TOWER CRANE LOCATION ON SITE FOR BUILDINGS

Peter Makýš
Slovak University of Technology in Bratislava, Faculty of Civil Engineering,
Bratislava, Slovak Republic
peter.makys@stuba.sk

The tower cranes belong to essential building machines which are widely used for transport of the construction products from storage area or vehicle to their final positions in process of building-up of the constructions. Their positioning affects a fluency, costs and total consumed time of building-up. This article is concerned with analysis of possibilities of the tower crane placing in site, with risk identification for each single variant and recommendations on design of tower crane positioning in case of several situations. It also analysis the problematic of mounting and dismounting of tower cranes and risks related to design of higher number of the cranes. At the close it defines a procedure how to determine optimum distance of the tower crane with folding jib and the building.

KEYWORDS: crane, site, construction.

INTRODUCTION

Tower cranes represent crucial construction mechanisms influencing the course of high-rise construction. The cranes project specifying their number, type and location is decisive for work organisation on site, construction term and construction costs.

In Slovakia, crane project is drafted prior to the issuing of construction permit. The permitting authority requires for the submitted project documentation to also include "Construction Organisation Plan" which is to document that the project is feasible. Further, it shows environmental impacts throughout construction (Lavrincikova, 2001). This part of project documentation deals with the construction organisation concept and also defines the types of tower cranes, lengths of beams, their location, method of cranes fixation and their maximum heights, method of construction materials supply, method of cranes assembly and disassembly, as well as electric power requirements (Makýš, et al., 2005), (Szalayova, 2004). Utility managers voice their opinions on the proposed facts, including air traffic authority in case of high-rises. The entire documentation is studied by the permitting authority. This documentation only deals with construction concept. Therefore, the facts on cranes are only general and require further detailing.

Actual and detailed plan of tower cranes is prepared by the contractor (Kozlovská et al, 2005). The contractor modifies facts included in the Construction Organisation Plan depending on the actual project status and types of cranes available at the time of construction. Further, the contractor studies crane load on subgrade, which represents a basis for suitable foundation structure.

The development of a tower cranes plan is not a simple task. The attempt to speed up the construction process is manifested in the higher number of tower cranes used within one site (Figure 1), whereby, optimisation of their distribution on the site is one of the key tasks of the plan. Tower cranes distribution plan needs to be processed so as to provide for the following:

- Coverage of places requiring load transport (construction material, parts, various equipment or structures) by a crane with sufficient carrying capacity;
- Coverage of load supply places, the best would be directly above transport means, by a crane with sufficient carrying capacity;
- Crane positioning in a place posing minimum obstacle to construction progress and on-site transport;
- Sufficient crane system performance enabling project supply at the required rate;
- Cranes installation and removal;
- If necessary, cranes anchoring in the high-rise structure, and last but not least
- Maximum operating and standby safety.

