Chubb Construction Risk Engineering

Tower Cranes Resource Guide

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Index:

Purpose and Summary:

The purpose of this guide is to heighten our clients' awareness regarding the importance of tower crane operations and safety. Addressing safety measures proactively during the pre-construction phase, operational phase, and the dismantling phase will help ensure that appropriate safety aspects, which include identification of potential exposures along with determination of necessary controls to mitigate those exposures, are addressed in advance.

Tower cranes are the life blood of any major building project; they can also be one of the deadliest pieces of equipment associated with the project, if not utilized properly.

The safe operation and execution of crane-related activities requires a collaborative effort involving skilled craft labor and knowledgeable management supervision. Failure to successfully integrate this collaborative involvement can negatively impact the safety of workers and the general public as well as have financial implications to the overall project should a serious crane-related failure occur.

- It is the responsibility of management to ensure that workers engaged in tower crane operations involved in erection, jumping, dismantling, operating, rigging, and hoisting are trained and qualified in both safety and operational procedures
- Tower crane operators must have the training and qualifications such as jurisdictional licensing and/or certification from an accredited crane testing organization to operate the specific type of crane they are assigned to
- Personnel involved in the rigging and handling of the loads must have the necessary qualification and training in the principles of operation, ability to establish weights, distance, clearances, and measurements, capable of selecting and inspecting rigging equipment suitable for the loads to be lifted, determining center of gravity of the load being hoisted, and be capable of directing the movement of the crane and load to ensure the safety and well-being of all personnel

Introduction:

With the growing number of construction projects across the United States tower cranes have been a core component of constructing major building structures sometimes utilizing multiple tower cranes to facilitate a project.

Over the past few years, tower crane-related accidents have occurred in major cities around the country causing fatalities and property damage.

Potential causes of tower crane accidents vary and could involve:

- **Improper installation of tower crane components**
- **Utilizing incompatible components**
- **Exceeding crane rated capacity**
- **Excessive wind**
- **Rigging equipment failure such as, but not limited to, wire rope failure or fatigue**
- **Improper selection of rigging equipment**
- **Failure to determine the center of gravity of the hoisted load**
- **Ground condition failures**
- **Buildup of ice on boom sections**
- **Failure of the concrete foundation base and/or anchor bolts**
- **Structural damage to the boom sections**
- **Hoisted loads coming into contact with the boom sheave**
- **Contact with overhead power lines**
- **Modifications of crane components without manufacturer approval**
- **Crane operator qualification and qualification/experience of riggers**

In 2019, a deadly accident occurred on the west coast during the dismantling of a tower crane. In this incident, the tower crane had been partially dismantled with the jib sections and counterweights already removed. Crews were preparing to remove the turn table and cab, which were on top of the tower/mast sections, when the tower section fell. Following an extensive investigation of the incident, citations were issued resulting from the alleged pre-mature removal of pins securing sections of the tower/mast sections together ahead of the dismantling of the turn table and crane.

- Pre-mature removal of the tower section pins/bolts that secured the tower sections to one another apparently weakened the tower. With some of the pins removed, the weakened tower was vulnerable to the reported 45 mph wind speeds; which allegedly caused the tower to fall.
- The practice of loosening or removing pins/bolts that secure the tower/mast sections in expectation of dismantling the crane is not an uncommon practice as noted by crane safety specialists; the purpose being to expedite the disassembly of the crane. However, it is a practice that is not recommended by crane manufacturers. Owners and CM/GC should be cognizant of this potential practice and address this issue/concern with the appropriate contractors in advance.

