1.2.4 Cranes

The following section describes the most common crane types within the Danish construction and civil engineering sector.

Tower cranes

The tower crane is the most common form of site crane, and is sometimes called a "building-crane". They are usually available as "*turning tower cranes*". Table 1.15 gives data for some turning tower cranes. They can be erected as stationary cranes on a concrete foundation, or they can be equipped with bogies (a bogie is a chassis or framework carrying wheels, attached to the crane, and has the ability to turn), which can be carried on rails, or which can be erected within the building and is able to climb through the building's floors in step with the progress of the construction. Turning tower cranes have several designs, see Figure 1.18.

Turning tower cranes with hook-block trolleys are the most common building-cranes in Denmark. The tower comprises sections of 4 to 6 metres and can be extended after the tower is erected by inserting extra sections, or by telescoping. Figure 1.19 shows the insertion of an extra section. The jib sections' lengths are between 2 and 12 metres, so that the jib can be adjusted to the task.

The hoist cable can either carry the hook-block with 2, 4 or 6 falls (cables), and we name it 2-part, 4-part or 6-part lifts. The maximum load depends on the number of wires, just as the number of wires affects the speed with which things can be hoisted and lowered (see Table 1.15). "Trollying" is the movement made with the hook-trolley, which moves the wires to the hook back and forth along the jib, while yaw is the jib's horizontal rotation about the tower's symmetrical axis.

Aside from the capacity of the wires, the danger of toppling sets limits on how much the crane is able to lift. The latter is stated as the load-moment, which is dependent on the size of the crane's jib. If the load-moment, for example, is 25 tm, i.e., the crane can lift 1 ton at 25 metres along the jib. It is possible to say with certainty that with a 12.5 m outreach, the crane can carry twice the load if the maximum tensile wire capacity is not exceeded. The crane's range is measured from the centre of the crane track, where the crane also has its axis of rotation located. One should not assume that the crane can lift loads closer than 3.5 m from this axis. The newer cranes have two type designations, which are, respectively, calculated according to the common European FEM Norm and the German DIN norms. The FEM norm allows typically 10% larger loads than the DIN norm - however, the same maximum loads. Figure 1.20 indicates a carrying capacity curve (after the FEM norm) for a 180 tm tower crane.

	Unit	Krøll K-70	Krøll K-125L	Krøll K-320	Krøll K-550
Length of jib	m	12 - 45	50	35 - 75	35 - 70
Load-moment	tm	70	100	320	550
Max load:					
1-part wire	t		4		
2-part wire	t	2.5	8	8	10
4-part wire	t	5.0		16	20
Hook height, on rails	m	9 - 41	23 - 55	10 - 64	14 - 92
Movement:					
Maximum lift and lowering*:					
1-part wire	m/min		70/120		
2-part wire	m/min	60/120	35/60	36/60	40/80
4-part wire	m/min	30/60		18/30	20/40
Yaw speed:	r/m	1	0.7	0.6	0.6
Trolley speed:	m/min	60		70	70
Driving on rails:	m/min	25	25	25	16
Gauge of rails	m	4.5	6	6	9

* Dependent on load. Highest max. Speed valid up to approx.50% of the wires´ maximal.

Table: 1.15: Turning tower cranes. The L-types with jib. The others with trolleys.

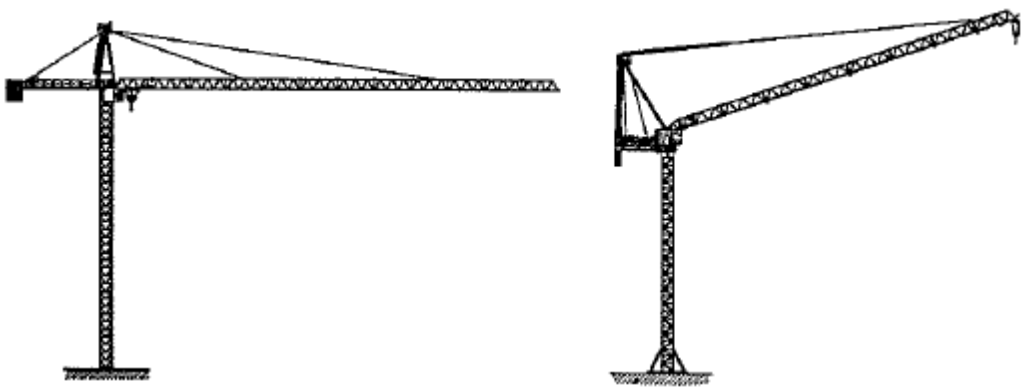

Figure 1.18A: Turning tower crane with jib (boom) and turning tower crane with jib and hook trolley