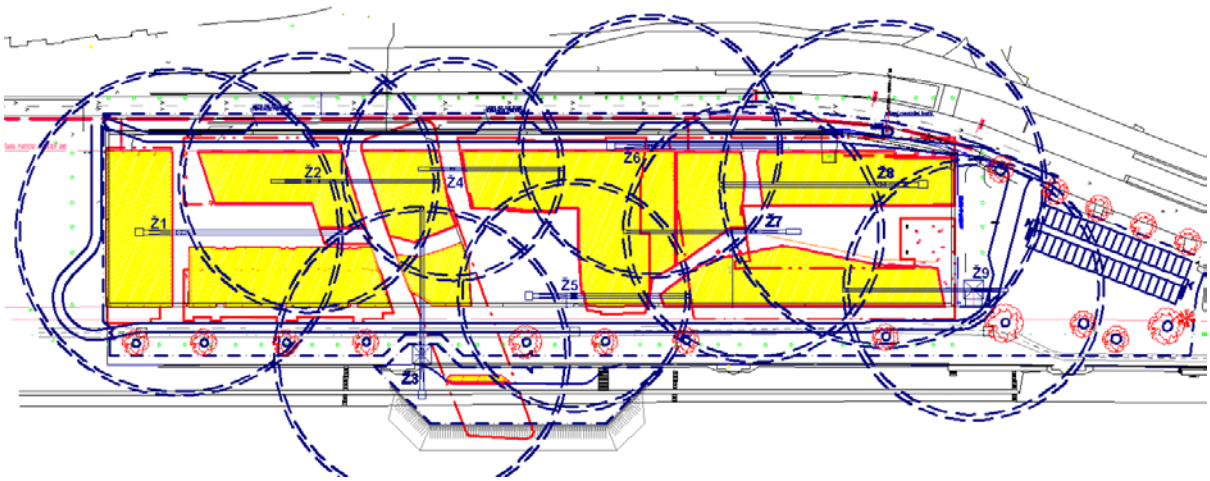


Figure 1: Tower Cranes Plan – Multifunctional Complex RiverPark Bratislava

Depending on crane positioning within the site, we may speak of a position outside or inside the construction project floor plan.

CRANE POSITIONING OUTSIDE THE CONSTRUCTION PROJECT FLOOR PLAN

In terms of construction progress, it is better to place a tower crane outside the floor plan of the constructed structure. Such crane does not pose an obstacle to construction work progress and, if necessary, the date of its removal may be shifted with no negative impact on construction process. It also enables early crane installation prior to the first work on foundation structures. Crane positioning outside the floor plan of the constructed structure provides for simple crane supply with construction material (Motyčka, 2000) and good view from the crane operator's cabin on the transport means during material collection, which speeds up crane work and improves work safety.

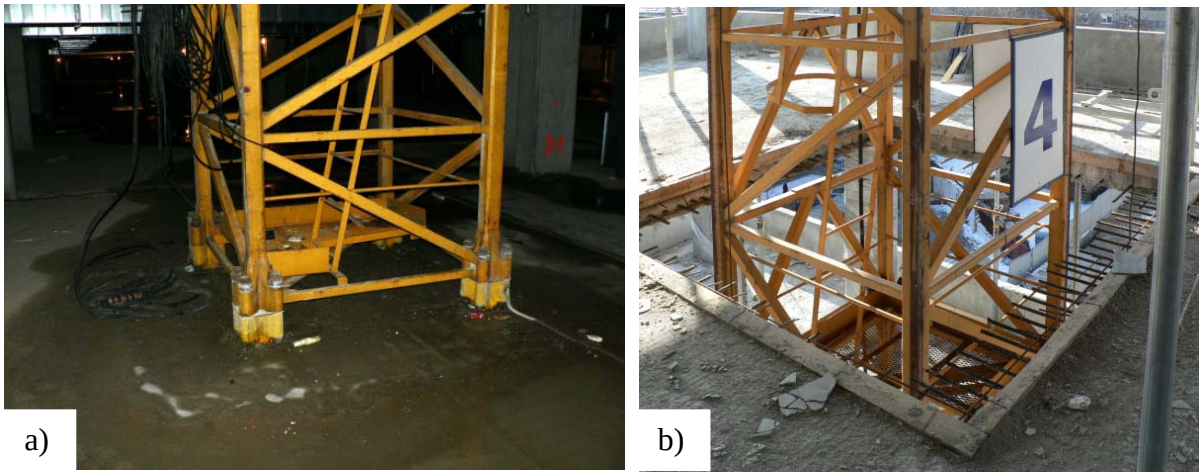
However, in this type of crane positioning, complications may be caused existing underground infrastructure services in front of the structure and their protection zones (high-pressure gas pipelines, sewage collector, etc.), outlying underground part of the structure or construction pit for basement complex of the structure. Then, the tower crane needs to be moved away from the structure, to a distance posing no threat to underground infrastructure services or construction pit wall stability, possibly, special foundations have to be prepared

for the crane, e.g. micropilots, to avoid load on the construction pit wall. A crane positioned outside the constructed structure may also call for the need to occupy larger site and use more powerful and expensive installation mechanisms with longer reach. Especially the limited special conditions within a site and the desire to minimise crane costs often require crane placement within the constructed structure.

CRANE POSITIONING WITHIN THE CONSTRUCTION PROJECT FLOOR PLAN

Should the crane be positioned within the constructed structure floor plan, it is often installed on the structure's based structure, which is modified adequately (Figure 2a). Part of the base structure, where the crane is to be anchored, may be constructed in advance, which speeds up the construction process. Placement within the structure minimises requirements for horizontal reach of the crane. Therefore, its beam may be shorter, compared to crane installed outside the floor plan of the structure.

