Certain Safety Considerations for Formwork

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Formwork, the temporary mould and support for fresh concrete until the concrete is strong enough to support its own weight and other construction loads, itself requires a support called ‘falsework’. In many codes, formwork and falsework together are called ‘formwork structure’ or just ‘formwork’ - which last will be the terminology used in this paper.

The problem with formwork is that it is ‘temporary’. In many under-developed and even some developing countries, the word ‘temporary’ is automatically associated with lack of need for planning, design and care, and with neglect of appearance, strength, and safety. As the owner pays only for the finished permanent structure and not the temporary structure, least cost (including cheapest labour and materials, and in the worst case scenario, low compensation for accident and fatality claims) are often the easiest way to cut costs on this ‘non-essential’ item.

In advanced countries however, it is recognised that most accidents and in fact most fatalities and property damage occur during the brief construction stage and not during the long usage phase of a structure. The business case for safety in these countries also has amply demonstrated the wisdom of preventing or mitigating the effects of accidents as against paying for large compensation and work disruption costs due to accidents. This is exactly why hazards present in formwork must be identified, and the risks arising from them must be assessed and controlled.

In this paper, not being sufficiently familiar with Indian practices in regard to formwork safety - except as a lay observer during his visits to India - author will focus on his experience with Singapore practices, in the hope that Indian professionals may make their own comparisons and draw their own lessons for local application.

Basic Safety Requirements

The basic safety requirement is set in the Singapore Workplace Safety and Health Act of 2006 as the responsibility of every employer, as far as is reasonably practicable, to protect every employee from injury and ill-health at the workplace.

This aim of providing a ‘safe place to work’ is achieved by adopting guidelines provided by the Ministry of Manpower and Workplace Safety and Health Council, including the following:

- Risk assessment and control, before work starts [Ref.1].
- Safe Work Procedure for every activity at the workplace which may involve risk.
- Permit to Work for all hazardous activities such as work at height.
- Construction Reg. 2007, Sec. 22(2) reads: “In a worksite, every open side or opening into or through which a person is liable to fall more than 2m, shall be covered or guarded by effective guard-rails, barriers or other equally effective means to prevent fall.”
- Construction Reg. 2007, Sec. 63(2) reads: “Any formwork structure that (a) exceeds 9m in height; (b) consists of any formwork which is supported by shores constructed in 2 or more tiers; or (c) consists of any formwork where the thickness of the slab or beam to be cast in the formwork exceeds 300mm, shall be designed by a PE.”

Figure 1 depicts formwork for a condominium block in Singapore.

Hazards in Formwork

‘Hazards’ are potential dangers. Hazardous activities in formwork design, erection, use and dismantling are as follows:

- Incorrect or incomplete formwork design
- Erecting frames and bracing
- Erecting bearers and joists
- Placing deck and beam formwork
- Moving around on formwork during rebar placement, concreting, and curing
- Dismantling formwork
In erection, use and dismantling phases, most activities involve following common hazards:

- Climbing up to or down from formwork, usually by ladders
- Working at height with unprotected edges on platforms
- Tripping and falling at level
- Falling through gaps and holes in formwork
- Falling from incomplete or badly designed formwork
- Hit by formwork components
- Carrying heavy loads
- Struggling with awkward shapes
- Fitting damaged connections and components
- Handling sharp objects and corrosive materials
- Working in harsh (sunny, cold, wet, windy, dusty, noisy etc.) environments
- Uneven, sloping and cramped work surfaces
- Overloading of formwork

In addition to these, dangers may also arise from inadequate supervision, material flaws etc. To cover all these in a paper would be an onerous task. The author will therefore focus only on the following factors in this paper:

1. Some design considerations,
2. Working safely at height, and,

Some Design Considerations

Factor of safety

India has its own design norms, and they are likely to be world class. Problems may arise during implementation, and in the safety culture that may be prevalent in various enterprises.

Author has seen some excellent formwork in big projects in cities. (Fig. 2.)

