c) Environment Factors

- Physical (terrain, site, climate)
- Technological (new technology)
- Managerial (communications)
- Social, political, legal
- Economical (insufficient fees)
- Time (early finish pressure)

5.3 Accident Types and Resulting Injuries

Most construction accidents fall into certain types and cause certain common injuries all over the world. Common ones are listed below, roughly in the order of their occurrence:

(a) Common Types of Accidents

- Falls (same or different level)
- Struck against objects
- Motor and industrial vehicles (on and off-site) Overexertion
- Back injury
- Inhalation of fumes
- Exposure to temperature extremes
- Electrocution
- Explosions
- Struck by objects
- Equipment and tools
- Contact with chemicals

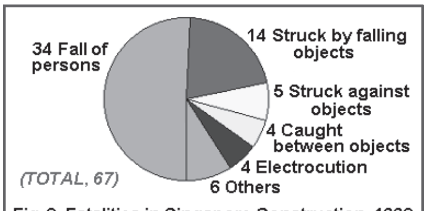

Fig. 8. Fatalities in Singapore Construction, 1998

Figure 8 displays a pie-chart of the causes of fatalities in Singapore construction accidents in 1998.

This shows that falls and being struck by objects are the most common types of accidents. This is true all over the world. Unfortunately, most of the fall deaths are needless, because a few simple, relatively inexpensive precautions would have prevented them.

(b) Common Types of Injury or Illness

- Cuts, amputations
- Foreign body (eye, body)
- Hernia
- Burns, hypothermia
- Puncture wounds
- Fracture
- Allergies
- Heart attacks
- Bruises, contusions, abrasions
- Sprain and strain, back pain
- Dermatitis
- Latent illness (cancer, hepatitis)

5.4 Human Factors in Accident Causation

Personnel related factors contributing to accidents are listed in Tables 1 and 2. Although the exact percentages may vary with country and other factors, their relative importance is fairly common.

Table 1. Failure Sources by Personnel	
Site staff 60%, Workmen 17%, Head office 4% Total, Contractor	81%
Structural designer	48%
Resident engineer	31%
Inspector	28%
Project architect	3%
Operator (crane, vehicle, etc.)	3%

Table 2. Failure Sources by Human Failings	
Ignorance, negligence, carelessness	82%
Underestimation of influence	72%
Insufficient knowledge	67%
Lack of education / training	57%
Lack of authority in decisions	45%
Lack of ability to communicate	37%
Reliance on other parties	29%
Objectively unknown situation	33%

(Percentages in these and subsequent tables may not add up to 100 due to multiple contributions.)

5.5. Failure Locations and Affected Materials

Common locations of failures and the materials affected thereby, from recent surveys in the West, are listed in Tables 3 and 4. Again, percentages are included only to show relative importance.

Table 3. Failure Location	
Slabs and plates	34%
Beams and trusses	11%
Vertical (columns, Piles, walls)	11%
Connections	9%
Foundations	6%
Others / unknown	34%

Table 4. Failure Affected Materials	
Reinforced concrete	86%
Steel structures	9%
Rock and earth materials	6%
Timber elements	3%
Glass cladding	2%
Prestressed, precast concrete	1%
Aluminium, plastic, masonry etc.	<1%

6 Codes and Standards

6.1 Need for Codes and their Scope

To address and counteract all the potential failures discussed in the preceding sections, most developed nations establish standards and codes of practice, based on extensive analyses, experimentation, research, and experience. Smaller and less developed countries either specify these other codes for their construction, or adopt and modify them to suit their special needs.

For instance, Hong Kong recognised that bamboo scaffolding which had been successfully in use for hundreds of years could not be eliminated by a law forbidding it. Instead, it accepted bamboo as a feasible scaffolding material, and developed a code of practice for various aspects of its safe use.

The Singapore Ministry of Manpower (MOM), like OSHA in USA, and similar authorities in other countries, has the responsibility and duty of checking various temporary structures, ensuring that they meet the minimum specified standards, and levying penalties for any violations. They investigate accidents and failures and use findings therefrom to improve the standards.

Codes contain elaborate rules for analysis and design, tables and charts for selecting sizes, spans, etc. for various configurations and loadings, and drawings of typical arrangements and details.

