## 5. References


- Ministry of Manpower, Singapore, "Workplace Safety and Health Risk Management: Risk Assessment Guidelines" 2006
- Queensland Government, "Tilt-up and Pre-cast Construction Code of Practice", 2003
- Worksafe Victoria, "Checklist for the Manufacture of Pre-cast Concrete Panels", 2002
- WorkSafe Victoria, "Industry Standard on Precast and Tilt-up Concrete for Building" http://www.workcover.vic.gov.au/construction
- U.S. Dept of Labor, Occupational Safety & Health Administration, "Hazards Associated with Strand Restraint Devices in Manufacturing Prestressed Concrete Beams", 2004 http://www.osha.gov/dts/shib/shib060204.html
- U.S. Dept of Labor, Occupational Safety & Health Administration, "Precast Concrete Panels - Hazardous Storage", 2004 http://www.osha.gov/dts/shib/shib021004.html


## 6. Useful Websites

- U.S. Department of Labor, Occupational Safety & Health Administration http://www.osha.gov
- The Victorian Workcover Authority http://www.workcover.vic.gov.au

*The information in this TA is intended for general use and the information presented is non-exhaustive. It should be use in conjunction with the Workplace Safety and Health Act and is not a definitive guide to the law.*

*For enquiries, please email us at **enquiries@wsh.sg***

ProBE

# Programme-Based Engagement

Technical Advisory for Concrete Pre-cast Industry

WSHAC

Workplace Safety and Health Advisory Committee

**This technical advisory (TA) is meant for workers at concrete pre-cast yards where repetitive or complex pre-cast concrete components such as pre-cast slabs/planks, modular units and façade bay windows are made in large quantities.**

**There are many hazards associated with the production of pre-cast concrete components. This TA is intended to provide you with an awareness of these hazards, how to prevent them from occurring and how to properly store pre-cast components.**

## 1. Background

Over the last six years, there were six fatal accidents that occurred in pre-cast manufacturing yards. The number of injury-related accidents involving the pre-cast industry also increased by three-fold from 37 cases in 2005 to 108 cases in 2006.

Of the six fatal accidents, three cases were due to pre-cast components collapsing onto workers while they were being lifted by lifting equipment such as gantry cranes, overheard travelling cranes and mobile crawler cranes.

Injury-related accidents involving the pre-cast industry were mainly due to workers stepping on, knocking into or being caught in or between objects. Others were caused by workers being struck by falling objects and falls.



## 2. Accident Case Studies on Systemic Weakness Involving the Pre-cast Industry

### Case Study 1

**Worker Crushed to Death by Falling Pre-cast Concrete Panel**

**The Incident**

A worker was crushed to death by a falling pre-cast concrete panel while the panel was being turned over and lowered onto the ground using an overhead travelling crane.

**Investigation Findings**

The safety catch on the hooks of the set of chain slings was defective. Because of this, the lifting lugs of the panel slipped out from the hooks during the lifting, causing the pre-cast concrete panel to fall and crush the worker who was performing the lifting operation. No lifting supervisor was appointed to supervise the lifting operation at the said pre-cast yard at the time of the accident.

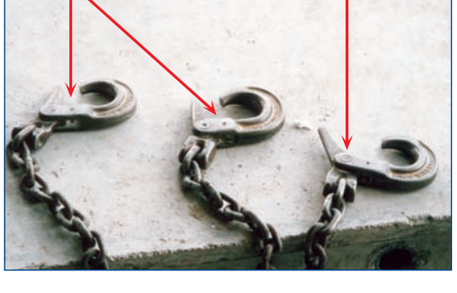
Position where worker was partially pinned down by pre-cast concrete panel and protruding rebars

**Weaknesses**

- There was no Risk Assessment performed to identify and reduce the hazards of panel turning over during lifting operations.
- There were no safe work procedures implemented for such operations.
- There was no regular maintenance plan for equipment at the pre-cast yard.
- There was no safety inspection programme to identify hazardous conditions and unsafe acts at the pre-cast yard.

The safety catch of these two hooks were found missing

The spring of this safety catch was found to be broken



## Case Study 2
### Worker Crushed to Death by a Pre-cast Concrete U-drain Section

**The Incident**

A worker was crushed by a pre-cast concrete U-drain section which fell from the top of a 3.6m high stack of U-drain sections. The accident occurred when the chain slings suspended from the crawler crane got entangled with a protruding rebar of the U-drain section that had just been placed on top of the stack of U-drain sections. The chain slings of the crane subsequently dragged the U-drain section along with it, causing it to fall and crush the worker below.

