Erection and accident prevention on tier buildings (erection practice on large steel-framed tier buildings)

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Erection and Accident Prevention on Tier Buildings

(Erection Practices on Large Steel-Framed Tier Buildings)

Méthodes de montage pour les ossatures métalliques des bâtiments à étages multiples

Montage-Methoden bei großen Stockwerkrahmen aus Stahl

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Over many years, experience in the United States in the erection of structural steel tier-building frames has resulted in the development of procedures, equipment, and safe practices that have been found to produce efficient, economical, speedy and safer results for this particular type of construction. This paper deals with the procedures and safe practices found to give the best results, together with the type of organization necessary to use these methods to best advantage.

The basic equipement most suitable for erecting the majority of multistory structural steel building frames is the guy derrick. In some special situations, stiffleg derricks are used to supplement guy derrick erection. And under certain circumstances, crawler cranes are used, with occasionally truck cranes being employed on low buildings. The guy derrick consists essentially of a boom, load falls, boom falls, and a vertical mast which is slightly longer than the boom, with guys from the top of the mast, in several directions, to some form of anchorage.

The boom is pivoted horizontally at its foot, or heel, at the bottom of the mast, by means of a steel pin, and is held in position by wire cables reeved into tackle or falls, called "boom falls" or "topping lift", between the head of the boom and the head of the mast. This permits the boom to rotate in a vertical arc about the boom heel pin. The lead line from the boom falls enters the top of the mast, then continues down the mast, through the foot-block, to one drum of the hoisting engine.

The load falls or tackle is reeved through blocks — the upper block secured to the upper end of the boom, while the lower block is free to be raised and lowered. The lead line from this set of falls feeds through the top of the boom, down the upper face, through sheaves in the lower end of the mast, down through the foot-block with the boom cable, to a second drum on the hoist. A suitable overhauling ball of sufficient weight to overhaul this load falls is secured to the lower load block. Slings or lifting devices used to pick the steel members can be secured by shackles to suitable loops or eyes or directly to a hook on the lower end of the overhauling ball.

Anchorages for the guys can be the building frame itself once the steel has been erected above the ground. Or, with the derrick starting at ground level, the guys may be anchored to the column footings, to "dead man" anchors buried in the ground, or to eye bolts grouted into holes drilled into rock foundations where available. The anchorage is needed to resist uplift and horizontal movement, due to tension in the sloping guys, which, being generally of wire rope cables, can transmit only tension.

A gudgeon pin is secured to the top of the mast. A casting called a "spider", with a hole in its center, is slipped over the gudgeon pin. To this spider casting the guys are attached. By means of these guys, the spider, and the gudgeon pin, the mast and boom may rotate through 360°. However, the mast must be longer than the boom so that the guys from the spider will clear the top of the boom as the mast and boom are rotated. This introduces the only objectionable feature of the guy derrick — the boom must be raised to its highest position when turning from an area between any two guys to an area between any of the other guys. At the foot the mast rotates in a foot-block where it rests on a bronze washer generally, to reduce friction in turning, or on roller bearings, or in a ball-bearing race.

The rotation of the mast and boom about the vertical axis of the mast is generally accomplished by means of a bullstick, a reasonably long piece of pipe 4 or 6 inches in diameter, inserted through a pair of angles bent into "*U*" shape to form brackets, and secured to the mast, about waist high above the working floor. However, in the case of heavier guy derricks of greater capacity, a bull wheel is often required. This consists of a large, circular ring composed of angles or channels secured to the foot of the mast. Wire rope cables around and secured to the bull wheel, leading to a power-driven drum, provide the necessary force to turn the boom and mast.

In the case of the guy derrick and the stiffleg derrick the motive power for the boom and the load is a separate hoist — powered either by gasoline, diesel oil, electricity, or steam, though steam is relatively obsolete for tier buildings.

Cranes, on the other hand, are completely self-contained in that the power for raising and lowering the boom, as well as for raising and lowering the load, is part of the crane body proper. Rotation of the boom and mast is accomplished by rotating the entire body of the crane, with the boom always on the same line with respect to the crane body. The crane body in turn rotates on, and is supported by a pair of tractor assemblies in the case of the crawler crane; by a truck chassis in the case of a truck-crane; and by a frame supported on railroad trucks in the case of the locomotive crane. In all three types the crane body acts as the mast, the entire body rotating in similar fashion to the mast of the guy derrick or stiffleg derrick. The boom is pinned at its foot to the crane body, somewhat similar to the derrick boom, except that it is generally designed to have as wide a lower end as the crane body design will permit, tapering to a narrow width at the upper end.

Derrick booms are generally box sections of fabricated angles, plates, and straps or lacing, either of practically uniform size in cross-section throughout, or enlarged section at the mid-portion of its length, tapering toward the ends. In addition, the derrick booms usually have the upper load falls block attached independently to the head of the boom, with only lead sheaves integral with the boom, whereas the crane booms frequently have the sheaves corresponding to the upper load falls block incorporated into the head of the boom itself. The mechanism for raising and lowering the load and the boom is self-contained in the crane body, as is also the motive power for rotating the crane body about its support. In the locomotive crane and the crawler crane, the power for traveling is also in the crane body. In the truck crane, the power for traveling is usually in the truck chassis separate from the crane body, though some manufacturers have built completely self-contained forms of truck crane bodies.