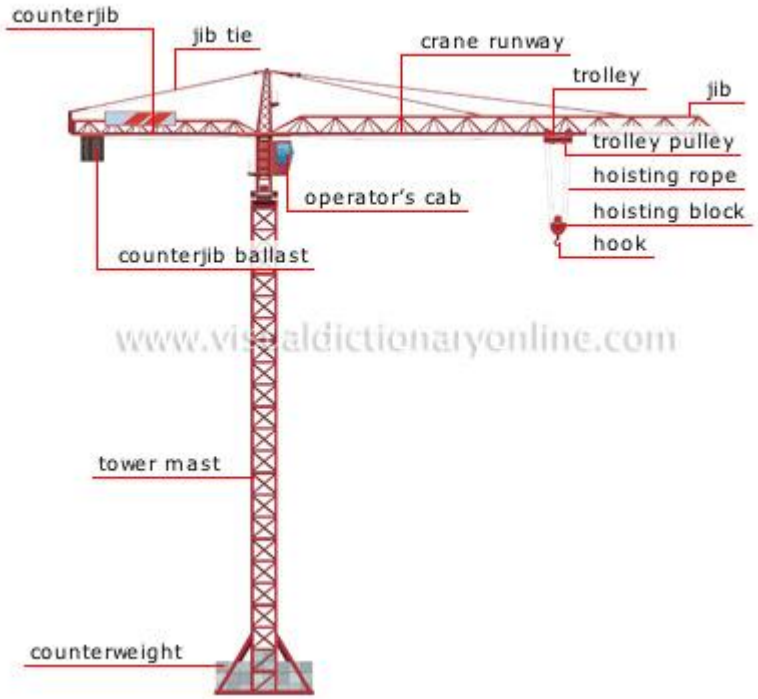

Figure 1.18B: Turning tower crane – technical terms.

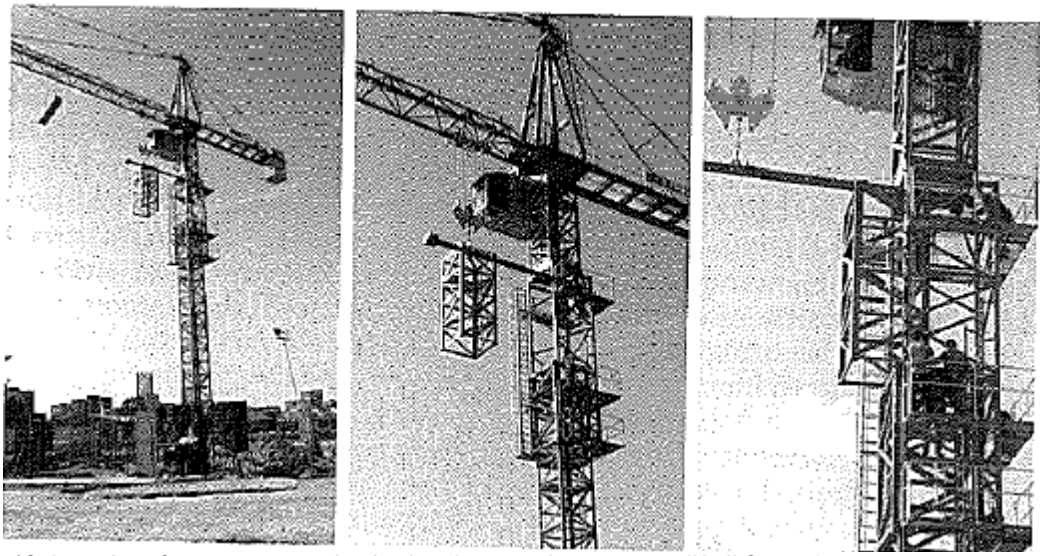

Figure 1.19: Insertion of extra tower section in already erected crane tower (Krøll Cranes).

The crane driver sits in a small cabin located just below the jib, but attached to it. From here, the construction site is seen in bird's eye view so placing a load accurately requires routine. Modern tower cranes are controlled via a joystick.

Tower cranes arrive at the site separated into smaller components. The tower crane is assembled and installed by specialists with the help of a mobile crane. The crane's counter ballast is placed on the counter jib, which also houses the crane's engines. Often, the erection of the tower crane requires an effort of 12-15 man-days and associated mobile crane assistance. Because of the jib, tower cranes have a very high-lying centre of gravity. It is therefore important that they are erected on a very precise horizontal, sustainable, well-drained surface that does not give rise to difference-settlement. When using stationary cranes, an absolute central location of the crane is usually sought, and the stationary crane is often placed within the building's outline.

Savings in the number of mast sections is achieved by using the rotating tower crane as *climbing cranes*, and the crane can be placed strategically more correctly with a considerably shorter jib. Climbing cranes are particularly suitable for tall slender buildings, but also for elongated buildings, two climbing cranes can be regarded as an alternative to a crane on rails, where the advantage lies in the fact that two cranes work twice as fast as one. Using two cranes at the same site means that special precautions have to be taken to avoid collision. Climbing crane are born at the bottom by two iron profiles that are laid across an elevator or staircase shaft, and the crane tower is then wedge-fastened to the two overlying floors. The actual climbing is executed by special electro-hydraulic climbing equipment in a few hours. When the building is up, the crane is dismantled and taken down piece by piece with the aid of a smaller building-hoist.

Figure 1.18 shows a different type of crane, a *turning/rotating tower crane with boom*, which is, however, less used. This crane has a boom, which is hinged to the tower so that the load's distance to the crane tower (outreach) can be changed by raising and lowering (flipping) the boom. The yaw movement happens between tower and base. The boom crane is less suitable for assembly work because of excessive elastic movements. On the other hand, it is more suitable than rotating tower cranes with a boom in cramped site conditions, such as in cities. Also turning tower cranes with booms can function as climbing cranes. Some turning tower cranes are fitted with trolleys.