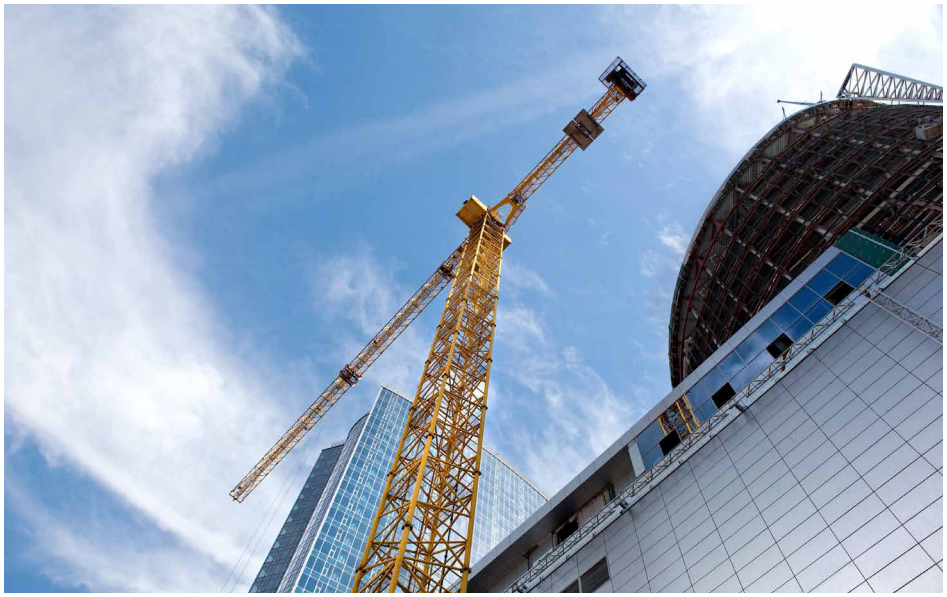
What is a Tower Crane?

Typically, tower cranes are erected after the completion of the foundation and utilized to construct the buildings' skeleton. These cranes hoist the structural steel columns and beams for mid- and high-rise commercial structures, reinforced steel, form work for concrete towers, and large mechanical equipment such as emergency generators, air handling units, and cooling towers needed to operate these structures.

Supported by large robust reinforced concrete footings/pads, typically at the base of the buildings foundation, the crane's steel tower or mast sections are assembled and stacked vertically as the building rises in height. At the top of the tower sections sits the crane's turn table and cab; where the crane operator positions himself/herself to safely lift the loads or equipment, along with cranes compliment of counter weights, wire rope and boom sections. Depending on the height of the structure, the tower/mast sections can be free standing up to an approved height, or the sections are secured back to the building structure with collars/ties at pre-determined heights. This is to ensure the stability of the tower section and crane.

Although there are variations of tower cranes, they typically fall into the category of Luffing Jib or Trolley Jib (Hammer Head) types.

- Luffing Jibs (also referred to as Kangaroo Cranes), have booms that luff or pivot/move up or down in similar fashion to mobile cranes
- Trolley Jib cranes have horizontal sections equipped with a trolley assembly that positions the load along the length of the jib section



Depending on the model type, size, counter weights, and configuration of the crane, these cranes have maximum rated load capacities determined by the manufacturer. Typically the longer the boom length and greater the radius, the rated capacity is lowered or reduced.

Tower cranes can be erected on construction sites to be free standing, self-climbers or interior climbers.

- Free standing tower cranes have a maximum unsupported height that the tower/mast sections can raise before support bracing must be in place. Typically, the maximum unsupported height is no greater than 265 feet. Confirmation regarding the maximum unsupported height of a free standing crane tower/mast sections must be obtained by crane manufacturer and/or licensed professional engineer qualified in crane design.
- Self-climbing tower cranes are utilized to facilitate the construction of high-rise structures and typically situated at the exterior of the building. The erection of this type of crane requires the crane to jump or increase the height of the tower sections as the building increases in height. Self-climbing cranes "jump" themselves by inserting tower sections on top of one another until the crane has reached the necessary height to erect the structure.
  - Typically, hydraulics lift the crane's cab and components while the crane is hoisting additional tower sections and positioning them between the created void to increase the height of the tower.
  - To support the tower, ties or collars attached to the tower/mast section are then secured to the building structure at intervals pre-determined by the engineer of record and as noted on the approved crane erection drawings.
  - Once the structure has topped out and the tower crane has completed its work, the crane dismantles itself by removing the individual tower sections and proceeds to "climb itself down."
- Interior climbing cranes are erected within the body of the building structure and rises as the building increases in height. The location of the crane could be in a section of the building floor plate or within a vertical shaft. Unlike an exterior self-climbing crane, the interior crane will not add additional tower sections as it rises but rather will hydraulically raise itself, typically every 4 floors in height.
  - Once the crane has been repositioned, the void in the floor plate is filled and the area recaptured to complete the work in that area.
  - Unlike an exterior self-climbing crane, the interior crane requires a different method of dismantling. Typically, dismantling requires the utilization of a derrick, positioned at the top of the structure to dismantle the turn table, counterweights, cab and boom sections.

Crane and hoisting-related activities are a dangerous undertaking that come with safety exposures and concerns. Structure failures related to the tower cranes base, tower/mast sections, ties, turn table, counter weight, cab components or boom sections can have catastrophic results should a structural failure occur. This is amplified in densely populated areas where these pieces of equipment often operate.