Let us assume that a contract has been made to erect a structural steel tier-building frame, and the preliminary study of the design drawings has been completed. At this time a decision should be made as to the type, number, and size of derricks or cranes to be used. In addition, a study of the site conditions should have been made, to determine how the steel can be delivered and erected. Foundation drawings are checked to determine the weight and stability of footings as anchors for the erecting derrick, if derricks are to be used. After these studies the erector can confer with the draftsmen who will prepare the detail drawings from which the various members are to be fabricated. He will also instruct the shop on shipments. The terrain at the site will influence the delivery of steel — by rail directly to the site, by truck from fabricating shop, or by truck from nearby rail or water delivery points, or by truck from unloading yard. For most efficient tier-building erection, an unloading or sorting yard is necessary, unless the fabricating shop has sufficient facilities to sort the steel into small areas as installments and deliver it in these installments as needed by the erector. The capacity of the equipment may limit the size of pieces to be shipped. Special connections should be studied to insure safe and speedy erection wherever possible. Decisions should be made on shipments of trusses if there are any in the structure — knocked-down, partly assembled, or completely assembled.

All permanent beams on which the derrick will be supported at the various floors must be thoroughly checked for shear at the end connections, moment due to the derrick loads, web buckling, and end bearing. Often shores are needed to transmit part of the load to beams below. Sometimes heavier beams must be used in place of the designed weight beams, or additional connections may be provided to support the erection load, which, in the case of the guy derrick, includes not only the weight of the derrick itself and its temporary supporting beams, but also the lead line pull of the load and boom cables leading down through the building to the hoist below, the stress in the mast from the guys, the planked floor, as well as any steel which may be landed in the immediate area around the derrick. The effect of the vertical and horizontal components of the guy stresses due to the loads to be picked must also be checked.

Schedules are prepared for shipments, based on the expected production by the type and number of pieces of equipment selected. Tool lists are prepared so safe and adequate equipment can be assembled, overhauled when necessary and small tools put into proper, safe condition. Supplies are arranged for such as fuel for engines, coal for rivet forges, electrodes for welding, oxygen and acetylene for cutting. Laws and ordinances must be checked to determine local requirements such as the planking of working floors, minimum sizes of ladders, maximum number of open floors permitted between the concreted floor and the derrick working floor, and similar restrictions that might affect the work. With the preliminaries taken care of, such as shipping equipement, scheduling steel, arranging for men, conferences with the general contractor to insure cooperation and dovetailing of the work of other trades with steel erection, the job is ready to start. Let us follow through on a typical tier-building, which, as stated before, is usually erected by guy derricks.

In most tier buildings in large cities, the lowest level is usually well below street level. If the site is large, a ramp is often built for the excavator to haul away excavated material. The steel erector using the ramp can then deliver his derricks close to their planned locations and later truck steel into the excavation close to the derricks. Care must be taken to make sure that the ramp has been built strong enough to support the heavily loaded trucks. The side walls of the "hole" are usually shored to prevent dangerous cave-ins, and care must be taken to keep the shores in such locations that the steelwork can be erected without interference.

The parts of the derrick are unloaded with a crane when such equipment can be secured, and the various pieces assembled on the ground in their relative positions, to make the required lengths of the mast and boom. The crane sets up the mast or boom, which is then guyed to anchorages in the foundations. The remaining member, boom or mast, is set into place by the crane, and the boom falls and load falls are reeved up so the derrick is ready to work; or the boom can be assembled and tripped up into place by means of the boom falls. By using power for setting up the derrick the hazards present when the men have to assemble the sections by hand are eliminated. However, if no crane or other rig is available, the derrick sections must be rolled off the truck and bulled by manpower into position for assembly into mast and boom. The hoist which will later power the derrick falls is set in place, and cables reeved through blocks to form tackle are used to upend the boom. Then, using the boom as a pole, the mast is tripped up into place. The bottom end of the boom is pinned into its seat at the foot of the mast to act as a hinge and thus permit the boom to rotate in a vertical plane, as previously explained.

Grillages for heavy column loads, or slabs for light loads, are next set to line and grade on screed angles or thin shims. Leveling bolts are sometimes used where heavy slabs must be set. After setting the grillages or slabs accurately, forms are built around the grillage by the general contractor, and concrete or grout of cement, sand, and water, is poured to be sure the column load is properly transmitted through the grillage into the footing. When a relatively light slab is used, whenever possible foundations should be brought to finished elevation, or a thin plate set to grade, the slab shop-assembled to the column, and the slab and column then erected on the finished footing. This eliminates the entire operation of setting the slabs by means of shims, screed angles, or leveling bolts, and reduces the number of pieces to be erected.

The steel is divided into tiers, usually two floors each, and the first tier is now delivered to the job site. Usually the beams arrive first so that they can be distributed about the site approximately under their final location in the structure. Timber skids are laid to help keep the beams from rolling over as the men distribute them. Otherwise, the beams landed on the usually rough, uneven ground would easily be knocked over, thus unnecessarily endangering the men. Sorting of the steel into general derrick areas should be done at the shop where possible, with further sorting at an unloading yard within reasonable trucking distance from the site. These areas should be such that the derrick can distribute all the steel in any installment between two guys. This eliminates the need of raising the boom to its maximum upright position to clear the guys, turning the derrick, and then booming out again while still carrying the load of steel by the load falls. Eliminating such moves removes the possibility of men's hands being caught between beams in the load as it is steadied while booming up, ducking a guy, and booming out again to land the load where it is to go.