As explanatory and supplementary material to the codes, government and professional bodies also develop guidebooks, manuals, brochures, posters, slides, etc. They produce videos and conduct seminars for contractors. They send out advisories to contractors, and conduct announced and unannounced site visits. They provide telephone hotlines and web sites to offer clarifications and answers. They require safety officers and workers to undergo training courses and get certified.

Once a code becomes law, any violation carries legal prosecution and penalties. Upon finding violations, the authority issues a citation with a fine, and in extreme cases, stops the work, until the violations are rectified, the conditions are re-checked and re-certified for continuance of the work.

Companies for their part are required to have safety officers on their staff. They should budget for safety management. They may get safety audits by third-party companies, so that they may find out and rectify any deficiencies in the work site, before MOM visits and discovers these shortcomings.

6.2 Common Code Violations

Violations cited by MOM (Singapore), and also by other authorities around the world in recent years include the followings, roughly in the order of frequency:

- Missing or inadequate bracing
- Missing or inadequate barriers, guardrails, and other safety measures
- Unstable or improperly secured planks, posts, other structural deficiencies
- Unconnected or loose joints, other inefficiencies in fabrication
- Personal protective equipment not used or inadequate

- Poor housekeeping (meaning allowing debris to accumulate in the working area)
- Inadequate design
- Incomplete instructions and/or poor communication between various parties
- Insufficient supervision

7 Hazard Assessment and Control

Formal procedures are available to identify and assess the hazards (dangers) that can lead to accidents, and to install measures ("controls") to eliminate or at least to minimise them. The phases of general approach to hazard assessment and control are as follows:

7.1 Hazard Identification

Methods of identifying hazards include:
(a) Consultation with workers
(b) Consulting representatives of industry associations, unions, and government bodies
(c) Employing specialist practitioners
(d) Examining workplace injury and incident records

Person(s) responsible for safety must go around the work site with a senior supervisor, watch every procedure, break each activity into distinct tasks, and note all items that can possibly go wrong.

7.2 Risk Assessment

"Risk" is defined as the combination of two factors: (1) Likelihood of a hazard, and (2) Consequences of a hazard.

The simplest way of evaluating the risk in a certain hazardous task is to quantify its likelihood and the severity of its consequences. Each of the two factors may be given values of 1, 2 or 3 on a 3-point scale, low probability or severity being assigned 1, medium assigned 2, and high assigned 3.

Then risk is calculated as the product of likelihood value and severity value. This product will range from 1 for low likelihood and low severity (like stepping in a puddle), to 9 for high likelihood and high severity (like a child leaning over a low parapet), with intermediate values for other estimates. Table 5 depicts the 3 by 3 matrix for risk assessment, with risk values shown in square brackets.

Table 5. Risk Assessment Matrix

Severity→ ***Likelihood ↓***	***1. Low*** (Slightly harmful)	***2. Medium*** (Harmful)	***3. High*** (Very harmful)
1. Low (Very unlikely)	**[1]** Trivial	**[2]** Tolerable	**[3]** Moderate
2. Medium (Unlikely, but possible)	**[2]** Tolerable	**[4]** Moderate	**[6]** Substantial
3. High (Very likely)	**[3]** Moderate	**[6]** Substantial	**[9]** Intolerable

Generally, the lowest risk of 1 is considered trivial, even "normal", and the highest risk is considered intolerable, sufficiently serious to stop work, evacuate personnel, etc., until further notice.

7.3 Risk Control

Once the risk value is computed, the proper "control" must be established. That is, ways and means to eliminate or reduce the likelihood and/or severity of the hazard must be identified, evaluated, and implemented.

Note that in Table 5, the risks align neatly along the diagonals, into five categories. Control and corrective actions for the five categories of risks are as listed in Table 6.