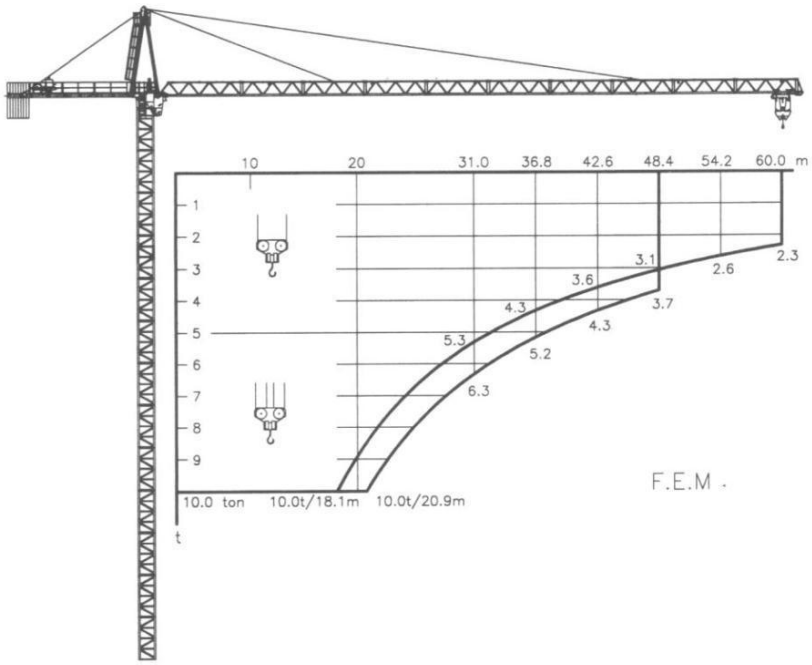

Figure 1.20: Load bearing capacity curve for 180tm turning tower crane (Krøll Cranes, K180)

Semi-mobile tower cranes

Figure 1.21 shows a semi-mobile crane, which is folded during transport. After arrival at the site, an engineer and the crane driver can erect the crane in half a day using the crane's own motor equipment. Building sites can cast the counter ballast of concrete themselves. The crane can be erected as a stationary installation supported by "pyramids" placed against the tower's support outriggers, or it can be provided with bogies, i.e., double castors to make it rail-driven. Table 16.1 gives examples of data for semi-mobile cranes.

	Unit	Liebherr 22SE	Liebherr 42K	Liebherr MK45
Action radius, max.	m	25	25,5/36	27
Max. Load:				
2-part wire	t	2	2	-
4-part wire	t	-	4	6
At max. Action radius	t	0.9	1.1	1.7
Hook height, max.	m	19	26	17.7

Table 1.16: Data for semi mobile tower cranes

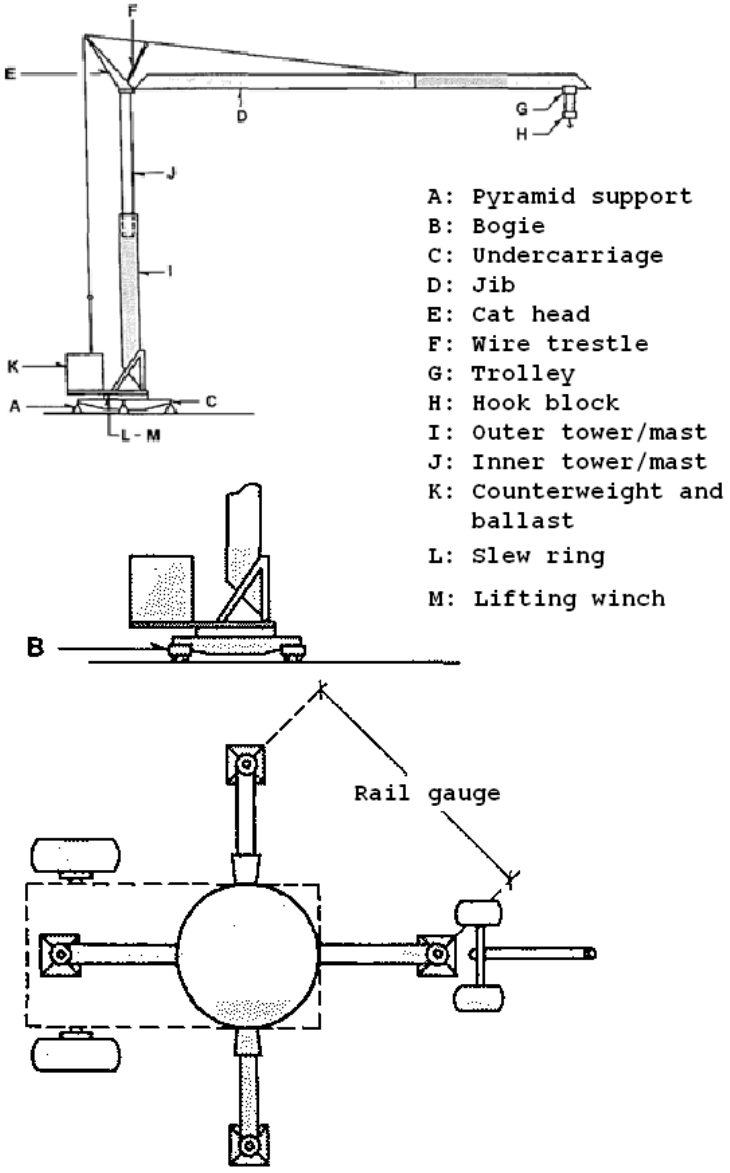

Figure 1.21: Semi Mobile crane with trolley.

Mobile cranes and auto-cranes

Mobile cranes with lattice jibs (strut-boom cranes) perform the horizontal transport of the load either by driving or by raising/lowering the boom. The crane requires a fairly large space to perform tasks. In these types of cranes pieces of equipment may be mounted, such as a guide-rail, so that the crane can serve as a pile-driving machine, or a grab or shovel can be mounted so the crane can operate as an excavator. Mobile cranes with lattice booms can be mounted with tracks or rubber wheels. Engines and hoists are located at the back to give the utmost stabilizing torque. Often, the crane is equipped with additional counter-weight to reduce wear on the yaw bearing (slew ring). It is essential that a fortified underlay is established when the crane is operated when carrying a load. The chassis can be fitted with outrigger supports to be used when the crane is working from a fixed position. The outrigger support's maximum load must be supplied by the manufacturer.