The foreman of the raising gang knows where to place the various pieces by means of erection diagrams showing the ultimate location of each piece by means of a schematic line drawing and a numbering system — the same number being on the detail drawing, on the piece, and on the erection diagram. This distributing is done between delivery of truck-loads, and columns should be delivered for an area at such time that the derrick can erect the columns in a panel, fill in the beams between, and continue erecting or unloading mors steel in adjacent areas. The erection diagram, in addition to showing the mark and location of each piece, usually gives the size of the beam sections and important dimensions, such as distance between columns, and distances off center of a beam if it is not on the centerline of column. Where there may be difficulty in knowing how a piece is to be erected, a small section is also shown or some indication given, for example, the direction a channel should face, or whether an angle is to be erected with the outstanding leg at the top or bottom of the vertical leg.

Erection is usually started in the panel furthest from the derrick and away from the street or delivery point. The steel in front of the derrick at the delivery point is filled in last so that the boom can be used up to the last minute to unload trucks. Finally the derrick fills in the steel in the area around itself. It is then ready to jump to the upper level of the steel erected, usually two floors or one tier above. The derricks proceed to erect a tier, jump to the upper level erected, erect the next tier, and so on upwards until the structural steel frame is completed. It is this ability of the guy derrick to jump from floor to floor by itself that makes it safer, more efficient, and more universally used in erecting a high tier building than the stiffleg derrick which generally requires a second derrick to raise it from floor to floor. There are additional objections to the use of the stiffleg derrick for tier-building erection. These will be pointed out later.

Efficient erection requires the use of any devices which will aid in safer and more economical and expeditions work. An example of this is the column-setting "hickey" which requires holes on the centerline of the upper column splice plates when fabricated. The column is picked by means of a pair of slings secured to two shackles fitting over these holes in the upper splice plates. A long steel pin through the special holes in the plates and through the shackles, permits the column to be rotated from its horizontal, delivered position, to its vertical position for erection. The column then hangs plumb, whereas with a sling around the shaft it cannot hang truly vertical. This scheme eliminates one of the hazards in erecting. Once the column is in place and secured to the shaft below, a line to the long pin through the shackles, is pulled to remove the pin. This disengages the shackles from the column without the need of a man having to climb the column to "cut it loose", as is the case when a sling is used.

Where a building lends itself to erection of one portion with a few derricks, followed by the second portion, it is often advantageous to all concerned to complete the first section before starting the second. The fabricating shop can ship the steel at a faster rate, the derricks will jump sooner, and the general contractor will be able to follow through on a small area and concrete it. This makes that portion of the floor available for the various trades to build walls, install electrical conduits, plumbing, etc. It also reduces the equipment to be shipped, with no loss in overall time.

But to go back a bit. The steel has been shipped from the fabricating shop by truck, if the shop is close to the building site; or more generally, in railroad cars. It arrives at an unloading point where it is unloaded by locomotive cranes, or crawler cranes, or truck cranes, or even by an overhead railroad gantry crane. The latter, however, is much slower than the more mobile and flexible cranes. In erecting a tall tier building, especially in a congested area, it is usually advisable to establish a yard where the steel can be unloaded, sorted, and stored in advance of need at the building site. If delays develop in transit, there will then be ample time to absorb this delay at the yard. Also, additional sorting can be done at the yard to eliminate some of the sorting at the site.

Actual erection of the individual beams, girders, or trusses requires the use of wire rope slings with an eye spliced into each end, or shackles secured to hitches previously installed on the piece. The size of slings used should be watched carefully to make certain that they are of adequate strength. Erection of diagonal members introduces a special hazard as the sling must be heavy enough to hold the piece but light enough to grip it without sliding upward. For sorting the steel and distributing the pieces into locations approximately under their final positions in the structure, special hooks on the ends of a pair of eye-and-eye slings are used. The hooks are shaped to slip over the ends of beams, gripping the web, and so designed that they will not catch the hand of a man holding the hook in position and squeeze it against the beam.

When filling in the steel in a tier, a single sling is usually used so that the beam can be tipped safely by means of a line called a tagline, hooked into one end of the piece to permit threading the piece through the steel already erected. For heavy girders, and trusses, two slings or hitches are customary to make the piece hang level as erected. For very light, possibly unstable members, a balance beam may be used, or a stiffening timber or beam temporarily secured to the top flange. A balance beam also permits two rigs of unequal capacity to pick proportionate loads in lifting a piece too heavy for either one alone. A balance beam consists essentially of a structural member supported at its center by the erecting rig and provided with connections at the two ends for slings or shackles with which to pick the piece being erected. The length of the balance beam is such that the piece can be picked safely. By inverting the balance beam and using the center connection to pick the piece, the end connections may be used by the two rigs picking jointly.

Often a crane is used to erect the first tier of steel on which it sets up the guy derrick for erecting the balance of the structure above. This eliminates all the hazards of setting up the derrick in "the hole" and the need of safe anchors for the guys in the foundations or footings. It also does away with the first jump from the ground to the top of the first tier steel, which is never as easy as the subsequent jumps. On reasonably low tier buildings cranes can be used to good advantage. With guy derricks on the other hand, an entire floor can be completed for the general contractor to do his work, whereas a crane erecting a multi-story building usually requires complete erection from ground to roof by panels or bays, allowing the general contractor to work on very small portions of all floors at a time, instead of all of any one floor. In addition, with this method it is usually not possible to install adequate temporary planking below the men working on the steel or above men concreting floors below.