Table 6. Controls for Various Risk Categories

Category	*Risk*	*Control*
Trivial	[1]	Acceptable, normal, no action
Tolerable	[2]	Monitor the situation, modify as needed, continue
Moderate	[3. 4]	Check the situation, correct all deficiencies, and proceed
Substantial	[6]	Stop work, rectify problems, check the system, and proceed with care
Intolerable	[9]	Unacceptable, stop work until problem solved, checked and approved

The actual control measures considered and implemented may be one or more of the following:

- Eliminate the hazard from the machine, method, or material system
- Substitute with alternative or modify the procedure to minimise hazard
- Control by isolation, enclosure, guarding
- Train personnel for hazard recognition and in safe job procedures
- Prescribe personal protective equipment to shield personnel from the hazard

8 Safety-Related Considerations

8.1 Causes and Remedies for Accidents and Failures

(a) Causes of accidents and failures:

- Pure accidents
- Bad design
- Equipment failure
- Poor management
- Flawed supervision
- Lack of training
- Worker negligence (ignorance)
- Plus human error as an underlying cause

(b) Remedies for accidents and failures:

- Good design
- Careful construction
- Correct training
- Proper supervision
- Efficient management
- Worker diligence
- Conformance to rules
- Government regulation

While temporary structures may theoretically behave in the same way as permanent structures, the fact that they are temporary and must be capable of easy removal and reuse makes their design and use different. Designers and contractors should pay to temporary structures, at least as much care as, if not greater care than, they pay to permanent structures. Specific measures to improve safety in construction industry are detailed below.

8.2 Special Considerations in Design

1. Timber, steel, aluminium, and plastic are the materials commonly used for temporary structures. They are all easy to install and dismantle, and may be reused a number of times. They are also ductile, and hence

will warn of impending failure by yield and visibly noticeable deflections. Design should involve the strength and stiffness of the particular materials proposed to be used. The designer should specify the exact grades of timber or other materials assumed in the design.

2. Loads for temporary structures are different in type and magnitude from loads on permanent structures. Designer should include not only final anticipated loads on the temporary structure, but also loads during different phases of construction (such as trench shoring), and even accidental loads to a certain extent. The lateral pressure of wet concrete on formwork sides is about 24 kN/m^2 per metre depth.
3. As temporary structures are not anchored to firm foundations or fully integrated like permanent structures are, they should be designed to stand alone as much as possible, with ties to existing permanent structures or guys to ground anchors. Triangulation of support frames, or anchors must be designed to prevent sidesway and lateral movement of the temporary structure.
4. As temporary structures are mostly built of long and slender members, buckling can become a very common problem, and proper cross bracings for panels and intermediate bracings for tall columns must be designed to prevent buckling.
5. Because of the uncertainty of foundation conditions, and the impossibility of ensuring fixity at supports and continuity at joints (except where welded), no assumption of fixed supports or rigid joints must be made in the design. The safest assumption and simplest to implement in practice, is to take columns as simply supported at bottom and top, and joints as pinned.
6. Because of the variable nature of materials, labour, and technology available at the site for fabrication, the factor of safety must be at least 2, although for the permanent structure, LRFD or other methods may provide lower factors of safety.
7. Certain structural details deserve special attention are:
   (a) Connections at the ends of tension members
   (b) Although ‘I’ sections are the most efficient, rectangular sections are quite common in temporary structures. Recently, ‘I’ sections of timber are available for wall formwork studs.
   (c) Platform planks are used in their least efficient position, namely with the longer side horizontal, to provide a walking and working surface for people and storage of materials. While this is unavoidable, its larger deflections and lower capacity must be remembered.
   (d) Cantilevers must be avoided except for walkways in site buildings, receiving platforms, outrigger scaffolds, etc., because of the difficulty of providing safe and secure support fixities.
   (e) Torsion is generally not a problem with temporary structures, but when unplanned connections are made at intersecting members, moment transfer may lead to torsion for which the members might not have been designed.
8. If no specific design code is available for the temporary structure, some other code applicable to permanent structures (such as BS-5950) may be followed, to meet professional requirements.
9. In computer analysis, care must be taken to model support and joint conditions realistically. For instance, swivel couplers in tubular scaffolds can transfer forces, but not moments.
10. Sufficient redundancy must be built in, to prevent any local failure from escalating to system collapse by domino effect.
11. Designer has the legal (and professional) responsibility to define the conditions and limits of his design in his documentation, and to provide sufficient instructions and guidelines for the contractor to implement his design in letter as well as in spirit.