Rigging failures during hoisting operations add additional safety concerns and exposures that all involved must be cognizant of and prepared to proactively address.

Another element inherent with crane-related operations that must be understood and addressed has to do with weather. In particular, awareness and understanding the impact that wind plays in crane operations is imperative. The installation design of the tower crane must take into account wind speeds to ensure the tower crane can safely sustain storm wind forces that can be generated.

Proactive Safety Measures and Considerations:

The success of any endeavor undertaken, most often involves carefully and thoughtfully planning each aspect associated with the task, identifying the potential exposures or obstacles' that may be encountered, followed by identifying the controls that should be implemented to eliminate and/or mitigate those exposures.

Plan the work and execute the plan.

- All tower crane-related operations should begin with the engagement and procurement of a licensed professional engineer, specializing in crane operations. Detailed engineered plan/drawings that include, but not limited to:
  - Logistics and location of the crane positioning
  - Review of ground conditions to ensure a stable base
  - Engineering of the crane base foundation and anchor bolts
  - Maximum free standing height of the tower/mast sections
  - Determination and identification of collar/tie locations to be secured to the structure
  - Engineering review and confirmation that the building can safely sustain the forces/loads of the crane that may be transmitted to the structure by the tie-ins
  - Wind action plan addressing in-service, climbing, and out-of-service conditions and grounding requirements
  - Identification of the equipment proposed to be used, including all machines proposed to be used in the erection or dismantling
  - A detailed identification of the assemblies and components required for the erection and dismantling of the equipment
  - A weight list of all assemblies and components proposed to be lifted (components should be clearly marked with their weights painted on the assembly or stamped on metal tags attached to the assembly) and the center of gravity of all components located and shown
  - The plan should also identify the crane manufacturer, model number and boom length as well as listing radius's and rated maximum capacity for each radius[1]
- Tower cranes must be selected to best accommodate the project. In selecting the most appropriate type, size and number of tower cranes for a particular application, the characteristics of the various machines available must be considered against the requirements imposed by the loads to be handled and the surroundings in which the crane will operate.

Factors that must be considered include the weight, dimensions, and lift radius of the heaviest and largest loads.

Additional factors include: the type and size of base for the crane, the climbing arrangement, jib lengths availability, available head room between the maximum height position of the hook and the upper most work level, the area that has to be covered, the hoist speeds, the length of cable the hoist drum carries, the number of parts of line that crane needs to do the required hoisting, and the capacity of the crane to ensure the necessary safety factor to lift the heaviest load is maintained.[2]

- Tower crane installation design/ engineering must incorporate consideration regarding positioning of the crane that allows adequate space for layout of the cranes components before erection as well as positioning of the mobile assist crane needed for the initial erection.

Once the tower crane is erected, the crane must have the necessary clearance to freely weathervane 360 degrees without obstruction to jib slewing. If multiple cranes will be positioned on-site, attention must be given to ensure sufficient clearance to avoid booms from coming into contact with one another. When in position, the crane must provide the necessary hook coverage and adequate load capacity at all required points. Consideration must be given regarding access and clearance to allow for the mobile assist crane to position itself during the dismantling of the tower crane.[3]

- Transporting of tower crane components to the project site requires thoughtful consideration and planning. Considering the number of components required to assemble a tower crane, this aspect of the project will require heavy-hauling-services which will add substantial cost that must be incorporated into the budget.

In addition, consideration must be given regarding planning travel routes to the construction site. Transportation agencies may have restrictions regarding maximum allowable truck weights traveling on their roadways or bridges as well as travel times permissible for transport. The transportation of tower crane components requires precise coordination to ensure components arrive on-site in the order necessary to ensure a smooth and orderly assembly and erection of the tower crane.