**Investigation Findings**

The worker was not trained in rigging and signalling work, yet he had been assigned to unrig the U-drain sections after they had been placed onto the stack of U-drains. No proper access was provided to allow him to get onto the U-drain stack to perform the unrigging work safely. Furthermore, no lifting supervisor had been appointed to supervise the lifting operation at the time of the accident.

**Weaknesses**

- There was no Risk Assessment performed to identify and reduce the hazards associated with the lifting and stacking of u-drains.
- There were no safe work procedures implemented for such operations.
- The deceased had not been trained in lifting operations.


## Case Study 3
### Worker Crushed to Death by Moving Gantry Crane

**The Incident**

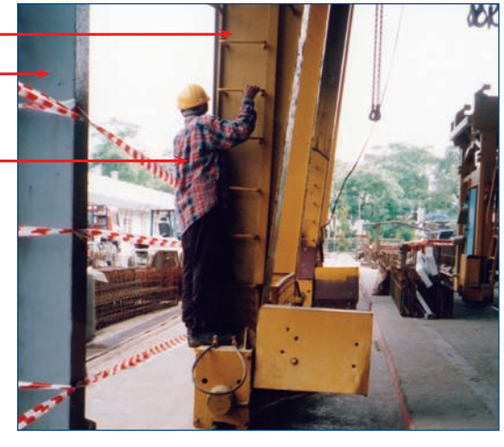
A worker took a ride on a moving gantry crane. Unfortunately, he was caught in between the moving gantry crane and a building column next to the wheel track of the crane and was crushed to death.

**Investigation Findings**

The crane siren had been wailing loudly when the worker unexpectedly boarded the carriage of the crane for the ride. The worker was not aware of the dangers associated with the gantry crane. The safety loop installed had also failed to prevent him from boarding the crane from the side.

**Weaknesses**

- There was no Risk Assessment carried out to identify and reduce the hazards associated with the gantry crane operations.
- There was no safety training and promotion.
- There was no safety inspection to verify safe work practices.
- There were no in-house safety rules and regulations to ensure that all personel know their safety obligations and responsibilities.



## Case Study 4
### Worker Crushed to Death in Between Two Trailers

**The Incident**

A worker was mixing cement mortar to touch up the concrete panels pre-loaded onto a stationary trailer. He was using another trailer parked behind as a table top to mix the cement mortar. At the same time, a driver was trying to connect his prime mover to the trailer pre-loaded with the concrete panels. The trailer lurched backward during the coupling process and sandwiched the worker in between the two trailers.

**Investigation Findings**

The driver did not notice the worker standing behind while connecting his prime mover to the trailer. His vision was blocked by the stacked concrete panels on the trailer. Further more, the trailer's brakes were faulty, causing the trailer to lurch backwards instead of remaining stationary.

**Weaknesses**

- There was no Risk Assessment performed to identify and reduce the hazards associated with the coupling of prime movers to trailers .
- There was no designated loading and unloading bay for the trailers.
- There were no safe work procedures such as prohibitions against touch up work at trailer areas, or a requirement for wooden chokes for parked trailers.
- There were no traffic controllers or signallers to assist trailer drivers.

Pre-loaded trailer which lurched backwards crushing the worker standing behind

## Case Study 5
### Worker's Fingers Amputated by Machinery

**The Incident**

A worker was operating a batching plant to mix a batch of cement products when he noticed that one of the hopper valves was open. Without switching off the valve pneumatic supply, he went to the side opening of the hopper and attempted to manually pull the valve close with his fingers. The valve suddenly closed and trapped his left middle and ring fingers in the process. When he panicked and tried to pull his hand out, the tips of his trapped fingers were amputated.

**Investigation Findings**

There was no regular maintenance plan implemented for equipment at the pre-cast yard. The pneumatic valve was not serviced and there was no guarding over the side opening to prevent contact with the moving parts of the valve. There were no safe work procedures or "Lock Out -Tag Out" procedures to handle malfunctioning valves.

**Weaknesses**

- There was no Risk Assessment performed to identify the dangers of workplace operations involving the said machine.
- There was no "Lock Out -Tag Out" procedure for minor machinery failures.
- There was no safety training and safety promotion on work procedures involving the said machine.
- There was no guarding over the side opening of the hopper, to prevent contact with moving parts.
- There was no regular maintenance plan for concrete batching equipment at the pre-cast yard.