However, crane positioning within the structure complicates construction progress. In most cases, it requires the leaving of assembly holes in ceiling structures for the crane tower (Figure 2b). The position of assembly holes is assessed statically. The size of an assembly hole is designed 1.0 to 1.6 m larger than the size of the crane tower, which avoids tower collision with the ceiling slab due to the work related swing. Assembly hole size also has to enable safe crane disassembly.



a) b)

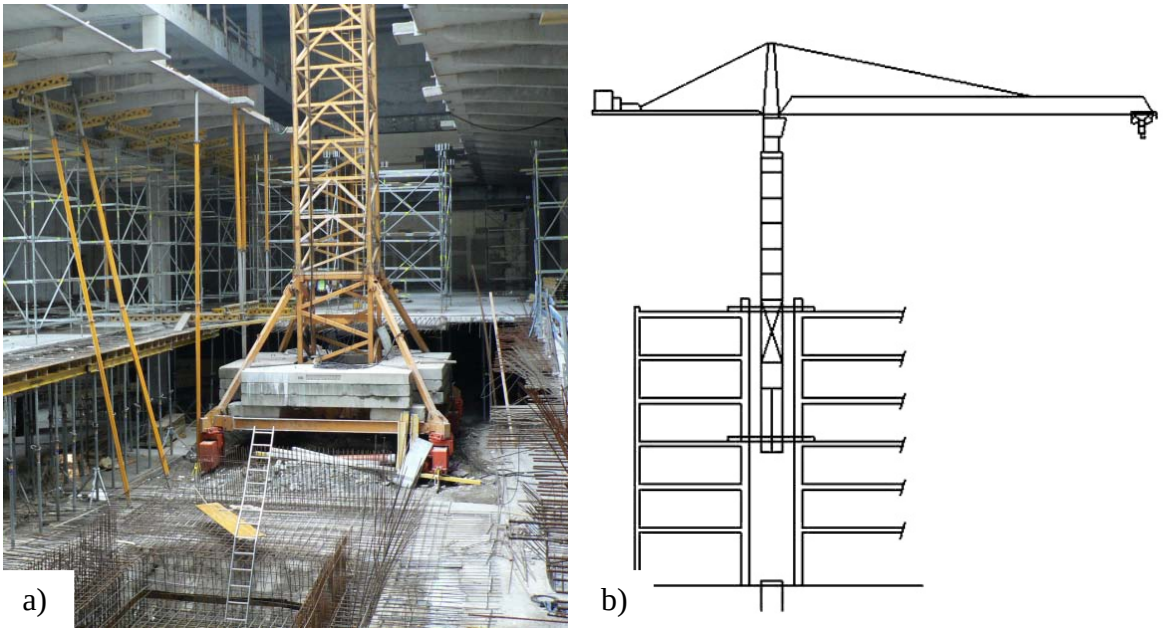
Figure 2: a) Crane Placement on Structure Base Structure, b) Assembly Hole

Assembly holes may be avoided by placing cranes e.g. into elevator shafts, which however need to be spacious enough not only for the crane tower and its assembly and disassembly, but also formwork of the shaft walls (Juríček, 2005). Therefore, elevator shafts are only rarely fit for the placement of cranes.

Inside the floor plan of a constructed structure, tower crane may also be positioned directly onto terrain (Figure 3a) and shifted to give way to further construction following the completion of a certain structure part. This construction method is suitable in projects divided into various sections – usually in low-rise buildings. In this case too, the crane may be installed prior to the first work on foundation structure and a shorter beam crane is sufficient.

On the other hand, crane relocation is only possible following the installation of all heavy parts of the construction structure, which may slow down construction progress. There may also be a problem in case of underground water presence. The said crane installation hinders the completion base structure and construction of watertight basin. In case of underground water presence, its level needs to be lowered by pumping for a relatively long period of time.

