Safety during Steel Erection

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Abstract

Construction is known to be the most hazardous of all industries all over the world. The number of accidents and fatalities during steel erection is quite high, to the extent that many special safeguards have to be planned and implemented. High incidence of these erection accidents continues in spite of research and development to reduce them, mainly in the West over past decade. Principal causes of steel erection fatalities were found to be: Fall from heights; hit, crushing or fall during lifting operations; struck by falling object or projectile; and electric shock. Author has been involved in teaching, research, and consultancy on steel design and construction in U.S.A. and Singapore for more than five decades. In Singapore, he consults and trains on workplace safety and risk management, and carries out research for government agencies on safety-related subjects. Paper will focus on the most common and traumatic hazards of working at height, and manual handling and other ergonomics, and review controls and safeguards available and locally feasible solutions.

1. Introduction

Steel structures can be made as safe as or safer than other construction materials, but steel erection demands intensive and extensive safety planning and compliance to ensure risks are eliminated or mitigated to the maximum extent. Accident statistics abroad are quite bad in steel erection (46 fatalities per 100,000 in USA in 2007). However, the positive side is that the record has been improving (down to 27 in 2011) according to Bureau of Labor Statistics (2012) and can improve further.

Figure 1 depicts fatality statistics in USA, UK, and Singapore, indicating clearly that construction is the most hazardous of all industries around the world.

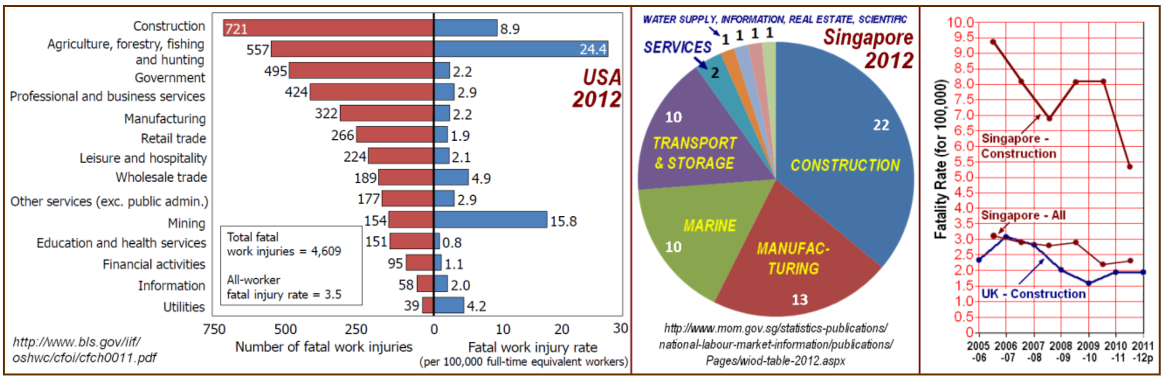

Figure 1 : Fatality statistics in various industries in USA, Singapore, and UK

In particular, Singapore fatality rates for various industries in recent years show that:

(a) Construction fatality rates are much higher than fatalities in other industries; and,
(b) Singapore fatality rates are decreasing overall, although still higher than UK and many other advanced nations.

2. Hazards and causes of accidents in steel erection

In addition to normal hazards of construction, unique hazards arise from inherent properties of steel structures, namely: (1) Large, heavy components must be lifted and placed into position; and (2) structure can be unstable in the part-erected condition.

Main safety objectives in steel erection are:

(a) Safe access and working positions;
(b) Safe lifting and placing of components; and
(c) Stability and structural adequacy of part-erected structure.

Table 1 shows conclusions from OSHA (2002) data on steel erection fatalities:

Table 1 : Accidents and Causal Factors

No.	***Accident***	***Causal factor (FP = Fall Protection)***
1.	Collapse while landing or placing a load	Placing loads on unsecured or unbridged joists
2.	Collapse while connecting joists or trusses	Prematurely disconnecting the crane before the piece was secure
3.	Worker struck by object	Walking or working under a load
4.	Worker struck by object and falling	Struck while landing a load or making a connection, by a tool slipping, etc, FP not provided
5.	Improper use or failure of FP	Employee failure to use available FP system
6.	Unsecured/unstable decking	Stepping onto or working on unsecured decking, slipping out of place when FP not provided or used
7.	Plumbing, bolting, welding and cutting	Worker not tied off while at the work station (whether or not FP was provided)
8.	Walking/standing on beam/joist	Most were slips or falls where FP was not provided or used

Wilshar Steel Erectors (2008) mention a few more hazards:

(a) Narrow footing resulting in falls;
(b) incoming loads being difficult to control;
(c) workers being trapped between loads causing a crushing injury, or being felled by swinging loads; and,
(d) joists losing bearing or connectors that separate causing connector to fall and injure someone below.