Position where worker's fingers were amputated while attempting to manually shut an open hopper valve

## 3. Common Hazards at Concrete Pre-cast Yards

The following are common hazards usually found in concrete pre-cast yards:

- Struck by pre-cast concrete components during lifting operations due to:
  - Failure of lifting machines and lifting equipment
  - Defective lifting gears such as chain slings with defective safety catches
  - Overloading of the weakest link within the lifting system
  - Untrained crane/equipment operators
  - Improper rigging or signalling by untrained riggers or signallers
  - Lack of supervision by lifting supervisors
  - Lack of safe lifting procedures
  - Bad design of lifting lug/pre-cast component inserts
  - Lack of details on the weights, lifting locations, bracing inserts/fixings and concrete strength
  - Lack of information on rigging, lifting, transport and storage of the pre-cast panels
  - Entanglement of slings with adjacent materials/objects
- Entrapment in between suspended pre-cast components and other fixed structures or other materials during the lifting of pre-cast components
- Struck by falling pre-cast components during storage due to:
  - Lack of storage space planning or safe storage procedures, resulting in unstable/haphazard storage
  - Inadequate supports resulting in unstable pre-cast panels
  - Overloading of poorly designed supporting structures
  - Insufficient ground support strength
  - Pre-cast components exceeding a stable height
  - Lack of in-house enforcement of safe storage procedures
- Crushed by pre-cast components during loading and unloading from trailers due to inadequate supporting structures on trailers
- Accidents resulting from reversing trailers loaded with pre-cast components due to lack of safe work procedures, unobstructed traffic lanes and proper traffic management
- Struck by wire rope cables when the wire rope snaps during pre-stressing operations for pre-stress concrete beams or columns due to restraint devices failing during the tensioning process
- Electrocuted by defective electrical equipment due to not having any effective electrical shock prevention systems in place
- Fire and explosions due to defective gas cutting or welding equipment
- Falling from heights due to improper access or work platforms for rigging/unrigging of pre-cast components
- Trips and falls due to poor housekeeping and insufficient lighting
- Point pressure or piercing dangers due to protruding rebars from pre-cast panels
- Fingers being crushed due to unguarded rebar cutting or bending machines or during manual handling of materials
- Noise-induced deafness from noise generated by rebar cutting and trimming
- Chemical dangers caused by improper handling of form oil or wet concrete

# 4. Risk Management

Employers and contractors are required to reduce or eliminate workplace risks under the Workplace Safety and Health (Risk Management) Regulations. The first thing they have to do is assess workplace risks and then take steps to remove or reduce them in order to protect workers' safety and health.

Risk Assessment and Management should cover all work activities at the yards where pre-cast components are made. These include pre-stressed beams/columns production, casting and finishing processes, rebar yards and storage yards, handling and transportation as well as the maintenance of pre-cast concrete equipment and facilities like cranes and batching plants.

## 4.1 Carrying out Risk Assessment

Carry out an assessment of the risks in the pre-cast yard with everyone, including the contractors' representatives and all workers.

**Step 1: Identify hazards**

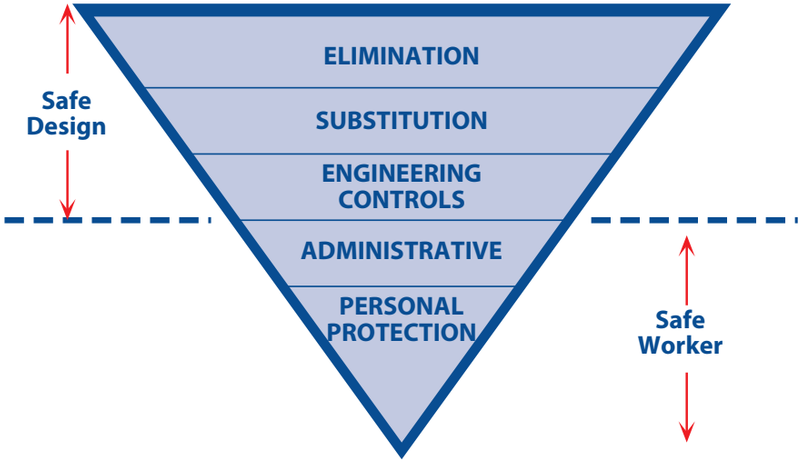
Employers must have a plan in place to identify dangers and risks and deal with them. One common hazard is the entanglement of pre-cast components such as U-drain sections with chain slings while being stored at the yards. Other hazards include riggers falling while unrigging chain slings from the U-drain sections, workers being pierced by protruding rebars or being hit by a U-drain section falling from an unstable stack.