In case of high-rises, scansorial cranes may be used. Initially, these cranes are installed onto foundations. Later, however, they detach and climb up along with the building using its structure, to which they are attached (Figure 3b). They are positioned within the structure floor plan, usually inside elevator shafts. Disassembly is done from a helicopter, or via a light columnar support crane. These cranes are little used in the European Union. They are especially known from abroad, e.g. the U.S.A, Dubai. According to informative calculations, they would be feasible for buildings above cca 250 m in Slovakia.



a) b)

Figure 3: a) C rane P ositioning ont o T errain w ithin S tructure F loor P lan – Aupark B ratislava, b) Scansorial Crane Scheme

Cramped site conditions, as well as construction progress may establish a situation, in which tower crane needs to be installed onto a completed ceiling structure. This solution is used, e.g. for the installation of support cranes speeding up construction, possibly to relocate tower crane at a later stage. Ceiling structure is assessed by a structural designer and reinforced or supported by struts if necessary (Figure 4a). Struts transfer crane load onto several ceiling slabs under each other, possibly into the base structure. Crane may be installed onto ceiling structure after the bearing structures reach the necessary strength, which impacts construction progress. Smaller and lighter tower cranes tend to be installed onto ceiling structures. However, with sufficient support, even large and heavy cranes may be installed this way.

TOWER CRANES INSTALLATION AND REMOVAL

When drafting a tower cranes plan, crane installation and removal requirements may pose limiting conditions. Many tower cranes are composed of several parts assembled directly on

site using other assembly means, usually mobile crane. It has to reach above the centre of gravity of the beam, counter beam and above the tower of the assembled crane and sufficient bearing capacity in these places. Weight of the heaviest crane parts depends on the crane type and may reach from 3 to 12 t. Crane assembly is not coupled with any problems, since the site offers plenty of space in the initial phases and there is good access to the assembly site. When removing a tower crane, the constructed structure establishes a new obstacle. This is a problem especially in the removal of cranes situated within the floor plan of a structure, when the car mounted crane needs to reach the crane to be removed over the edge of the finished structure (Figure 4b). Mobile cranes dispose of high carrying capacity. However, this carrying capacity drops significantly with the beam disengagement. For example, mobile crane Liebherr LTM 1090 has maximum carrying capacity of 90 t with a 3 m overhang. However, this carrying capacity drops by 94% with horizontal overhang of 25 m. Therefore, tower crane may only be installed in a certain distance from the structure's edge that is accessible for removal, where the mobile crane will have reach with the required carrying capacity.