Mobile cranes with lattice booms have gradually and largely been superseded by cranes with telescopic booms. The boom is a rectangular beam and the telescopic-action is achieved by using hydraulics. Telescopic boom cranes require less space both during work and during transport and are, therefore, mostly used for regular crane functions. Conversely, they usually have a higher centre of gravity, and that is why they are more wind sensitive.

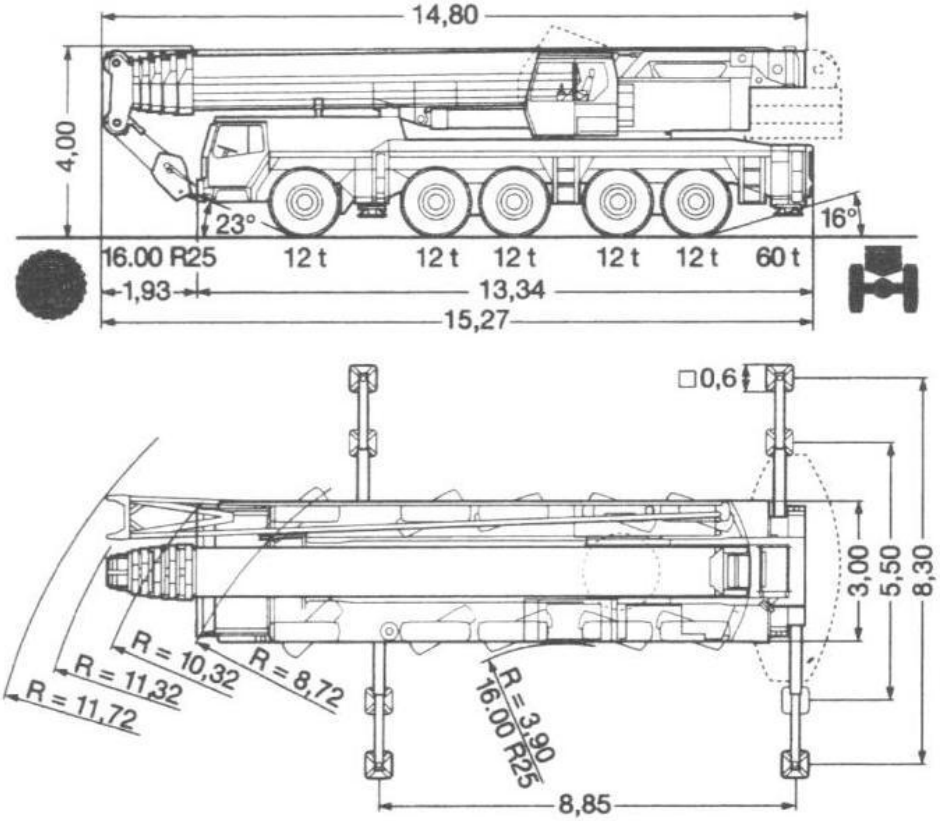

Figure 1.22: 160 tons auto-crane with telescopic boom. Liebherr LTM 1160/2 (BMS Belina). Viewed from the side and from above.

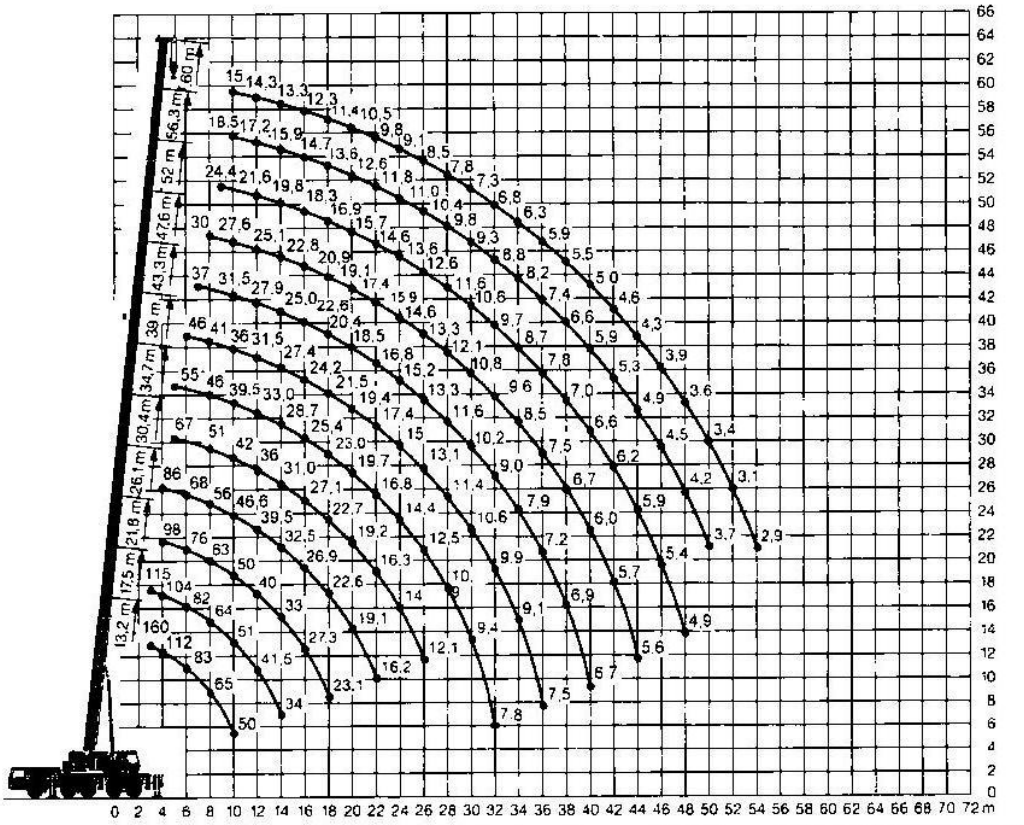

Figure 1.23a: 160 tons auto-crane with telescopic boom. Liebherr LTM 1160/2 (BMS Belina).
Lifting capacity of main boom in tons. Counterweight 50 tons. Outrigger supported, 8.85 x 8.30 m.