**Step 2: Assess the level of risks involved**

Find out how serious the risks are and determine the likelihood of it happening, given the existing control measures in place.

**Step 3: Adopt the most appropriate risk control measure**

The following shows the hierarchy of risk control measures you can adopt:




1. Eliminate the hazard

   This could involve the pre-cast yard adopting the "Just-In-Time" (JIT) manufacturing process to avoid storing large quantities of pre-cast sections whenever possible.
   This would then completely remove all hazards associated with the storage of such pre-cast components in the yards itself.

2. Substitute with a safer method

   If it is not possible to practise "JIT" production or reduce the large stockpile of pre-cast components, you may adopt a safer storage method to prevent the components from collapsing.

3. Engineering control

   Make a rack so the pre-cast sections are always stored in a safe and stable manner. This will prevent the pre-cast sections from collapsing. Also provide a suitably designed mobile work platform for workers to safely access the storage rack.

4. Administrative control

   Have safe storage procedures to reduce the risk associated with the storage of pre-cast components in the yard.

5. Personal protection

   The use of personal protective equipment (PPE) should be a last resort in the heirachy of risk control measures.

***For more details on Risk Assessment, please refer to the MOM guidelines at http://www.mom.gov.sg/OSHD***

## 4.2 Handling and Storage

Methods of handling and storing pre-cast components depend on the type of pre-cast components involved. All methods should ensure that the pre-cast components are safely transferred from the mould to the storage area and can be easily and safely removed when needed. At no time should pre-cast components be unsupported or unsecured unless they are inherently stable.

### Handling Pre-cast Components Using Cranes and Lifting Gears

Which crane to use, where to use it and how to park it are important considerations in ensuring the safe handling of pre-cast components. Using mobile cranes for lifting pre-cast components close to their maximum capacity increases the likelihood of the crane overturning, particularly if the ground is soft or not level.

Conduct a risk assessment to remove or reduce as many risks as possible with any pre-cast lift. Start by preparing a set of safe lifting procedures/plans before any lifting is carried out.

The plan should take into consideration the following details:

- The number and type of crane to be used and its capacity
- Where the crane is set up
- Where the pre-cast components are to be lifted from and to, with the operating radius of the crane shown
- Areas of obstacles that may be in the slewing path
- Areas where the crane cannot be set up, like on trenches and soft ground
- The type and set up of lifting gear to be used
- Responsibilities for rigging and signalling crew

The crane capacity must be adequate for the largest and heaviest pre-cast component to be lifted. The load to be lifted should include the pre-cast component weight, lifting gear weight and any dynamic factors like wind load. In some cranes, the hook block weight should also be added unless the load chart specifies otherwise.

The ground condition and slope will affect the stability of crane significantly. Soft ground and ground depressions increases the risk of the crane overturning. If you are doubtful of the ground strength, ask the geotechnical or soil engineer to verify the ground's bearing capacity, especially when:

- The ground has not been compacted
- The ground is muddy or wet
- The crane and the load are particularly heavy
- There are underground services or cavities

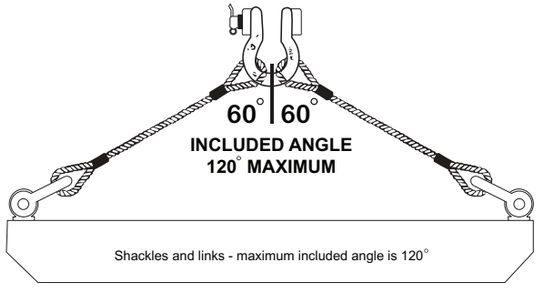
Where the crane is set up on outriggers, please ensure the following:

- Adequate timbers or steel plates are correctly placed under the outrigger pads
- The crane is not set up next to excavations or over ground cavities that are covered
- The crane is set up on level ground

Where lifting gear is involved, please ensure the following:

- The lifting gear is tagged and all relevant information listed. For example, in the case of a chain sling, the chain's grade, the safe working load, the manufacturer, the chain's size must be lifted
- There are operable safety catches for the lifting hooks
- The shackles are prevented from unscrewing
- The lifting eyes and inserts are compatible
- The lifting slings are not damaged by excessive wear, damaged strands, cracks, deformation or severe corrosion
- The sling is appropriate for loads being lifted, including adequate capacity and protection from sharp edges

Single, double and four-legged slings are commonly used in the lifting of pre-cast components. In selecting the sling capacity, include in your calculations, the increased force due to inclination of slings and the change of direction at reeving points. The included angle between the slings at reeving points should not exceed 120 degrees.