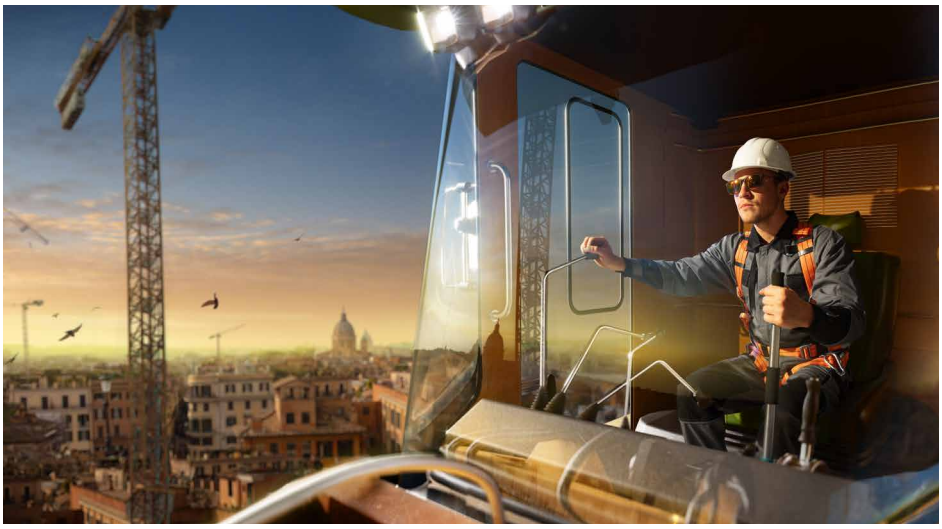
- When renting tower cranes, ensure you rent only from reputable firms and obtain verification and documentation that the tower crane and associated components are in good condition.

- Retain the services of a professional engineer to design the base of the tower crane. Engineering drawings and calculations must address ground conditions, size of the concrete pad and reinforced steel, concrete design strength and size of anchor bolts required that will safely support the tower/mast section along with the tower crane and its components.

Once erected, procedures should be in place to monitor any differential settlement. As soon as possible after the completion of the crane erection, the initial or control elevation reading should be taken. Intervals should be determined regarding the frequency of monitoring readings to determine if any settlement activity has taken place.[3]

- Prior to erection of the tower crane, the building department agency and/or independent third-party engineering firm specializing in crane operations, should receive from the professional engineer of record the designed drawings and specifications for the tower crane erection and operation.

No work should commence until the building department returns approved engineered/drawings for the tower crane erection and utilization. The designed/engineered drawings must be prepared by a licensed engineer in conjunction with a licensed rigger and must be in compliance with manufacturer's recommendations for erecting, jumping, climbing, and dismantling of the specific crane.



- Consideration should be given to retaining the services of an independent third party crane engineering/inspection firm to perform a review of the crane engineer of record's drawings and calculations. In addition, the qualified firm should provide on-site inspection of the tower crane erection, jumping, climbing, and dismantling operations to verify installation and procedures are in compliance with approved drawings and specifications. Periodic inspections of the tower crane by the third-party firm should be scheduled throughout the duration period of the tower crane.

- Erection of tower cranes requires staffing the project with qualified team(s) of workers experienced in crane erection operations. In addition to the utilization of professional engineers for the design/engineering aspect of the operation, specialized personnel including but not necessarily limited to; licensed master rigger, lift director, and certified crane operator must be part of the erection team. An experienced and qualified project manager/superintendent responsible for coordinating and overseeing the tower crane installation must be in place along with safety measures that ensures compliance with approved plans, traffic and pedestrian controls, and weather condition restrictions.

- All workers engaged in the erection, jumping, climbing, rigging, or dismantling of a tower crane should be required to demonstrate completion of safety training. Training should include instruction pertaining to fall protection, crane assembly and disassembly, pre-lift planning, calculating weights and materials, utilization, selection and inspection of rigging equipment, proper means of communication and signaling with crane operators.

- Prior to hoisting any load, the weight of the load being hoisted and the ancillary weights must be calculated along with the length of the boom and working radius to ensure loads are within rated capacities of the crane.

- A pre-construction safety coordination meeting should be held by the general contractor prior to the erection, jumping, climbing, or dismantling of the crane to review all aspects associated with this operation. Those required to attend this meeting should be; GC/CM, professional engineer of record for the crane, master rigger, lift director, safety manager, crane operator, jumping crew, signal person, and flagger.

- A risk assessment/job safety work plan should be completed by a qualified person as part of the safety pre-planning process for tower crane erection, jumping, climbing, dismantling and hoisting operations. It should identify and list the step-by-step sequence of each task associated with the operation, the potential hazards that may be encountered with each of those tasks and the controls that will be implemented to eliminate and/or control those exposures.

This plan should be submitted by the contractor performing the operation and submitted to the GC/CM for review and comments. The plan should be reviewed in detail during the pre-construction safety coordination meeting and upon its approval; the responsible contractor for the operation must review the plan with the crew that will perform the work. Crew members should certify participation in the meeting by signing the plan which also indicates they understand all aspects of the plan. Documentation and retention of the signed plan should be maintained.