Auto cranes are mobile cranes on rubber wheels. In addition to the cab and engine for use in the execution of crane functions, a separate cab and engine is provided for use when driving on the highway. The chassis is similar to that of a heavy truck and is equipped with multiple axles. Figure 1.22 shows a 160 ton crane with a telescopic boom. The radii (R) shown on the floor plan indicates the radii of the circles, which, respectively, each pair of wheels and the crane's front end describes when turning. Furthermore, Figure 1.23a demonstrates the lifting capacity of the main boom when mounted alone. The horizontal axis indicates the outreach in metres, while the carrying capacity of each individual outreach is marked on the individual circles corresponding to the beam's length.

The jib is a tipping/folding jib, usually constructed as a lattice construction, which partly makes it possible to handle elements with two sets of wires (one at the end of the main boom and one on the end of the jib), but which also allows the crane easy access over a building.

Figure 1.23b shows an auto-crane's bearing capacity with a 36 m jib. The horizontal axis indicates the outreach in metres. The load-bearing capacity of the crane with a hook mounted at the tip of the jib is read on the curves. The figure indicates load bearing abilities for the jib dependent on the main boom (47.6 m - 52 m – 56.3 m - 60 m) and the jib's angle to the main boom (0°- 15°- 30°- 45°).

Mobile cranes are well suited to building sites where large lifts occur. You can then have a small construction crane at the site for light elements and other works. Usually these cranes are rented. In that case they are manned by a crane operator, and larger cranes have another person to set the crane up.

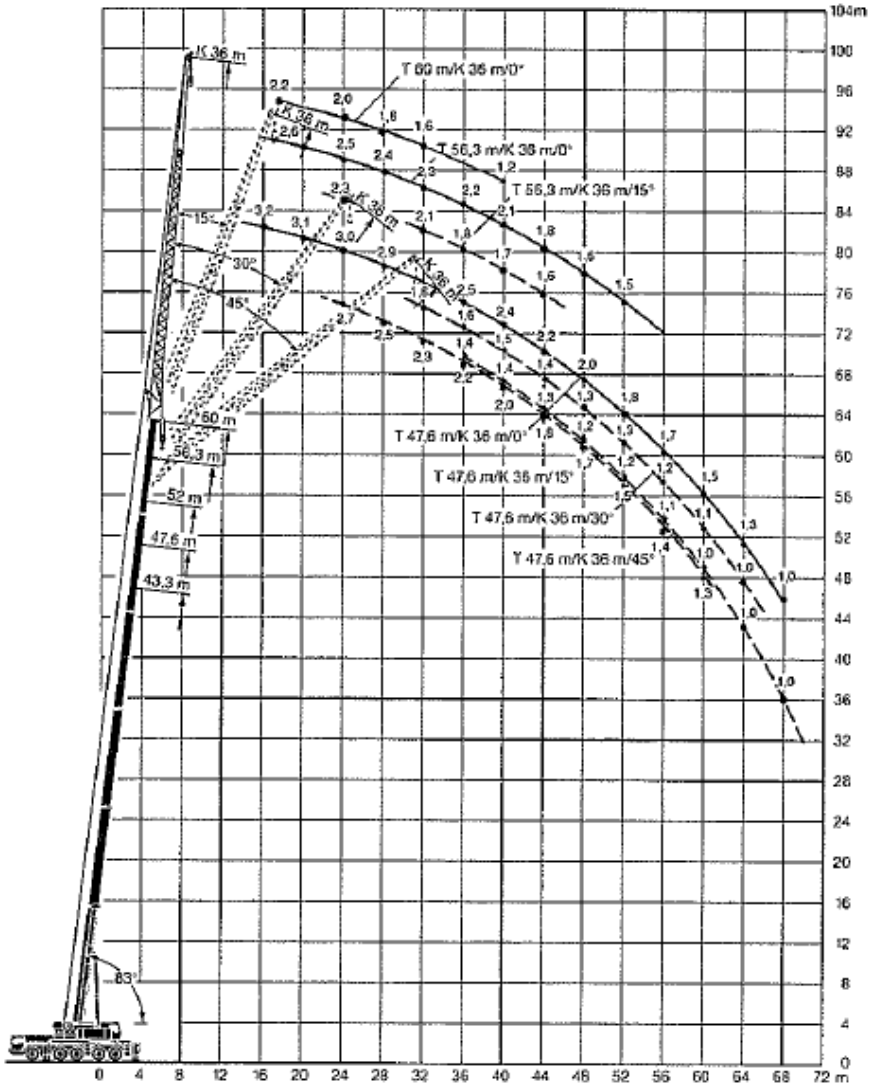

Figure 1.23b: the same crane as in Figure 1.23a, but here equipped with a 36 m jib.
Lifting capacity of the jib in tons. Counterweight 50 tons. Outrigger supported, 8.85 x 8.30 m.