When lifting is done with fixed length multi-legged slings, any two legs of the slings must be capable of supporting the total load of the pre-cast component.

The rigging system and lifting lug configuration should be designed and detailed on the shop drawing. The rigging system to be used and the method of handling of each type of pre-cast components should be set out in the appropriate work method statement. The minimum concrete strength to be achieved before the pre-cast component is allowed to be removed from the mould and transferred to storage should be specified in the shop drawing.

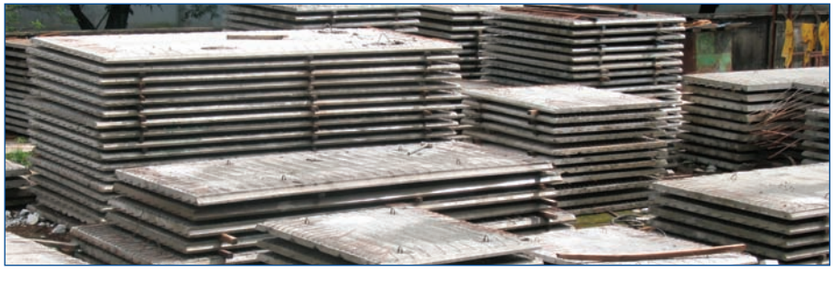
In addition:

- Operators must be qualified/ trained.
- Operators must carry out daily inspections on the crane components - hoist rope, hook block, slings and lifting gears, limit switches and various brakes.
- Authorised examiners should examine and test the cranes in accordance with statutory requirements.
- Lifting supervisors must manage pre-cast component operations and implement safe lifting procedures.
- A qualified person must control the design and construction of lifting lugs.
- A qualified person must detail in work plans the pre-cast components' weights, lifting locations, rigging methods and concrete strengths.

## Storing Pre-cast Components

### Storage

- The storage area should be large enough for pre-cast components to be stored properly.
- There must be enough room for lifting equipment and for vehicles to access the components easily.
- The area should be reasonably level and hard-surfaced with adequate drainage.
- Do not store pre-cast components directly on the ground. Generally, you should provide two discrete support points unless design requirements specifies otherwise.
- In all cases, use timber supports raised above the ground or dedicated racking systems.
- Store pre-cast components in such a manner that each component supports only its own weight without any load being imposed by other components.
- Where components are stacked horizontally on top of each other, the following should be observed:
  - Ensure that support points are directly above each other unless a competent person has specifically designed otherwise.
  - Avoid stacking components too high so that the lower level and ground components can support the loads above them and the stack remains stable.
  - Ensure that the stack height is not higher than twice a component's width unless specifically documented otherwise.
  - Make provisions to reduce the risks of vehicles or other components accidentally hitting against each other.
- Cover points of contact between components and supports with protective material to prevent breakage if necessary.