- Every major structural, electrical, and mechanical component of a tower crane should have a permanent durable plate bearing the manufacturer's name, machine model number and serial number, year of original sale by the manufacturer, and weight of the unit. In addition, identification numbers should be clearly marked on all basic removable components and attachments of the machine to show they belong with that machine.[2]

- Any components or structural sections designed and manufactured or altered by anyone other than the original equipment manufacturer or his agent must have the certificate of a qualified professional engineer attesting to their structural integrity to accommodate all the loads which the structure or components of the original equipment manufacturer can sustain and must be permanently identified in the same manner as the structural sections from the original manufacturer.[2]

- Refusal to purchase, lease, or use any piece of equipment which has been modified, altered, or otherwise subjected to any deviation from the original manufacturer's specification, in anyway which could affect the safety operation unless you have documented proof that the change was engineered and certified by a competent authority. In addition, check the documentation to ensure that any piece of equipment that has been damaged in anyway affecting the safety of operation was repaired by reputable persons and certified by a qualified authority.[2]

- All electrical components should be grounded to the cranes structure, which should be connected to a suitable ground.

- All tower cranes must be equipped with built-in safety devices which operate automatically to prevent damage to the machine should the operator make an error. The most important of these are limit switches which would eliminate the possibility of crane overload or over travel of the crane components.[2] Limit switches keep a crane from lifting loads above the rated capacity and helps to prevent a hoisted load from coming into contact with the upper block and rope drum.

- Brakes are critical components of the crane that must be understood and inspected on a regular basis. Every brake on the crane must be fail-safe in that the break will be automatically applied whenever there is a loss of power (pneumatic, hydraulic or electric). The breaks must not be released until the power has been restored.

- Wind plays a critical role in tower crane operations and it must be a daily endeavor to ensure awareness of current and upcoming weather conditions that may impact the project.

A wind action plan should be established that pro-actively addresses safety measures and procedures, as per the requirements set forth by the crane manufacturer, city/state/municipality agency and/or licensed professional crane engineer of record.

These safety measures must be followed when wind speeds approach critical levels.

All tower cranes should be equipped with anemometers to measure wind gust, average wind speed and wind turbulence. Maximum allowable wind speed as per the crane manufacturer or governing agency requirement must be known and adhered to.

Tower crane operations must come to a stop once the wind speed or gust reaches the designated level. If the tower crane operator feels the weather condition poses a safety concern at speeds lower than the designated level, the operator should have the authority to shut down the crane.

- When cranes are left overnight or the end of the work shift, they must be able to weathervane 360 degrees. This requires that there are no obstructions that can cause the crane to collide with other cranes on site or structures.

The cranes main jib should be allowed to turn freely in the wind (weathervane); aligning itself with the wind direction similar to a flag. On hammer head cranes, the crane is able to weathervane because the sail area of the main jib is greater than the sail area of the counter jib. If however, someone hangs a sign or banner on the counter jib, the wind balance is upset and may have serious consequences; for example wind loads introduced on the sign can prevent the crane from swinging into the wind. Also locking the slewing brake will not allow the crane to weathervane, which could have serious consequences if not in compliance with manufacturer's specifications.

- Each tower crane must be provided with a manufacturers operating manual. The manual should contain all pertinent data relating to operation and maintenance for the specific model crane in use.

- Consideration must be given regarding proximity to overhead electrical power lines. If there are overhead power lines located within the radius of rotation of the crane, there must be a sufficient distance of clearance to prevent accidental contact between the power line and the crane. Discussions should be held with the local electrical utility to determine if the electrical lines can be de-energized or isolated.

- One of the most common errors made in tower crane erection is that of applying improper bolting and torqueing procedures. All nuts and bolts must be well lubricated, of the correct size and grade and tightened sufficiently to develop a pretension greater that the dynamic loads that will be applied to them. If the dynamic loading exceeds the preload, the fastener will ultimately fail in fatigue.[2]

  – Loose nuts or bolts should never be re-torqued. If it was tight initially and has become loose then it has either stretched or stripped its threads. New bolts and nuts should be installed.

- The dismantling procedure of a tower crane is usually the reverse of the assembly procedure, however because of the heights involved and the interface of the structure that the crane was used to build, the dismantling operation is far more difficult and hazardous.