With a small area, one derrick may be able to handle the entire floor. With larger areas, a decision must be made if one derrick with longer boom and mast, or two smaller derricks, should be used. The longer boom and mast generally means slower erection and possibly heavier equipment to handle the loads at the greater reaches. On the other hand, the two smaller derricks will involve greater freight or trucking costs, and probably greater total cost for setting up and dismantling. All these factors are weighed before the decision is made. Occasionally all except a small portion can be reached with the rig selected. A jinniwink can then be easily set up to erect this portion and it can later be used to help dismantle and load out the derrick.

The jinniwink is usually a low-capacity rig with all of its members light enough to be handled easily by two men. It consists essentially of a vertical A-frame acting as a mast, with a sloping stiffleg from the top of the A-frame back to a single stiff, horizontal sill, hinge-connected at its other end to the center of the front sill of the A-frame. The boom is held at its upper end by falls to the top of the A-frame and at its lower end is secured to the center of the front sill in a special knuckle permitting horizontal and vertical rotation inasmuch as the mast is fixed and cannot rotate as in the case of the stiffleg and guy derricks, where the mast rotates in a horizontal circle and the boom in vertical planes.

For a long, heavy, moderate height tier building, cranes may be inadequate or ground conditions too poor. In such a case a stiffleg derrick with greater capacity can be mounted on a platform to be slid or rolled on the steel as erected, or on rails laid on the structure, and moved ahead, panel by panel as it erects. This is called a "traveler". At the two ends of the building, a guy derrick is often set up to pick the stiffleg derrick traveler bodily and turn it around at the next higher level to permit it to return, erecting the tier above as it goes. This is especially convenient when speed in erection is not important or where the shop is unable to fabricate or ship rapidly enough to feed more than one or two rigs.

The stiffleg derrick consists basically of a boom and mast; the mast, similar to that of the guy derrick, rotates at its lower end in a seat corresponding to the guy derrick foot-block, but is designed to resist uplift. The upper end differs from the guy derrick mast in that it is held in place by two inclined, stiff back-legs connected at their lower ends to horizontal sills, which transmit the horizontal stress between the foot of the boom and the lower ends of the back-legs. The boom is hinged horizontally to the mast at its lower end, or heel, and the two rotate as a unit about a vertical axis, like the guy derrick.

However, whereas the guy derrick boom and mast can rotate 360°, the stiffleg boom and mast can only be rotated from the position of the boom against one back-leg around to the other back-leg, with intermediate positions where there may be compression in one of the legs, or tension in one and no stress in the other, from the load being handled, or tension in both legs, all depending on the position of the boom and the angle between the back-legs. Since there is always the possibility of tension, provision must be made to tie down the sills to the structure, or otherwise provide counterweight to resist the vertical component of tension in the back-legs. Stiffleg derricks are not very mobile and are generally used only for heavy work. They do not lend themselves to efficient erection of tier-building frames except in special situations. Furthermore, the sills and back-legs must be strong enough to take not only tension, as in the case of the guy derrick guys, but also compressive stresses. The boom can be longer than the mast since the top of it does not have to clear under guys when rotated, as in the case of a guy derrick.

Ingenious devices must be used to expedite the work, reduce costs, and promote safety. Crawler cranes with booms and jibs extending as much as 200 feet aloft can erect high structures, if the ground conditions are satisfactory. Ordinarily, the cranes will erect the sides and end of a building, backing out as they erect more and more of the structure. Where ground conditions are poor, timber mats are used to distribute the loads and maintain the crane in level position.

Low tier buildings are often erected more speedily by crane than by derrick, especially if the structures cover large areas. The time of setting up and later dismantling the derricks, or moving them laterally to reduce the number of derricks, is saved by the use of cranes. The crane has greater mobility and flexibility than a derrick. However, it needs good ground conditions to operate safely and must have more space to travel kept clear of unloaded and distributed steel.

Structures with reasonably light members, and not too great height, lend themselves to erection by truck crane, which is even more mobile than the crawler crane. It can move rapidly over the highways under its own power without damaging the paving while crawler cranes must be moved on special carriers both due to their slow rate of travel and the probability of damage to the road by the crane treads. And with both truck cranes and crawler cranes, ground conditions must be carefully watched. When muddy or wet, adequate mats should be used to support the cranes safely in a level position. Under such conditions the men must also be constantly watched and cautioned not to go aloft with muddy, slippery shoes which may make them slip on the steel and fall. The same hazard exists with snow on the ground.

Often the weight of individual members, especially in the lower floors, is greater than the capacity of the available guy derricks. Where this is the case and the layout of the building is such that two guy derricks cannot be used together to unload and later erect such heavy steel, stiffleg derricks are sometimes used. The stiffleg derrick starts at ground level in the street, erects a section on the structure ahead of itself, from the bottom of the excavation to ground level, moves forward on the panel just erected, and sets more steel ahead — moving forward progressively on the steel as erected. Meanwhile, it will be setting up guy derricks of lighter capacity on this steel, to erect the steel above in the usual fashion.