In addition to the rental price incl. Manning, one must expect to pay for time spent travelling and for erection and dismantling.

Portal Cranes

Portal Cranes, see Figure 1.24, have booms that are supported by two "towers" so that the crane provides a portal over the structure. The portal crane cannot yaw, so movement of the load is carried out by the whole crane, which is driven on installed wheels at the base of support legs, moving in the constructions work's length axis, and a hook-trolley running to and fro on the cross-bar of the portal frame. Portal cranes are often specially built to fit the task, and sometimes the jib is cantilevered over the portal crane, avoiding having to arrange storage space between the rail system and the body of the structure being constructed.

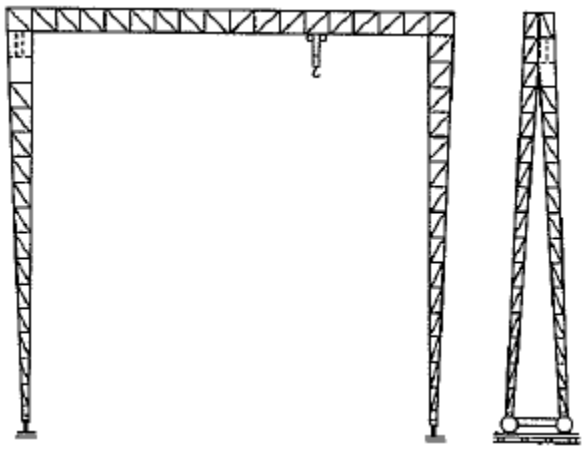

Figure 1.24: Portal Crane.

Truck mounted cranes

This is a crane boom mounted on trucks. The effect to the crane's hydraulic system is supplied by the vehicle's engine. The operation of the crane is done from a control panel, which is permanently mounted on the truck or boom. The truck can be equipped with outriggers. Figure 1.25 shows the combinations of load and outreach for a very small and a very large truck crane. Especially when large loads are being lifted there are special requirements for hook placement on the crane boom. The big crane boom can be extended with a jib, so the range is increased to 26 m. The permissible load is just over 800 kg here.

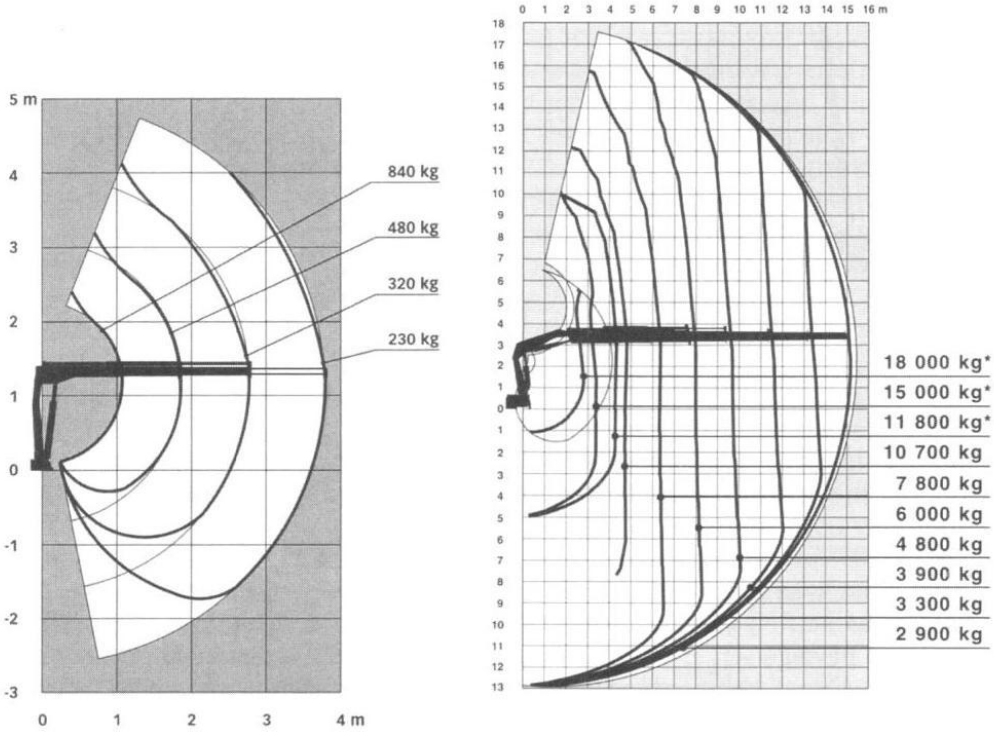

Figure 1.25: Load diagram for small and large truck cranes (HIAB 008T and HIAB 550-6).

Tractor cranes

A tractor crane is a tractor equipped with a crane jib, which can be used for smaller loads. The tractor is equipped with outriggers, so the supporting surface increases. Table 1.17 shows data for two tractor cranes.

Tractor	Volvo BM	IH 955
Crane manufacture	HIAB	Effer
Max. Moment effect	8 tons meter	8 tons meter
Example of lifting ability:	4.4 tons, outreach 1.75m 1.0 tons, outreach 7.8m	3.9 tons, outreach 2.0 m 0.55 tons, outreach 10.7m
Length-width-height	5.0 - 2.3 – 3.5 m	5.5 - 2.3 - 3.4 m
Motor effect	76 HK	76 HK

Table 1.17: Data for tractor cranes.

Crane tracks

Crane tracks must, as shown in Figure 1.26, be laid down with a good distance from the track to slopes, excavations, fixed objects and material storage, etc. For semi-mobile cranes, one must for safety reasons recon with the chassis and ballast blocks protruding about half-track distance outside the track itself. Generally, rail-driven tower cranes are characterized by large area consumption on building sites because of their often very large gauge.