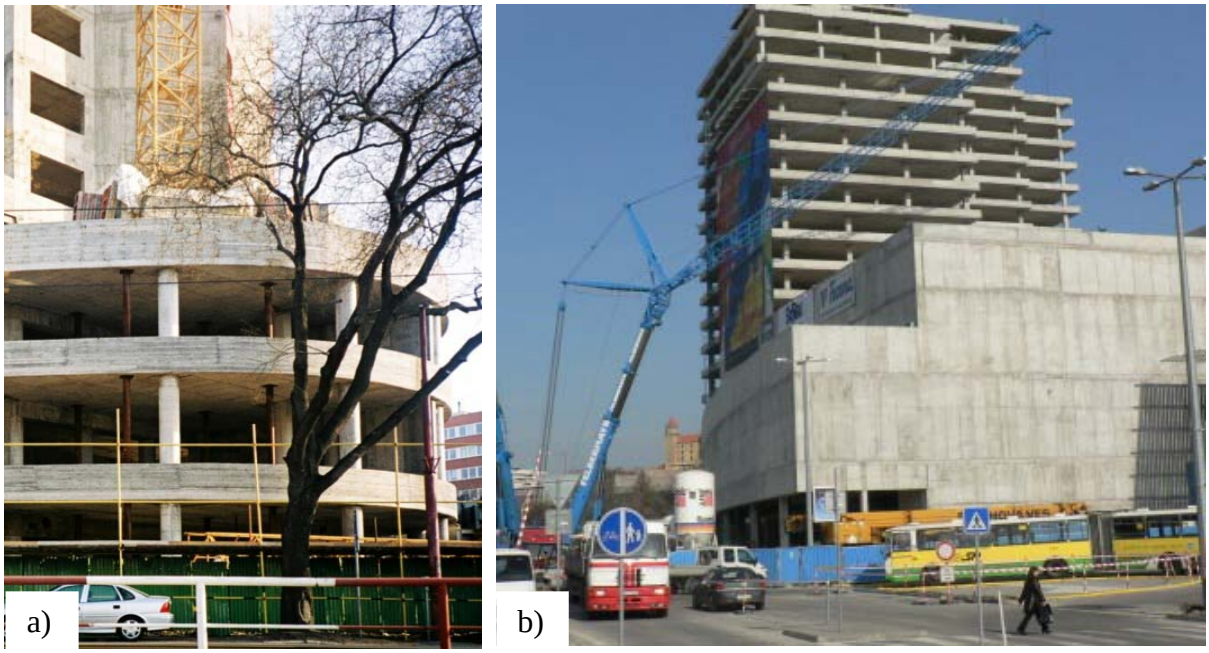


Figure 4: a) Crane on Ceiling Structure of the 3th floor – Gloria Bratislava, b) Removal of Crane Tower from Structure – Aupark Bratislava

Figure 5 represents an example of assembly means for business centre in Bratislava. Significant floor plan size of the structure and construction conditions called for tower crane location as deep in the structure as possible. C1 crane is Liebherr 71 ECB type with 47.5 m long beam with carrying capacity of the heaviest part representing 4.4 t including the required reserve. C2 crane is Liebherr 280 ECH type with 70 m long beam with carrying capacity of the heaviest part representing 11.1 t including the required reserve. C2 crane will be removed using mobile crane (C3 – Liebherr LTM 1400), which needs to use framework beam extension to increase its reach.

In extreme, the tower crane may also be removed using a helicopter. This removal method is especially known from abroad. Today, we have problems with availability of suitable

helicopters. Mi-17 helicopter, used for assembly work in Slovakia, has suspended load carrying capacity of only 4.4 t, which is usually insufficient for tower crane installation.

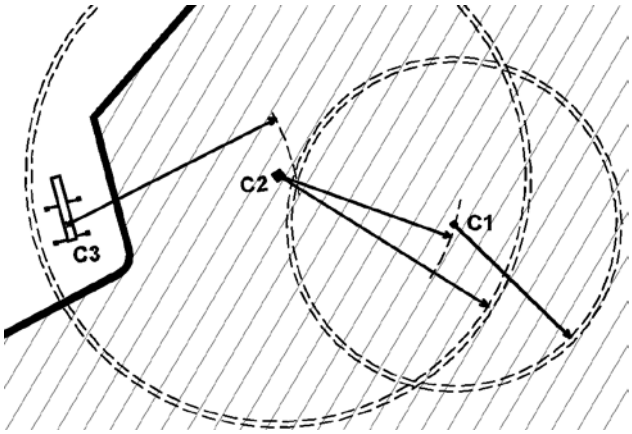


Figure 5: Crane Located within Structure Floor Plan – Business Centre Bratislava Lamač

TOWER CRANES HEIGHT

In larger projects, also with respect to the relatively short construction period, a larger number of tower cranes is usually planned. Plan of their arrangement needs to establish conditions for safe work to avoid their mutual collision (Hulinova, 2005). Therefore, respective cranes are planned with differing levels of beams. Thereby, the distance between any structure of two neighbouring cranes needs to represent minimum 1m, 2m is better. It is also necessary to consider, that to avoid crane tipping in strong wind, the crane needs to be able to position its beam downwind, meaning, that it needs to be able to rotate freely 360°. Therefore, when planning for several tower cranes, their height depends not only from building height, but also from the height of the neighbouring cranes (Figure 6). When using several cranes with partially overlapping reach, some of the cranes may need to be designed in big height.