The greatest advantage of the guy derrick probably lies in its ability to "jump" — move from a lower floor to an upper floor by itself. The derrick completes all steel in the tier directly above its working floor, finally hemming itself in as it erects the panel directly around it. The derrick then prepares to jump to the top of the steel just erected. The boom heel pin is pulled out so the boom hangs from the top of the mast by means of the boom falls or topping lift. The footblock has been temporarily fastened to the mast with turnbuckles and shackles. The boom is turned 180° and a device called a "boom seat" or "boom heel seat" is fastened to the foot of the boom by the boom heel pin, to protect the foot of the boom, which is landed on specially provided steel beams called "jumping beams". With the boom turned 180° the load falls is hooked on to the mast, just above its center of gravity. Four or five jumping guys extend from the top of the boom to sets of falls, to hold the boom as a gin-pole for raising the mast. The load block is now between the boom and the mast instead of outside the boom. The mast is ready to be picked by the load falls.

When the four guys have been fastened to the boom about 90° apart, with a fifth guy directly opposite the mast to be picked, a slight strain is taken on the load line and the mast is thus held up by the boom. Next the guys ordinarily holding the mast are cut loose from the columns where they are anchored, on the derrick floor, and are brought up two floors and fastened in readiness for the new position of the mast. The hoist operator now goes ahead on the load line and the mast is picked up by the load falls, the boom acting as a pole. The mast guys are gradually taking up the slack so that when the mast is up, the guys on it will be ready to go to work. Sets of falls still hold the temporary guys to the top of the boom.

The foot of the mast is raised slightly higher than the two steel beams on which the derrick is supported at each stage of erection. These beams are spread apart enough to allow the footblock to come up between them, from below. They are called "jumping beams" even though they are not only used in jumping the derrick but also serve as the support for the derrick when operated. They in turn transmit the derrick loads into the steelwork. As the mast is raised above these jumping beams, the mast guys are ready to hold it in place. Slacking down, the footblock which was temporarily secured to the foot of the mast lands on the jumping beams which are usually steel H-beams, but can also be heavy timbers. Next, the guys to the top of the mast are all made tight by means of turnbuckles at their lower ends, and the guys which held the boom as a gin-pole, are cut loose. The hoist operator now goes ahead on the boom-falls cable, and instead of the boom booming-up, the head of the boom is drawn directly upward to the top of the mast.

After the boom is raised high enough, the boom heel protective device is removed, and by means of a sling around the foot of the boom and the mast, secured to the load block, the foot of the boom is pulled over to the mast and when it is in proper position, the boom heel pin is reinserted. The derrick is now ready to go to work again, erecting the next tier above. While this is going on, a plank gang generally has been distributing plank on the new derrick working floor. The floor on which the derrick stands should be completely planked over, preferably with 2×12-inch planks, long enough to reach across two or three beams, but short and light enough that two men can safely carry them and lay them in place. With two or more derricks close enough together one can sometimes pick the other bodily and set it on the upper floor. This derrick in turn then picks the first and sets it on the upper floor. This eliminates the entire jumping procedure.

If plumbing and bolting, riveting, or welding can be completed in an area above the derrick working floor, the planks below that area can be gathered together into bundles, lifted by the derrick to the upper floor, and spread out on the completed area before jumping. In this way, the men bolting, etc., are protected by the planks two floors below. Also, workmen still further below are protected if a nut, or bolt, or any other object is accidentally dropped. Where this arrangement cannot be followed, planks are frequently left, and planks from the previous working level, generally two floors below, are gathered into safe bundles and leap-frogged past the derrick floor to the top of the newly erected tier of steel, to be spread out in advance of jumping, or at least before taking in the next tier of steel. Skids consist of a few planks piled two or three high, or 4×4-inch timbers that have been used to load the steel in railroad cars, or even special timbers. These are laid at such points on the planked floor that when a load of steel from a truck in the street is landed on them, the concentrated load of this bundle of steel beams is carried into the permanent steel frame rather than to the planked floor itself.

For structures bolted with A.S.T.M. A-325 high-strength bolts, impact wrenches are almost universally used. Whereas formerly the wrenches were individually calibrated, usually daily, to provide the torque to produce the required minimum tension in the bolt for the particular diameter being installed, the method presently used eliminates the daily calibration of the wrenches. After spinning the nut on the bolt to a snug fit, the impact wrench then rotates the nut an additional one-half or three-quarter turn, depending on the diameter and length of the bolt. Laboratory tests have determined the amount of additional turn sufficient to provide at least the minimum tension required in the bolt under the specifications of the Research Council on Riveted and Bolted Structural Joints of the Engineering Foundation. The required tension has been incorporated into the building codes of many cities in the United States. For a small number of such bolts, some erectors will use a torque wrench, but this is usually not as satisfactory as the turn-of-the-nut method or even the use of calibrated wrenches.

The riveters, bolters, or welders work from the steel itself or from the planked floors where feasible, but where this cannot be done, floats or needle-beam scaffolds are hung. The float consists of a plywood platform about 4×6 feet, or parallel boards covering about the same area, secured to, and supported on adequate cross-pieces suspended by manila lines near the four corners, the upper ends of the lines being generally tied to steel members of the structure. The needle-beam scaffold consists of a pair of long timbers, about 4×6 inches and 20 to 30 feet long, the ends being hung by manila lines from the steel above, with short planks laid across the two supporting timbers. In both types of scaffolds, the lines should be of first grade manila of sufficient size to hold the men and tools on the scaffold safely, and of sufficient extra size in case a strand is burned by a hot rivet, welding sparks, or hot metal from oxy-acetylene cutting. The men should be taught safe hitches for the lines around the supporting beams, as well as at the points where the lines are tied to the scaffolds.