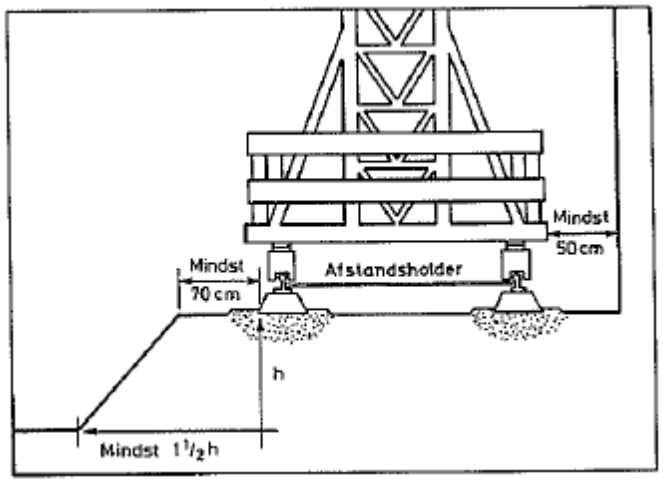

Figure 1.26: Crane rail and regulations about distances..

Ballast under the tracks will normally consist of crushed rock 12/24 and, if bottom conditions require it, additionally of stabilised gravel. The ballast width must be at least 1500 mm above and have evenly sloping sides (excavated slope at least 2:1). One must ensure that there is drainage from the crane track surface and that this is not laid over soft bottom from the drainage pipe fill back´s.

The ballast height is determined by the Nomo gram, see Figure 1.27. The maximal bogie pressure is drawn-in on the bottom left-hand scale. From here one goes vertically up to the line for the wheel spacing of the bogie, and then horizontally to the right to the curve for the building site's permissible soil pressure. Vertically below this point, the total ballast height is read on the lower right-hand scale. The curve for the permissible soil pressure = 2 kp/cm^2, which corresponds to approx. 200 kN/m^2, distributes the total ballast height into crushed rock and stabilised gravel, but the crushed rock height must always be at least 120 mm.

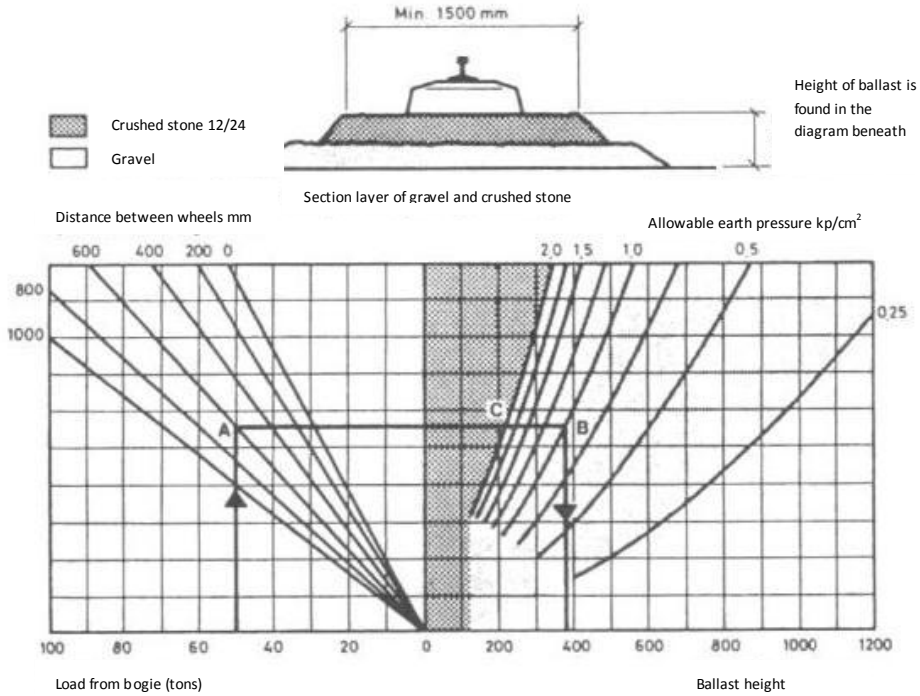

Figure 1.27: Nomo gram for determination of ballast height.

In the following drawn-in example you therefore get 220 mm crushed rock and 150 mm stabilised gravel. The guidance values for permissible soil pressure are given in Table 1.18.

Since these values are difficult to determine, it is advisable to find the actual values in the geotechnical investigations for the site. Nomo grams are also calculated for the sleepers and rails indicated in Table 1.19.

Rails and sleepers usually arrive on site in sections of 6 m, where they are assembled with fish joint´s so that the air gap between rail connections do not become larger than 5 mm; this is important not least where tracks switch. Tracks must be laid perfectly level both lengthwise and across. Spacers, between the first and second sleeper for each joint between rail sections (i.e., per 6m) are mounted to maintain the gauge. However, a buffer is positioned at the end of the track.

Soil type	Estimated permissible soil pressure
Fine sand	130 kN/m² ~ 1.3 kp/cm²
Gravel or sand	200 kN/m² ~ 2.0 kp/cm²
Clay or fine silt, loose	25 kN/m² ~ 0.25 kp/cm²
Clay or fine silt, half-firm	50 kN/m² ~ 0.5 kp/cm²
Clay or fine silt, firm	100 kN/m² ~ 1.0 kp/cm²
Clay or fine silt, very firm	200 kN/m² ~ 2.0 kp/cm²

Table 1.18: Estimated permissible soil pressure under crane tracks.