A10.13 Sub-Committee Chairman Treharne (2011) highlights many safety issues including:

- Caught-in-between-type injuries, such as getting limbs caught between man-baskets and steel, and beams rolling over due to unstable ground conditions.
- Strains from pushing or pulling to get something in place, in awkward positions.
- Eye and hand injuries, while pounding on something and it slips or breaks.
- Injuries from walking and working surfaces, especially during inclement weather.

- Ground conditions uncertain to temporarily support equipment and steel members.
- Live electrical wires in the erection area.

Falls from height take the lead with about 1/3 of the fatalities, and hits from falling objects with another 1/4. In health problems, bad manual handling and poor ergonomics top the list.

3. Safety considerations in steel design

Erection safety starts at the design stage. Design for safety implies 'Life Cycle Design' which covers safe construction, use, maintenance, and demolition. Apart from normal responsibility for strength and stability of completed permanent structure, designer must consider potential problems arising during erection, (Steel Construction.info, *ca* 2011), such as maintenance of stability of the part-erected structure; limitations imposed by lifting capabilities of cranes; and, safe access to and at working positions. Corus Group (2004) suggests that designers should include stability and bracing for individual members and assemblies during lifting into position, successive erection stages, partially erected, and in final erected condition.

4. Safeguards and controls for erection hazards

4.1. Fall from height

Fall arrest equipment has been the mainstay of fall protection methods after the belt and lanyard were banned for that purpose in the late 1990s. Collective fall arrest methods such as safety net should take precedence over individual fall arrest system of safety harness. With nets, hitting something on the way to the net may become an issue. U.S. PPE manufacturers are focusing on anchorage and fall-arrest systems that are easy to install and to use (Martin *et al*, 2002). These systems include lightweight stanchions that can be installed or removed with no special tools. Some have built-in shock absorbers that simplify horizontal lifeline systems.

Much unsafe work at height (WAH) may be eliminated by pre-installing edge protection on structural members in the shop or at site at ground level. As Pocock (2003) points out, technology is providing additional methods to help prevent iron workers from falling. Items such as retractable lifeline and horizontal lifeline systems and "Beamers" that attach by clamping on beam or column flanges provide effective fall protection anchorage points. New fabrics make harnesses lighter and more comfortable, and can be equipped with tool belts, back pads etc.

Beavers *et al* (2009) report valuable OSHA data on 123 fall from height events, which the author re-analysed to determine the physical factors contributing to falls, as listed in Table 2.

Lack of fall protection (FP) nearly half the time and improper FP are indeed massive management lapses, but fall protection unsecured one-third of the time is unconscionable! Cited paper also gives clues to such large violations, and suggestions for improvement:

- Time for implementation and personal use of FP will not affect total cycle time.
- 40% of employers were rated as having 'inadequate' or 'non-existent' safety programs.
- Many fall accidents happened while workers were changing locations.
- The victim himself was responsible for or contributed to 64% of the accidents.
- Intensive training, constant awareness of WAH hazards, enforcement of proper use of PPE always, and prompt rectification of unsafe conditions would reduce accidents.
- Principal management flaws were failure to communicate Safe Work Procedures.

- Employers failed to communicate the hazards and controls to workers effectively.
- Safety nets would eliminate the present tendency for workers to shed harnesses.
- Enhanced collection and better organisation of fall data would be essential, to move from reactive investigation to development of pro-active intervention strategies.

Table 2 : Contributing Factors to Falls from Height

No.	*Factor*	*No. cited*	*% of 123*
1.	Lack of fall protection (FP)	42	48
2.	Fall protection not secured	35	33
3.	Lost balance	31	28
4.	Unexpected movement of walking/standing surface	11	16
5.	Improper climbing	16	10
6.	Equipment failure	16	10
7.	Improper fall protection	11	8
Numbers in last two columns will not add up to 123 and 100 due to multiple factors.			

All components of FP should be compatible, preferably from a single manufacturer. Proper anchoring and positioning mechanisms must be available. Gear must be inspected every time it is put on, and must not be used beyond manufacturer's recommended lifetime for them. Author supports many of the management-oriented recommendations in Singapore context.

4.2. Struck by falling objects

The second most common cause of death and injury during construction occurs when a worker is struck by an object. Studies show that a high proportion of head injuries are due to the lateral impact of flying objects and not just the vertical impact of falling material. Special hats to cater to these extra forces have been developed, with additional conveniences.

Workers must protect themselves and their co-workers from falling objects, by securely fastening the materials they are working with to the loading equipment or to the structure, before they remove supporting cables. Lanyards will ensure that their tools will not fall if misplaced or dropped. Similar attention must be paid to other Personal Protective Equipment (PPE) necessary for job and site.