But more commonly, especially with formwork for residential and office building floors, a common sight that greets one is a forest of supposedly vertical and straight but actually twisted, bent, de-barked tree branches leaning at all angles some as much as 20 degrees to the vertical, supporting the beam and slab formwork. (Fig. 3.)

Other Asian countries also use natural timber for falsework. In the Far East, bamboo is common, with the advantage that bamboo is straight and nearly uniform in size along its length. In India we use all kinds of timber which are twisted, bent, and non-uniform along their length.

Having just finished an assignment on the formwork code committee in Singapore, author is very conversant with the need for strict and conservative design for formwork and other temporary structures, as already mentioned in the Introduction.

In the past, load factors of 1.5 were commonly used for falsework design. Often wear and tear in use, and poor field conditions of connections and erection encroached into this factor, and in certain cases resulted in accidents involving injuries including fatalities and property damage.
Current Singapore Formwork Code [Ref. 2] stipulates a minimum “Load safety factor” of 2.0 to be applied to all designs by whatever method, and for all testing, so that the designed or tested capacity is at least twice the maximum requirement under the worst combination of loadings.

What is the corresponding design requirement for Indian construction with such timbers?

**Inclined shores**

There is another aspect of such ad-hoc arrangement of shores that raises the question: If formwork has to be approved to satisfy design criteria, how are sloping shores handled?

An inclined member AB at an angle $\theta$ to the vertical subjected to a vertical compressive force $V$ will develop a horizontal component $H$, which would be 18% and 36% of $V$ for angles of 10° and 20°. This horizontal component will tend to increase the angle $\theta$. (Fig. 4.)

Then, how come we have not had all inclined members slide and fall down? That is because the horizontal components have been successfully resisted, as at top they may be nailed to some boards, and at bottom the friction and random projections will usually prevent sliding.

If in a particular case everything is fine when erected, but when wet the friction coefficient vanishes, and/or when the load increases the slide resistance is inadequate, disaster may strike.

Smart people may think that they can cancel out the slope effects by arranging adjacent members AB and A'B' sloping in opposite directions. But there will still be the same horizontal separating force $H$ at the top and bottom, and if the resistance to opening up at top and bottom is not enough, woe be unto the formwork! (Fig. 5.) Of course, someone who knows what is happening can easily take care of this problem by two simple ties at or near AA' and BB' - but this is not much in evidence.

Sloping shores may be the fast and cost-effective way to use available poles without cutting them down to required size. It may also be true that they have worked well for decades, and the permanent structures that emerge from these temporary structures of whatever shape, have been finished beautifully.

The point author is making here is that any structural resistance to failure is not by design, but by chance. Contractors have just been lucky, and professionals have not even considered, let alone provided for the horizontal component. That they survive is because of modifications by trial and error. Potential for failure continues to exist.

Author shows special concern about this sloping shore, because in a court case in which he was involved, he demonstrated that it was exactly such an undesigned inclined strut - although it happened to be a straight steel rod - that might have contributed to the formwork failure.

In this day and age, when India is contributing globally to the cyber era and space effort, engineers should be a little more scientific,
contractors a little more professional, and the owners who pay for all this a little more considerate of essential expenses in what they do, at least in the interests of ultimate structural safety, if not for the sake of appearance.

Working Safely at Height

Working at height has been the most hazardous activity all over the world from time immemorial, and continues to attract the maximum number of accidents and the maximum number of fatalities. There are many ways in which safety may be ensured while working at height [Ref. 3], as follows:

A. Guardrail and toeboard (Fig. 6A)
B. Work restraint, attachment to lifeline (Fig. 6B)
C. Retractable lifeline (Fig. 6C)
D. Auxiliary scaffolding (Fig. 6D)
E. Safety net below (Fig. 6E)
F. Safety harness (Fig. 6F)

In providing risk control against falling from height, collective control for all workers (A, D, or E) is better than individual control (B, C, or F); fall prevention (A, B, C, or D) is better than ‘fall arrest’ (meaning termination of a fall before hitting the base) to reduce the effects of fall impact after one has fallen (E or F).