	SRS concrete sleeper 132	SRS concrete sleeper 133
Maximal bogie pressure	25 t.	50 t.
Width-length-height	300-720-200 mm.	420-720-200mm.
Number of sleepers per 6m.	9	9
Weight of rail	43 kg/m	50 kg/m

Table 1.19: Concrete sleepers and rails

The ballast width is controlled each week. The rail height is checked, and sleeper soffits are possibly underpinned with broken stone, and the fishplates are also inspected and tighten if necessary.

The rails can be bent, and the track can be formed as curves. Normally, it is calculated that the minimum curve radius for the inner track may be two times the gauge.

1.2.5 Safety provisions

Cranes must be established so there is no risk of collision with other cranes, buildings, phone lines, etc., just as safety distances to overhead cables must be respected (see Section 1.1.3). In setting-up rail-driven cranes or mobile cranes, there must be room for a person between the undercarriage and, e.g., the adjacent building or structure. Unfortunately, there have been countless crane accidents over time. To counter these, a number of safety provisions have been introduced, the most important of which are listed below:

There are specific requirements for crane *operators' skills*. Crane operators are namely responsible for ensuring that work with cranes are executed in a safe and responsible manner, including observing laws, rules, requirements and instructions that are valid for crane operations. There is a requirement that crane operators have a crane operator certificate for a series of crane types. To obtain a certificate, the person must be 18 years old, have a medical certificate stating that they are not unsuited from a health perspective to operate a crane, and, furthermore, the person must have passed a theoretical and practical test in operating a crane.

Certificate category	Crane type (only commonly occurring cranes on construction sites are mentioned)
A	Turning tower crane. The certificate also applies to C-cranes.
B	Mobile Cranes. The certificate also applies to C-cranes and construction machinery that is used as a crane. If the certificate is acquired before 1.1.2000, it also applies to D and E-cranes.
C	All other certificate demanding cranes, except cranes listed under D, E and G.
D	Truck mounted cranes over eight tons meters, up to and including 25 tons metres. For assembly work, etc., however, 0-25 tons metres.
E	Truck mounted cranes over 25 tons metres.
G	Construction machinery arranged as, and used for, crane work.
• Telescopic loaders that are equipped and used for crane work, that requires D-certificate up to 25 tons metres, and E-Certificate over 25 tons metres. • Towing shovel machines that are used as cranes require B-certificates.	

Table 1.20: Crane certificate categories.

Crane operator certificates are grouped into five categories. Table 1.20 indicates the correlation between category and type of crane.

A Crane Operator Certificate is not required in the following cases; cf. Factory Inspection's Departmental Order re Crane Operator Certificates:

- When it is out of question that the lowering or rotation of the load can cause damage to the crane operator or others. This will normally require that the crane operates in a completely sealed off area where people cannot enter.
- For series-lifts with special purpose-tailored lifting equipment, e.g., lifting of similar items as part of a defined workflow. The lifting height must not exceed 1.5 m measured from the ground to the load's lowest point.
- When the load or the burden always falls within the crane's supported surface (for example, as for portal cranes and gantry cranes), so the burden does not give the crane a tipping-torque action, and the maximum permissible load is not over 5,000 kg.
- For console cranes, for among other things workshops, use with maximum loads less than 5,000 kg (but more than 5,000 kg in special cases).
- For truck mounted cranes not exceeding 8 tons metres.

- The lifting gear on board ships.

Where multiple cranes, or more than one winch in the same crane, lift and carry a load, special vigilance must be exercised and special safety provisions must be observed. Notably, the weight distribution must, for each crane or winch lifting and transporting, be calculated, and the load on each crane must not exceed 75% of the crane's maximum permissible load under the current outlay. For portal cranes, the rules are a little more lenient. Lifting simultaneously can only be performed by crane operators holding a certificate. For further details on rules for simultaneous lifting, see the Factory Inspection's announcement regarding this subject.

Other precautions:

- After the erection of the crane, the crane must be sample-loaded with 25% overload, and it must be verified that the required overload-fuses are adjusted to stopping crane movements when the permissible load is exceeded.
- The height-stop and signal regulated apparatus for rail driving (horn, bells, etc.) must be controlled.
- Signs must be posted showing the permissible load, and the crane operator must know the weight of the burdens carried, and he/she must have access to a manual in Danish.
- Rotating Tower Cranes must not come so close together that their counter jibs can collide. Similarly, rail cranes must be parked so far apart that jibs can yaw freely in the wind.
- Cross-pulls must not be performed, i.e., the crane's hook must not be pulled along the ground to the load because the crane's jib-reach is insufficient; resulting in the load having to be dragged before it is lifted.
- Fishing" should not be performed by the crane, i.e., for example, trying to lift a piece of formwork, which is not completely liberated from the concrete beforehand.
- The crane operator should never leave his crane with a hanging load. This applies also to heavy shovels or other auxiliary equipment such as lifting beams, as the braking system may fail during cooling.
- Crane operators must as far as possible avoid moving his load over places where people are engaged with other work.
- Tower cranes are reckless to use from a safety point-of-view when wind the speed is over 15 metres per second corresponding to wind force 7, where even large tree trunks move and weak twigs break off.
- Passenger transport with cranes are generally prohibited, but may in exceptional individual cases be accepted. It is permissible to lift people in baskets or platforms using a crane when the lift is of a shorter duration, lighter work, or on matters of a very special nature of shorter duration. For tasks of longer duration, dispensation must be sought.
- Helmets are mandatory in the crane radius area.