The connectors in the erection or "raising gang" are skilled in climbing the colums as erected, and walking the beams safely. However, as soon as possible after some steel is erected, ladders are put up to permit easier and safer access to the upper level. In the interest of safety, all the men should be provided with "hard hats" or "safety hats", made of fiber glass or other material, impregnated with an asphaltic compound and baked under controlled heat and pressure to become a tough, hard shell shaped to fit a man's head, with a properly fitted hammock or cradle to help cushion the shock of falling objects hitting the hat itself. Welders' helmets can be easily hinged to these safety hats. Goggles fitted with safety glass are used wherever there is danger of flying chips, sparks, coal dust or the like. Men cutting with oxy-acetylene torches are provided with goggles of tinted safety glass. Welders' helpers and men working in close proximity are equipped with safety goggles of a shade that will protect their eyes from harmful welding flash burns.

Columns are plumbed to the necessary verticality by a series of wire rope cables strung diagonally from the tops of columns in a tier to the lower ends of adjacent columns in the same tier, with turnbuckles inserted for pulling the upper ends in the direction necessary to plumb the columns and hold them until the permanent bolting, riveting, or welding has been done. Many other details must be taken care of in advance to assure an economical, efficient, and safe job. For example, the overhauling ball, mentioned before, hung on the lower end of the main falls block, must be heavy enough to overhaul the falls so that once a piece is erected, the block will come down again by gravity, the weight of the block and ball being sufficient to overhaul the falls. On a tall building this may be quite serious as the weight of the cable leading from the derrick down to the hoist can be excessive. In fact, on very high buildings, this weight and the loss of time for the load block to be lowered all the way to the street to pick a load from the delivering trucks, may be such great factors that it becomes expedient to install an auxiliary relay derrick part way up the building. In most such cases, the hoisting engines are moved up to the same level.

Occasionally, a structure is so narrow that the guys on the derrick would be too steep for safe operation and for turning the boom under the guys. In such cases, temporary outriggers are used to give more effective guying. Sometimes as the upper stories become narrower, due to setbacks, a long boom and mast derrick is cut down to shorter lengths to increase the effective guy distances in relation to the length of the derrick mast. When this is done, the auxiliary derrick or relay derrick is often needed to feed the derrick with the shortened boom. A guy derrick or even a stiffleg derrick, is assembled on the setback to unload from trucks in the street, raise the steel to that level, and then swing it in to a temporary storage platform where the erecting derrick can reach the material and raise it to the working floor.

Aside from the actual erection of the steel, the bolting, plumbing, riveting, welding, and similar operations at the site — there is still a great deal that goes into the erection of the steel frame of a tier building, which does not appear on the surface. The superintendent in charge of the field operation must be selected with a number of qualifications in mind. A good superintendent is usually one who has come up through the ranks. That is, one who has been an apprentice or helper, and then an actual ironworker in the gang. He should have shown his ability and moved up to the position of foreman in charge of a gang. Each erection crew or "raising gang" is in charge of a foreman, sometimes called a "pusher". The riveters, bolters, or welders are generally supervised by a foreman on the average-size tier-building job. If enough men are involved a foreman is often put in charge of men bolting and the men plumbing and aligning the structure. If there are a lot of small, light pieces not economically erected by the derrick, these are put in place by hand by a "filling-in" or "detail gang" in charge of another foreman. This gang can also take care of minor shop or drafting errors. If the area is large, or a number of derricks are used, or the building is very high, there is generally a "floor-boss" who really acts as an assistant superintendent and spends the bulk of his time on the working floors.

The superintendent must be a man who can be trusted. He should be steady and sober with enough innate psychology to properly supervise and be a leader of men, as well as being able to coordinate his work with that of the other trades working on the structure. He must be able to meet the owner's representatives and satisfy them that the work is progressing properly and expeditiously. He must, of course, know how to read and interpret drawings, and be able to foresee what is needed to have the necessary equipment, steel, or men available at the proper time. He must have the ability to plan so that he has work enough for all the men and does not have a top-heavy force. He must be able to judge men sufficiently well to pick the right men for his foremen. They in turn should have the right personalities for handling groups of men. The raising gang, and filling-in gang foremen should be good riggers, be able to read erection diagrams, and have some sort of logical mind so that as they sort the steel they will know where all the pieces have been distributed. Then, when the raising of the steel begins, there will be no floundering around looking for the next member to erect.

The raising gang on a guy derrick consists of the foreman in charge; an operator on the hoist to raise and lower the load falls or boom falls; a bull-stick man who turns the derrick; a signalman who transmits signals to the hoist operator; two connectors who do the actual connecting of the pieces in place; and two floor men who place the wire rope eye-and-eye sling around the piece, hooking the free end of the sling to the hook on the overhauling ball. One of these two guides the piece aloft, by means of a tagline. The tagline is a length of light manila rope with a small hook fastened to, or eye-spliced into one end. As the piece is raised with the hook placed in one of the connection holes at one end of the piece, the tagline man guides the piece between the pieces already erected, and swings the end within reach of the proper connector.