8.3 Special Considerations in Fabrication and Erection

1. What is missed in design, and what is not directly part of design, must be taken care of during fabrication. Saving lives is more important than assigning blame after a tragedy.
2. Where through passage is required for men and materials, special welded frames must be used.
3. Foundation conditions cannot be fully anticipated in design. They are also more susceptible to change with the weather, with far-reaching consequences to the temporary structure supports. Contractor must accept responsibility for proper trench shores and base plates.
4. The quality of the temporary work will vary more than in a permanent structure, because of variations in material and personnel skills. Extra precautions must be taken to ensure uniform, safe, and good quality work.
5. The grades of all timber items should be marked, to ensure that they are not mistakenly used for loads or spans beyond their capacity. Timber whose grade is not marked, must be rejected.
6. Contractor must strictly follow each and every instruction given by the designer and depicted on the drawings. If site conditions or available resources dictate any change, he must refer to the designer for a suitable change; or get approval of a change suggested by the fabricator himself.
7. In addition to conforming to design and drawings, contractor must ensure that any obvious errors of omission or commission are brought to the notice of the designer and owner, and rectified, before proceeding with the fabrication.
8. Beams are often supported at their ends by means of clamp around the posts. These, as well as the other connections, are potential weak-points which must be monitored.
9. Regardless of instructions from designer or owner, contractor has the ethical responsibility to see to it that lateral movement of the temporary structure is effectively prevented, and (unless specified otherwise) adequate bracings be provided for long and slender compression members.

8.4. Special Considerations in Use

Workers and inspectors on temporary structures must always be aware of the fact that what they are walking and working on are: (a) not on firm or rigid foundation, (b) not rigid or strong enough for the full loading of the permanent structures, and (c) exposed to the weather and risks of workers falling and other accidents.

They should wear the proper attire, helmets and other PPE, at all times. Scaffold users, and those working in trenches should follow all the rules strictly. Spotters should constantly watch for sinking of post bases, sliding of soil banks, and other danger signs.

8.5 Special Considerations in Inspection

In many cases, it has been discovered that by the nature of the work either the designer has overlooked some essential feature, or the contractor has missed implementing it. Site conditions during construction are also more chaotic than at the time the permanent structure is handed over.

Therefore, it falls to the inspector to look for and alert the contractor to such oversight risks, and see that the situation is corrected.

1. Inspector must pay special attention to foundation conditions and to connections.
2. Inspection is not a one-time affair. It should be done during fabrication, after fabrication, and during use, of the temporary structure.
3. He should check that the temporary structure is erected and used in the manner and sequence for which it was designed.
4. Use of proper grade of materials, movement and placement of materials by cranes and workers, foundation conditions, etc. should be monitored at all times.
5. Regardless of specific instructions from designer, owner, or contractor, inspector has the ethical responsibility to check for obvious flaws such as missing anchors and braces against sidesway and buckling. They must insist on the rectification of all deficiencies before proceeding.

8.6 Considerations during Rigging and Dismantling

Riggers and dismantlers are exposed to more risk than workers and inspectors, as they must stand and work from unstable and minimal supports at different heights. They must wear full body harness and anchor themselves to safety lines as shown in Fig. 9.

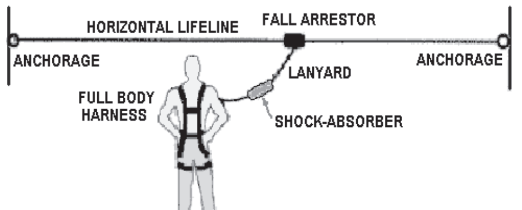

Fig. 9. Fall Arrest and Full Body Harness System

Dismantling is even more dangerous than rigging because if a wrong piece is removed, or a right piece is removed wrongly, the remaining system may be very adversely affected. Careless dismantling can pull down the entire remaining temporary structure, and even some or all of the permanent structure. The following may be relevant:

1. In large and complicated structures, the designer may have to specify the dismantling sequence and methodology.
2. Contractors have the responsibility to ensure that:
   (a) Loosening of connections and removal of pieces does not cause unforeseen loads on the remaining structure, or uncontrollable chain reactions.
   (b) Temporary supports are provided for heavy or unwieldy items during the process of removal.
   (c) Anchors are not removed before bracings are removed.
   (d) Riggers, users, and dismantlers are supplied with all the PPE that they need.
   (e) When possible, dismantling is done layer by layer from top down, not by vertical segments.
3. Inspectors must check that all the regulations and recommendations for dismantling are followed at all times, particularly that the dismantlers wear all their PPE and do not take shortcuts or risks they are not supposed to.