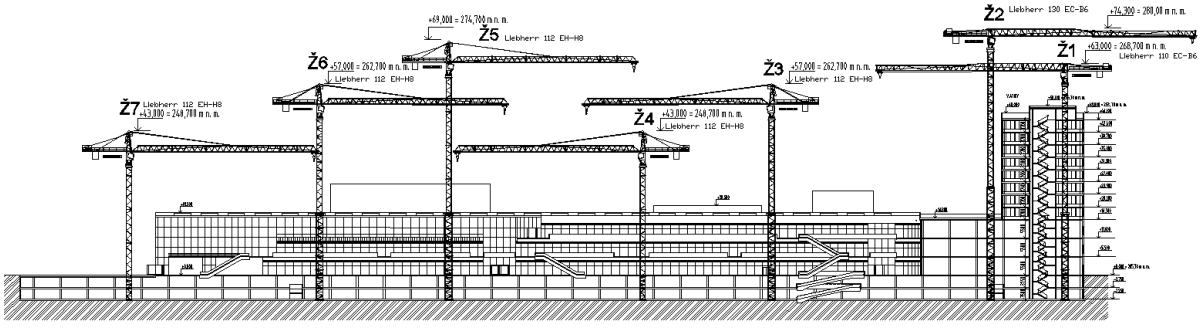


Figure 6: Vertical Arrangement of Tower Cranes – AUPARK Košice

The permitted tower cranes height depends on the permit of the local aviation authority defining not only maximum heights of buildings, but also of any temporary structures, including assembly means. This height is defined so as not to threaten the safety of air traffic.

Thus, through its requirements for maximum height of cranes, the aviation authority may also impact their number and location on site.

FOLDING JIB CRANES

Folding jib cranes are frequently used for construction. With high buildings, their horizontal reach over the building depends not only from the length of the jib, but also from the height of the building and distance between the crane and the building (Figure 7). The dependence between crane to building distance (X_c) and its horizontal reach over building (X_o) can be described with the following formula:

$$X_O = l_v \cdot \frac{(X_c - X_{ot}) \cdot \sqrt{(X_c - X_{ot})^2 + (h_O - h_{ot})^2 - b_r^2} - (h_O - h_{ot}) \cdot b_r}{(X_c - X_{ot})^2 + (h_O - h_{ot})^2} - (X_c - X_{ot}) \quad (1)$$

where: X_O is crane reach over building (m),
X_c - distance of jib horizontal rotation axis from building (m),
X_v - horizontal reach of crane jib
X_{ot} - horizontal distance between jib vertical and horizontal rotation axis (m),
l_v - length of jib (m),
h_O - height of building (m),
h_{ot} - height of the location of jib vertical rotation axis (m),
b_r - safe distance to building edge (m).

Safe distance (b_r) should prevent the jib from coming into contact with the building. It includes the jib to building distance (50 cm is recommended as a minimum) and jib assembly.

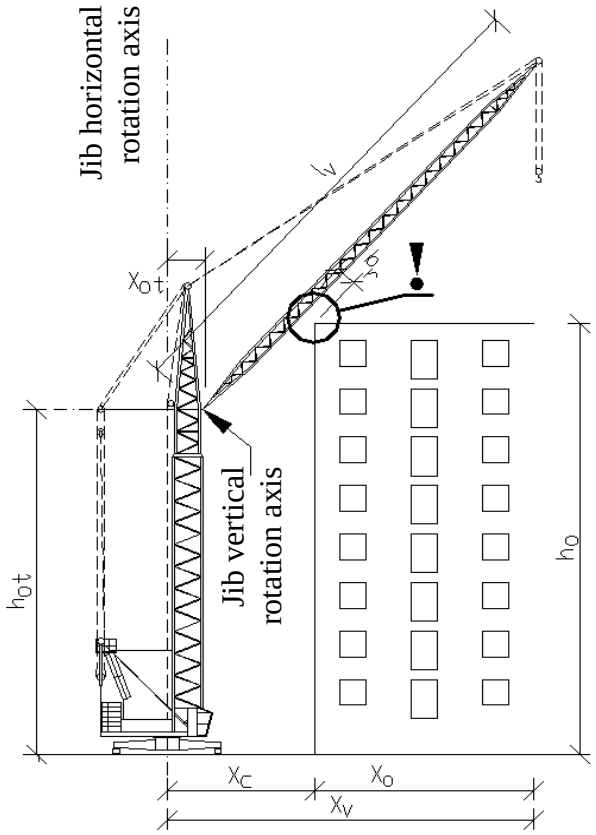


Figure 7: Location of folding jib crane

CONCLUSION

Development of optimum tower cranes plan for the conditions of a project calls for sufficient practical experience and theoretic knowledge. By paying sufficient attention to this process in the preparatory phase, the contractor may establish conditions for smooth and efficient construction (Jarsky, 2000) and observation of the required construction term.

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