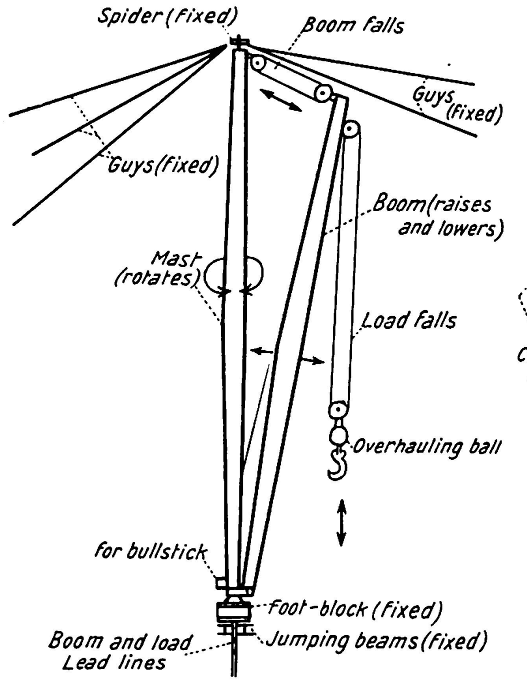
The signalman uses either light ropes such as clothes line, or wire rope, or electric controls, to ring a pair of bells at the hoist. Two bells are used, with different tones, one controlling the load cable, the other the boom cable. By the number of times the bell is rung, the hoist operator knows whether to raise, lower, or stop the drum on the hoist. With electrical controls lights of various colors are sometimes used in place of the bells; a white light to raise, and a green light to lower, with the light going out meaning to stop. With an electrical system using either lights or bells, it is, however, imperative to have an additional, positive signal to give an indication in case the current fails or the wires are accidentally cut.

Since a safe job is invariably the most efficient and profitable job, safety must be practiced rigorously. Not only must the equipment be safe to start with, but it must be kept that way. It is a simple matter for the main office to keep records of costs of accidents, and of frequency and severity of accidents, but it is also well worthwhile for that office to prepare reports so the superintendents on the different jobs may compare each other's records of safety as well as of production. This usually results in a healthy improvement by the poorer superintendent, as well as a pat on the back for the good man.

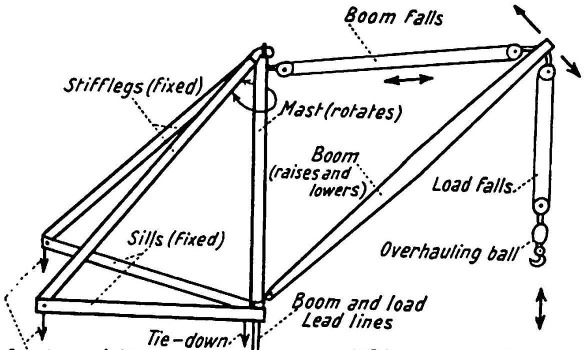
A good safety program is most important in addition to providing the men with safety hats, goggles with safety glass, life belts for use in extra hazardous operations or locations, and improving equipment such as providing safety glass around the crane operator instead of ordinary window glass, maximum lead line pull devices where the hoist is equipped with a torque converter, and similar improvements. Good housekeeping should be stressed both aloft and on the ground. In all types of erection, not only of tier buildings, safety should be paramount, and the men must be impressed at all times with the need to consider their own safety as well as that of their fellow workers. By studying past accidents, rules are established which would have prevented such accidents, and these can be incorporated into safety code booklets to be issued to the men at the time of hiring. Safety committee meetings should be held regularly on the job — with a small group of supervisory force attending one type of meeting, all the men on the job another type, or just demonstrations with small groups such as the raising gang, riveters, or bolters, showing the safe way to do their particular work. Safety posters are often used — either serious or comic, the latter being well liked by the men and thus more likely to be observed. Structural ironworker unions are cooperating by establishing apprentice training courses covering not only the work to be learned, but stressing the safe way of doing the work.

The man setting up the shipping schedule for the shop must have sufficient knowledge and experience to judge from the original plans and details just how fast the work will be done. If he plans on too much production per day, he may cause a pile-up of steel shipped faster than it can be taken. This will result in heavy demurrage charges, unless the unloading yard is of sufficient size to take such additional material, and provided it can be unloaded rapidly enough at the time the yard gang is feeding steel to the job site. If the original schedule is too slow, it is usually impossible to speed up the fabricating shop at the last minute. If shipped by rail or water, too often steel takes several days in transit, so that delivery cannot be speeded up even if the steel is all fabricated and stored at the fabricator's shop. That is the principal reason an unloading and sorting yard is almost a necessity in a large city where there is little or no storage space at the site.

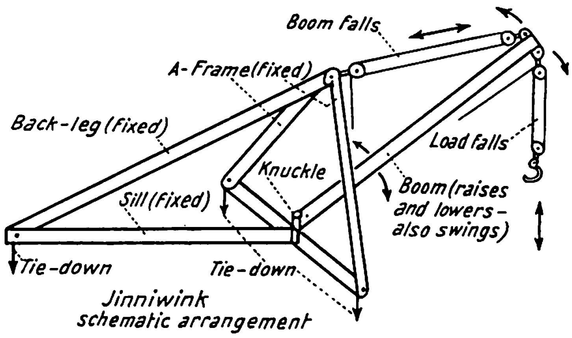
The estimator must not only know what can be expected from the men, in the way of production but he must be able to interpret the records of work done previously. An ideal method is to keep field records on the basis of production by units per man, or per gang, per day. For the actual erection of the steel, he must be able to use the records from one job, on one of similar nature, taking all the factors into account which may affect the result. Pieces-per-ton is often a good guide for selecting which previous job to use as an example of what to expect, provided the two buildings are the same type of construc-