In terms of hierarchy of safety then, A or D is the best, and F is the worst. The full-body harness (E) also comes with a number of other auxiliary requirements for effective deployment, including proper fit, sufficient fall distance, strong anchorage, and prompt rescue. [Ref. 4]

All these requirements are mandatory according to the Singapore Code of Practice for Working Safely at Height. [Ref. 5]

Manual Handling of Heavy Loads

In formwork - in common with most construction and factory activities - regularly carrying loads larger than about 25kg is an insidious risk, not sudden and dramatic like falling from height, but slowly causing musculoskeletal disorder (MSD) and escalating to permanent damage of the spine over a period of about an year.

Musculoskeletal disorders (MSD) are among the most common worker complaints in the West. In Asia and other under-developed countries however, it is not reported as much or taken as seriously, possibly because natives of these countries are more pain tolerant than citizens of the more developed countries, or because management will not do anything about it, or both. It may also be that both management and workforce do not realise that what starts as a little persistent discomfort can escalate into a permanent painful problem. In any case,
most do not recognise it as a problem, and even workers who experience it resign themselves to it as their lot in life, enduring lifelong discomfort if not suffering as a consequence.

So workers regularly carry heavy loads over long distances or keep doing repetitive physical activity; supervisors and bosses let them, expect it from them, and even order them to do so. The reason is simple: Labourers (by very name) have always been doing it. If they don’t, who will? They are paid for it, aren’t they? We are not forcing them against their will!

This topic comes under ‘Ergonomics’ the science of work posture. Author’s recent paper [Ref.6] covers many aspects of construction ergonomics.

Why is this important? What do we do about it? The answers are not simple. It becomes a matter of safety culture in a society, the concern of the more powerful groups of people for the weaker and less fortunate sections of society. Author hopes that once he explains his stand, professionals will rethink about how we are using or abusing our fellow human beings.

Many do not know that each kilogram of weight we bend and pick up and carry in front of our body develops a force of about 12kg on our low back muscle and bone. (Fig. 7.)

So a 50kg cement bag will put a load of 600kg on the back of a worker. An average Asian’s back is designed by nature to carry a maximum force of about half that (after allowing for the force imposed by our own torso weight), which means that nobody should be carrying more than 25kg on a regular basis.

Australia, where the average person would be larger in size and stronger than Asians, legislated a few years ago that no worker should carry more than 20kg routinely. UK had done likewise a few years earlier when their workers complained about 40kg hollow concrete blocks.

Singapore recommends a limit of 25kg for worker loads.

Author is not sure about any limitations mandated in India, but purely on humanitarian grounds he appeals to employers not to burden their workers with more than 25kg in their normal work.

If any activity requires lifting and movement of larger loads, mechanical aids like trolleys may be provided for moving the heavier weights around; two or more workers may be deployed to lift them on to trolleys, or carry them for short distances. Even the simple expedient of rotating the task between different workers would reduce exposure to risk to more tolerable levels. Proper procedure to lift heavy loads by squatting and getting up with the load is also easily learnt.

Needless to say, this analysis and recommendations for this particular hazard, apply to white collar non-construction workers too, such as office and lab assistants.

Conclusion

Author has highlighted a few of the hazards in formwork design, erection, use and dismantling with which he has personal experience in Singapore. Not all the hazards may be perceived as equally critical in India. But in a nation committed to democracy and concern for all citizens, the risks described and the solutions proffered by the author may serve to trigger improvement of overall safety culture.

References

3. Figures 5A to 5E sourced from “Falls from height during the floor slab formwork of buildings: Current situation in Spain”, by Jose M. Adam, Francisco J. Pallarés, and Pedro A. Calderón, Copyright 2009 National Safety Council and Elsevier Ltd.