4.3. Manual handling and ergonomic risks

A third problem is ergonomic risks while workers physically maneuver the heavy structural components into place and fasten them down. Preferably hoists should do the heavy lifting. Good communication with the hoist operator can save work and back muscle strain. Vibration injuries while using power tools should be avoided or minimised; symptoms such as finger blanching, tingling, and numbness should not be ignored. Low vibration tools and protective gloves should be used, and tools must be held with a light, secure grip. Prolonged awkward postures and repetitive work must be avoided and mini-breaks must be taken.

5. The Singapore Scene

Singapore had made its mark globally with its many iconic structures, most of which involve large quantities of steel. Singapore steel scene is quite healthy and well organised, thanks to:

(a) The Workplace Safety and Health Act which came into force in March 2006, and according to which all workplaces in Singapore must carry out risk management; and,
(b) The Singapore Structural Steel Society which offers certification and award schemes and up-dating courses, and provides advisory services to the local steel industry.

As the number of local steel-structure related accidents is small and data on them is scarce, author will make only general comments on critical factors discussed earlier, in the hope that lessons learned and controls developed elsewhere would be applied to advantage for steel.

5.1. Working at height

Author holds that with the relatively recent introduction of many safety procedures and certain new technologies, Singapore construction industry is still coming to terms with the demands made by new regulations and safeguards. Inadequate appreciation of ramifications of WAH, and misperception or misinterpretation of recommendations hinder faster progress.

The Workplace Safety and Health Council (WSHC) Code (2013) spells out clearly when safety harnesses must be given. Under the unique circumstances of steel erection, fall arrest remains the control of choice. Collective solution for all workers by a soft landing would be preferable, but lack of experience has kept Singapore employers away from this, leading them to individual full-body safety harness.

The safety harness is not a stand-alone safeguard, but part of a system which will become functional only if and when a number of other requirements are met, (Krishnamurthy, 2012):

- Proper fit of harness, to avoid injury at the end of the fall;
- Sufficient fall clearance (about 5.5 m), to avoid worker hitting bottom at end of fall;
- Strong enough anchor, to take the impact at end of fall – recommended at 16-22 kN;
- 100% tie-off, with a double lanyard; and,
- Prompt rescue system, to avoid suspension trauma to a fallen and slung person.

Singapore faces the problem that the vast majority of construction workers (80%) are immigrant, leading to enormous difficulties in communication and safety culture, with many of the listed regulatory requirements being misunderstood or ignored.

This potential escalation to further disaster can be remedied (and is being officially tackled) by improved education and training, increased enforcement, and, as author often urges in his talks, closer supervision.

Many findings from OSHA-USA are echoed in Singapore, but direct comparison is not fair. First, the relative size of the countries, with vast difference in problem scope and worker numbers involved, would preclude any useful conclusions. Author observes as follows:

- In USA, safety is worker driven; in Singapore it must be management driven.
- Americans are very independent at a personal level, having a higher risk appetite than Asians, particularly immigrant workers who have a huge stake in their survival.
- American workers know the dangers and may choose to ignore safety measures, but Asian workers may just be unable to adapt fast to tight safety measures in Singapore.

Hence, more and better supervision would be a big help in Singapore because the supervisor is the conduit between the workforce and the management, and the immigrant labourer can at least be watched, warned, and guided by a trained and attentive supervisor on the spot.

5.2. Manual handling and ergonomics

There is considerable lack of attention towards the basic need to check and control manual handling, wrong postures and repetitive motion. Many do not realise that one kg picked up from a bent position will impose about 12 kg on the spine, and hence frequent lifting of heavy loads wrongly can damage the back permanently. The immigrant majority of construction workers have little awareness or motivation to protect themselves from such long-term effects of misuse of their limbs. Supervisors and management too are often ignorant or unmindful.

Thus, although authorities have long been advocating limiting worker loads to 25 kg, very few know about relevant regulations, and fewer still prefer to follow the guidelines (Krishnamurthy, 2012). Other violation of ergonomic norms may occur when workers are assigned long term duties involving abnormal postures or repetitive work. While the problem has not yet surfaced as a major hazard here, elsewhere it has become a top item in workmen's compensation, and proactive education and enforcement may be worthwhile in Singapore.

6. Conclusion

Steel erection can be a very risky operation, unless its hazards are clearly identified and well understood, and good practice is adopted, aided with advancing technology. Singapore is well on the way to improving its record in the hazard controls that are common to steel erection as well to other construction activities. With clearer understanding and better implementation of safeguards as discussed here, aided by closer supervision at site and increased enforcement from the authorities, the current deficiencies should be easily rectified.

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