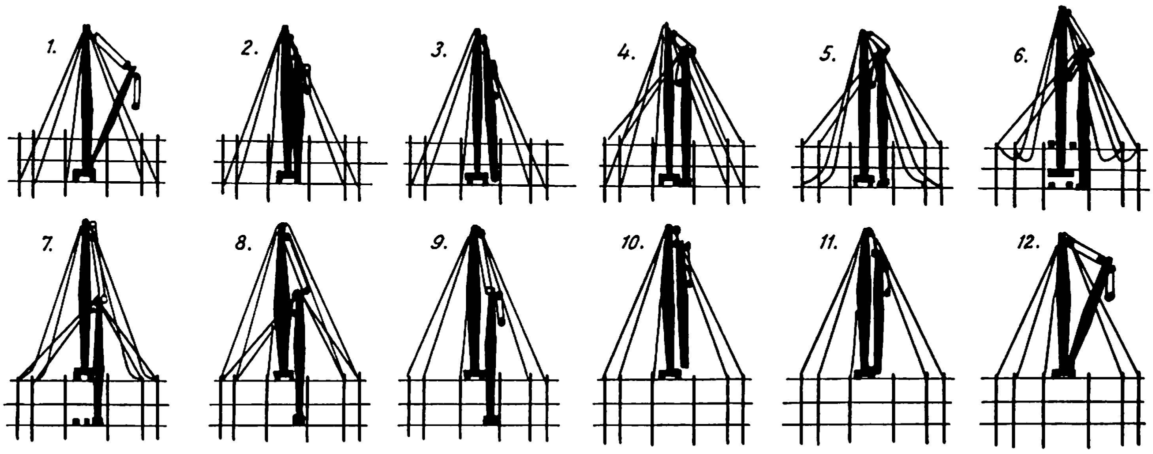
Guy derrick
schematic arrangement



Stiffleg derrick
schematic arrangement



Jinniwink
schematic arrangement



Jumping guy derrick
schematic arrangement of sequence

1. Derrick erecting steel.
2. Derrick completes erection of tier (two floors) directly above working floor.
3. Boom is separated from mast.
4. Boom is turned 180°, anchored in a "boom heel seat" and guyed to serve as a temporary mast or "gin pole".
5. Load falls is hooked on to mast.
6. Mast guys are cut loose and moved up to top level of steel. Boom starts to pick mast.
7. Boom lifts mast to new position two floors above.
8. Mast is landed on jumping beams at new level.
9. Temporary boom guys are cut loose. Topping lift (boom falls) starts to pick boom up to mast.
10. Boom has been lifted up to new position of mast.
11. Boom heel is again pinned to foot of mast.
12. Derrick is again ready to set steel on new level.

tion. But even if he has a similar building, with similar pieces per ton, he must still apply judgment to decide how the elements will affect the work — how the time of year will influence it — how a possible shortage of men may slow down the work. To make an estimate, the estimator must be able to visualize what type of equipment will be used — how many derricks, etc. For while the freight to ship two derricks is twice the freight for one, and the cost of setting up and dismantling two also nearly double, two light derricks will definitely erect more steel than one large one provided the areas are not too small.

So, to sum up, the estimate must be intelligently made, the preliminary drawings must be thoroughly studied to help expedite the work in the field and avoid impossible connections and details, the best erection scheme must be selected. The site must be thoroughly investigated and proper measures taken to utilize all favorable features and overcome all possible obstacles. The tools and equipment should be chosen to produce safe, economical, efficient and expeditious results. The supervisory force must be selected with the utmost care, picking the right men for the particular structure. Enough men, but not too many, should be hired. The fabricating shop shipping schedule must be thoroughly dovetailed into the needs of the field. The work of the erector must be coordinated with that of the other trades and sub-contractors.

This paper can only deal with the subject of erecting the structural steel frames of tier buildings somewhat lightly, for it is a tremendous subject. Time and again, two structures are almost identical in every respect save their location; but when an erection scheme for each structure is devised, too often the schemes are entirely different. Not only location affects the choice of erection scheme, but the availability of skilled men, the weather, the surrounding structures, and a hundred other details, insignificant in themselves, but vitally important when added together. So the conclusion must be reached that steel erection in general, not just of steel frames of tier buildings, is probably the most interesting phase of the steel industry, and offers the challenge of overcoming many obstacles and ending up with a safely, economically, efficiently erected structure.

Summary

Most structural steel tier-building frames in the United States are erected by means of guy derricks, with cranes used in some cases. A yard for unloading, sorting, and storage is generally required. The erection scheme should be devised to give efficient, economical, speedy and safe results, and a properly selected organization is necessary to achieve such results.

Résumé

La plupart des ossatures métalliques pour bâtiments à étages multiples sont montées aux Etats-Unis à l'aide de derricks haubanés; quelquefois on utilise aussi des grues. Il est généralement nécessaire de réserver un emplacement pour le déchargement, le triage et le stockage. Le programme de montage doit être conçu de façon à assurer l'efficience, l'économie, la rapidité et la sécurité des travaux; pour obtenir de tels résultats, une organisation bien étudiée est indispensable.

Zusammenfassung

Die meisten Stockwerkrahmen aus Stahl werden in den Vereinigten Staaten mit Hilfe eines «Guy»-derricks, in einigen Fällen auch mit Kranen errichtet. Ein Platz für Abladen, Sortierung und Lagerung ist im allgemeinen erforderlich. Der Montagevorgang sollte so geplant werden, daß nützliche, wirtschaftliche, schnelle und sichere Ergebnisse erzielt werden; eine geeignet ausgewählte Organisation ist notwendig, um diese zu erreichen.