**Storage Systems**

- If the storage systems for the pre-cast components are unstable, you must redesign it to withstand the loads and forces applied to it. You should:
  - Take into account wind loads, construction loads and impact loads generated while pre-cast components are replaced and removed. This includes vehicles accidentally colliding into them.
  - Ensure storage systems are strong and reliable. This is so that if one part is weakened, it does not result in the whole system breaking down. E.g. if one pre-cast component falls, it does not create a domino falling effect of other components.
  - Construct storage systems according to a qualified engineer's design. The engineer should be suitably experienced in the field of pre-cast concrete construction.
- Design and construct racking systems for vertically stored pre-cast wall panels in the following ways:
  - Provide at least two restraint points so that the panel is stable under the load. The top restraint should be above the mid-height or centre of gravity of the panel.
  - Design the restraint system to withstand the loads as well as loads generated when the panel is up to 5 degrees off vertical.
  - Where necessary, make provision in the design of the restraint system for panels such that the panels are firmly held in the racking system.
- Design finger rack storage systems with sufficient strength for the safe storage of concrete components and use them according to instructions. You can also improve a finger rack's stability in the following ways:
  - Increase the diameter and/or strength of the rebar pins such that they are less subject to permanent bending during use.
  - Place timber bearers under each and every panel in at least 2 locations (each within two feet of each end of the wall panels) to prevent twisting motions that could cause the panel to tip and/or cause the wedges to come loose.
  - Include specifications such as the size, thickness and the length of the steel horizontal restraining members and rigidly attach them to the rack.
  - Secure the wedges to the rebar pin to prevent them from falling out.
  - Include additional tier racks near the top of the panels to provide additional support.
  - Design the rebar pins so that they are of consistent size and shape to endure proper placement during installation, and that they are also restrained from horizontal displacement once installed. One way of restraining movement would be to install a clevis pin.
  - Include additional holes in the rack to minimise the movement of the panels between the rebar pins and the number and sizes of the wooden wedges needed.
  - Design the system and implement procedures such that if one panel tips over, it does not cause the adjacent panel to tip over.
  - Refrain from performing patching/finishing work on the panels while they are stored in the finger rack.
  - Mark the finger rack clearly to indicate design capacities (e.g. height, length and weight of the panels).
  - Establish, communicate, and enforce proper storage procedures.
  - Ensure a professional engineer reviews and provides specific requirements for the storage system and storage procedures of the panels.
- Design and construct single-sided, or double-sided A frames used to store wall panels, in the following ways:
  - Design the frame and its supports such that it remains stable and can withstand the forces mentioned earlier.
  - Ensure that panels remain stable in the frame when they are not restrained. The slope of the panels should be such that the panel will not tip out of the frame.
  - Design the frame and its supports to accommodate uneven loading of panels. Clearly show on the frame the limitations for uneven loading.

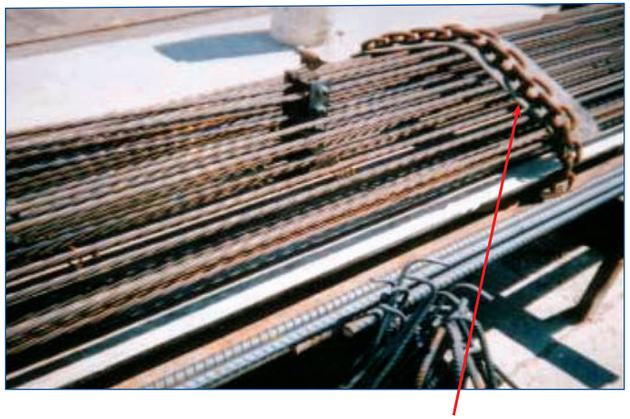
## 4.3 Safety Control Measures to be Taken in Pre-stress Concrete Component Construction

During the manufacture of pre-stressed concrete beams/columns, tension the wire ropes to a tensile load of possibly several hundreds kilo-newtons as required in the client's specification. This is necessary because highly tensioned wire ropes possess a great store of potential energy.

Sometimes wire ropes snap due to manufacturing defects or damage. At other times, wire ropes become ineffective because the clevises that hold them down fail from wear and tear under high tension. In either situation, the wire ropes could be accidentally released and injure the workers in the area.

Here are some possible control measures to reduce the risks of the tensioning process:

- Locate the clevises (restraint devices) to a zone further away from the wire ropes area.
- Install several restraint devices along the casting bed. This is so that if one rope snaps or a clevis fails, the others will still prevent the wire ropes from being released.
- Use adequately designed clevises that can withstand the required tensile load.
- Provide protective shields for workers to protect them from being hit by flying strands of rope.
- Set up a prohibition zone during the tensioning process.



Restraint device installed to prevent cables from releasing in the event of clevis failure during the tension process.

## 4.4 Responsibility for Managing the Risks

**Occupiers and Employers**

- Workplace occupiers are responsible for providing a safe workplace. This includes ensuring that there is an appropriate traffic management system in place to prevent accidents involving vehicles/lifting equipment and workers.
- Workplace occupiers are responsible for providing a safe means of storage for the pre-cast components when such storage is required.
- Employers are responsible for providing an effective management and control system for the work processes and operation of equipment.
- Employers are responsible for providing equipment with adequate safety. This includes getting the appropriate tools for work.
- Employers are responsible for the training and certification of pre-cast yard workers in the work processes and Safe Work Procedures (SWPs) before they are allowed to carry out the work.
- Employers are responsible for the maintenance and inspection of equipment at regular intervals to ensure safe and efficient operations.

**Workers**

- Pre-cast yard workers are responsible for following the appropriate SWPs when carrying out their work.
- Workers are responsible for using the safety features of the equipment they are operating where available. They are not to override or bypass any safety devices, nor overload any equipment that they are operating.