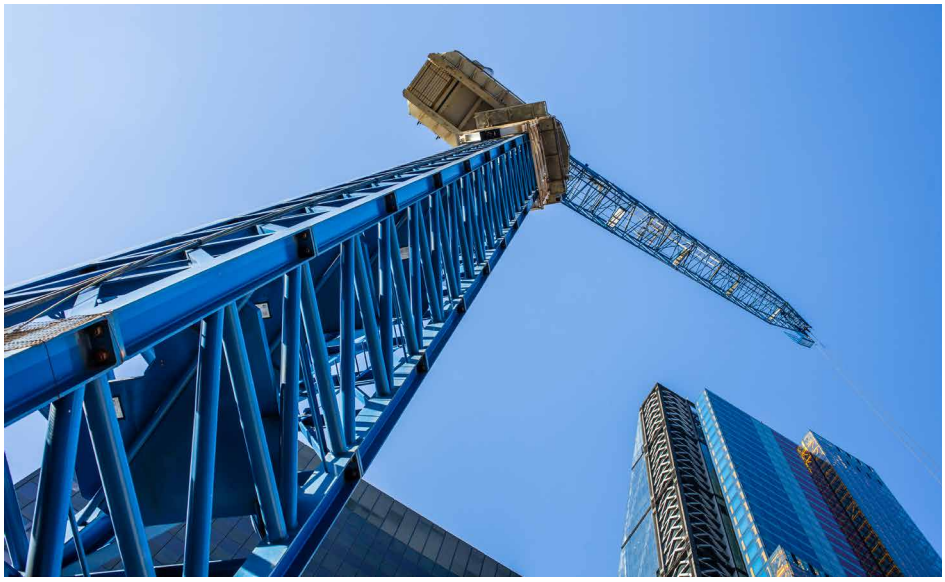
When dismantling the tower crane, never release any of the tower crane's pins, bolts pendants, etc. until the section or component is properly rigged and balanced and the total weight is being carried by the other crane or derrick.[2]

- Tower cranes are particularly severe on their slewing rings and ring bolts, and cracks have been found in many instances at the welding of the gusset plates in the tower ring and severe accidents frequently occur due to fatigue of the bolts.

Crane experts strongly recommend that the joint between the gear ring in the crane base and the tower top ring be broken whenever the crane is moved to a new site and the used bolts should be destroyed. The tower ring should be examined for weld cracks and for flatness of the bolting surfaces when dismantled and before each erection. Lack of bearing area at the content face of the bolt head can lead to slackness under cyclic loading, with the consequent danger of inducing fatigue cracks.[2]

- The crane should never be left unattended, however short the time period is, unless all loads have been removed from the hook and the electric power supply has been switched off or engine stopped and appropriate motion brakes and locks have been applied to put the machine in a safe condition. When the crane is left unattended, the hook should be brought to the highest working position at the appropriate radius and the power of the crane should be switched off.[2]

- The safety and dependability of the tower crane requires regularly scheduled inspections, testing and maintenance of the equipment and its components. A thorough inspection is required to identify and determine potential safety concerns and defects that would require necessary maintenance and repairs. It is the responsibility of the project's management personnel to ensure the tower cranes are given thorough periodic and regular scheduled inspections according to the manufacturer's recommendations conducted by trained and qualified personnel. All inspections should be documented and maintained with the equipment.



- In addition to regular and periodic scheduled inspections, the crane should be inspected prior to the initial use of the new or used equipment, after any modifications to the equipment or components, after every assembly, prior to using a crane that has been in storage and prior to using any crane that has been involved in a previous accident or mishap.

- Frequent and periodic inspections should include; running and standing wire ropes, sheaves, drums, rigging hardware and attachments. Visual inspection of boom and tower sections to for straightness and any physical damage such as cracks, bending, welds and deformation of steel elements are recommended. Special attention should be paid to cracking or flaking paint since this may indicate yielding of the metal, which may precede a failure.

- A Rigging Program should be developed and implemented prior to the start of crane operations. The project should have assigned a qualified rigger who has the training to oversee rigging activities associated with the project and authorization to shut down hoisting operations deemed unsafe.

The Rigging program should include but not be limited to; proper selection of rigging equipment required to safely performing all hoisting operations, inspection of all rigging equipment on a regular basis and prior to the start of each load being hoisted, as well as storage and maintenance of rigging equipment.

References

1. NYC DOB Cranes & Derrick Division
2. Crane Handbook – Construction Safety Association of Ontario
3. Cranes & Derricks – Howard I. Shapiro

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