9 Conclusion

9.1 Broad Approaches to Construction Safety

Thus, accidents and failures may be prevented by promotion of the following:

- Knowledge (Training and Education)
- Competence (Experience)
- Care (Control)
- Improved communications and organization in the construction industry

In the final analysis, construction safety is a matter of commitment by the authorities: The management of the organisation in setting out a budget and assigning safety responsibilities to trained personnel, and the government in establishing safety policies and enforcing regulations.

One final caution that may be mentioned is this: If and when someone, anyone, mentions some misgiving or reports some untoward happening about anything, higher ups should take them seriously. All too often, what appears to be a minor hitch turns out to be a deadly disaster.

9.2 Safety Management System

For all the safety precautions to be observed and safety measures to be implemented, the management must adopt a good Safety Management System (SMS). The 14-Point Safety Management System used in Singapore is given as Appendix A as typical.

10 References

1. SPRING, Singapore: *Code of practice for scaffolds CP 14 : 1996, Code of practice for earthworks CP 18 : 1992, Code of practice for formwork CP 23 : 2000, Code of practice for safety management system for construction worksites CP 79 : 1999.*

2. Govt. of Hong Kong Special Administrative Region, Labour Department: *Code of Practice for Bamboo Scaffolding Safety, Code of Practice for Metal Scaffolding Safety, Code of Practice on Safety Management.*

3. USA Dept. of Labor Occupational Safety and Health Administration, Washington, DC.: *Standards – 29 CFR, PART 1926 Safety and Health Regulations for Construction, Subpart L - Scaffolds, Subpart M - Fall Protection, Subpart P – Excavations*.

4. Japan Construction Safety and Health Association: *Statistics of Industrial Accidents on Construction Industry.*

5. Krishnamurthy, N., Notes for various short courses on Safety and Design of Temporary Structures, Scaffolds, etc.

APPENDIX A

Safety Management System

14-POINT SMS

1. Safety Policy
1.1. Safety organisation
1.2. Responsibilities and authorities
1.3. Resources
1.4. Policy review

2. Safe Work Practices
2.1. Type of safe work practices
2.2. Application of safe work practices
2.3. Permit-to-work systems
2.4. Statutory requirements on safe work practices

3. Safety Training
3.1. Identification of training needs
3.2. Statutory training requirements
3.3. Other safety training
3.4. Training for management and supervisory personnel & workers
3.5. Training records

4. Group Meetings
4.1. Safety committee meetings
4.2. Tool box meetings & safety briefings
4.3. Co-ordination meetings

5. Incident Investigation & Analysis
5.1. Identification & record of incidents
5.2. Investigation of incidents
5.3. Analysis of incident statistics

6. In-house Safety Rules & Regulations
6.1. In-house rules & regulations
6.2. Training and review of rules & regulations
6.3. Safety signs

7. Safety Promotion
7.1. Promotional activities
7.2. Safety bulletin boards
7.3. Recognition of good safety performance
7.4. Records of promotional activities

8. Evaluation, Selection & Control of Sub-contractors
8.1. Evaluation of sub-contractors
8.2. Selection of sub-contractors
8.3. Control of sub-contractors

9. Safety Inspection
9.1. Types of inspections
9.2. Competency of safety inspectors
9.3. Inspection methodology
9.4. Follow-up system

10. Maintenance Regime
10.1. Maintenance program
10.2. Listing of hand tools, plant, machinery & equipment
10.3. Schedule of inspection & maintenance
10.4. Procedure for breakdown & repair
10.5. Records of inspection & maintenance
10.6. Competency of maintenance personnel

11. Hazard Analysis
11.1. Hazard analysis plan
11.2. Hazard analysis method
11.3. Hazard analysis report

12. Control of Movement & use of Hazardous Substances & Chemicals
12.1. Management of hazardous substances & chemicals

13. Emergency Preparedness
13.1. Types of emergency situations
13.2. Emergency plan
13.3. Emergency team
13.4. Emergency drills & exercises
13.5. First aid program

14. Occupational Health Programs
14.1. Hearing conservation program
14.2. Respiratory protection program
14.3. Training & education