

PROPOSAL OF LIFTING MECHANISMS IN CONSTRUCTION SITES

Martin Sterba¹, David Cech¹, Vit Motycka¹

¹Brno University of Technology, Faculty of Civil Engineering,
Veveří 331/95, Brno 602 00, Czech Republic



Abstract

The shortening of construction time and an attempt to lower the costs of the construction have become important construction trends. A significant factor in building construction is an adequately chosen lifting mechanism. It has to be chosen not only in order to save time but it also has to be financially advantageous.

This article analyzes contemporary methods that are used for lifting mechanisms proposals. It shows the pros and cons of such methods and it attempts to show the right direction for the development of a new method.

The conclusion of this article highlights the necessity to create a new and more exact method for the optimal proposal of lifting mechanisms and their systems.

Key words: Proposal optimization, lifting mechanism, construction site, performance, working cycle

INTRODUCTION

Recently, the construction speed and low costs have become important criteria in construction. This trend started to result in low quality buildings which have been negatively perceived. If the two criteria are considered, any maker is pushed to work without detailed planning of the construction process and they will not be able to ensure that the building will be of required quality, price and in time. Neglecting the planning process leads to construction protraction which results in delay penalty. Another variant is construction completion in required time but not in the required quality which leads to complaints and to costly repairs. All these factors lead to financial loss for the maker.

Makers start to realize this and they start to do a detailed planning. Planning methods of construction as well as program equipment that facilitate this work are sophisticated. However, one of the crucial elements in a list of financial costs is a machine holding, notably costs of lifting mechanisms.

That is why it is necessary to emphasize this subject matter and suggest an easy but effective solution to this problem. The right design of lifting mechanisms can prevent complications during construction and it can also prevent the construction costs increase.

Division of lifting mechanism

Lifting winches, telescopic manipulators, high lift trucks, building lifts, stationary cranes and mobile cranes belong to the basic lifting mechanisms.

Stationary and mobile cranes are most commonly used during the construction of large building sites. These two crane types are discussed further in this article.

Mobile cranes

Mobile cranes move independently in the construction site and also in public traffic if necessary. Its main advantage is labour mobility and these cranes do not require building of special foundation sites. On the contrary, the main disadvantage of these cranes appears to be their capability to unload only under a certain angle. By this their usability in construction of higher buildings is considerably restricted.

These cranes can be divided according to several basic criteria such as:

Type of undercarriage:

- wheel undercarriage

The main advantage of such cranes is that they can be transferred on public road. On the contrary, their main disadvantage is their lower load-carrying capacity and they cover a smaller area.



Fig. 1. An example *Grove GCK 3045* (Source: Pragotechnik 2011a, accessed February 12 2012).

- caterpillar undercarriage

The main advantage of such cranes is their movement in rough conditions of construction sites. On the opposite, their biggest disadvantage is a necessity to ensure special semi-trailers while transporting to the construction site.



Fig. 2. An example *Crane for soft terrain* (Source: Pragotechnik 2011c, accessed February 12 2012).

- Special wheel undercarriage

The main advantage of these cranes is their high load-carrying capacity and an easy unloading process. The disadvantage of these cranes is their transport to the construction site. These vehicles are large-sized that it is necessary to ask for a transit permit and the crane has to be accompanied by convoy cars.



Fig. 3. An example *Grove GMK 7450* (Source: Pragotechnik 2011b, accessed February 12 2012).

Types of crane jib:

- lattice crane jib
- telescope crane jib

Type of load chart for a crane truck:

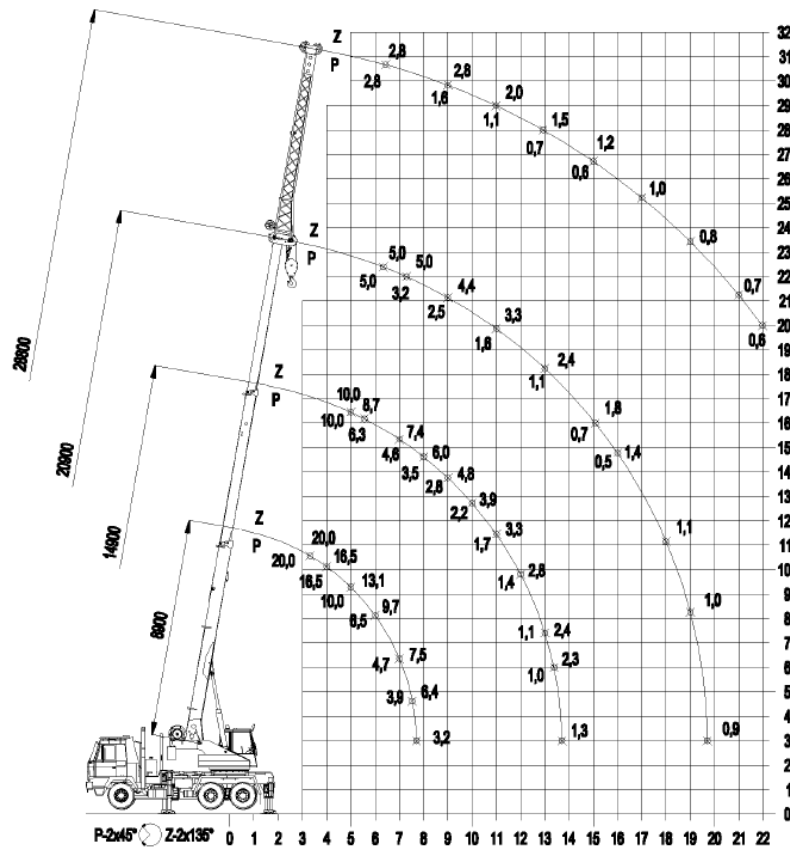


Fig. 4. An example *Load diagram* (Source: Pragotechnik 2011b, accessed February 12 2012).

Tower cranes

These cranes reach to vast areas from one point. These types of cranes are often used for high buildings and also in building sites where longer usage of the lifting mechanisms is expected. This category can be divided according to several criteria and the basic criteria appear to be:

Division according to load-carrying capacity:

- light cranes

These cranes have load-carrying capacity up to 3 tons and they are used for the construction of maximum five-floor houses with a width of about 12 metres.

- medium-size cranes

These cranes have load-carrying capacity from 3 to 6 tons and they are used for the construction of maximum twelve-floor buildings.

- heavy cranes

These cranes have load-carrying capacity from 6 tons higher and they are used for the construction of high-rise buildings and vast building complexes.

Division according to the turn type:

- with a lower turn

In this case the counterweight is located in the lower part of the tower so the crane turns around as a complete whole including the tower. It is necessary to bear this fact in mind and project the crane sufficiently far away from the building construction or any other obstacles.

- with an upper turn

In this case the counterweight is situated on the crane jib. The crane jib is rotary and the tower is stable. When using this crane type, it is possible to place the crane so that it is closer to the building construction or other obstacles.

Division according to a crane travel

- with a crane travel

This crane type is built on the crane railway. The main disadvantage of this variant is a necessity to build such a railway which is expensive. This disadvantage may appear to be insignificant because its main advantage is its capability to reach to distant places by means of one machine.

- without a crane travel

The advantage of these machines seems to be lower costs for the machine founding. On the contrary, the disadvantage is only one position of the machine which causes that it covers only a small area.

Division according to a tower type:

- with a lattice tower

This type is the most often used type. The tower height is variable and its change is done by insertion or withdrawal of a tower piece. The crane performs this change itself. The height of these types of cranes can reach heights above 100 metres. It is necessary to anchor the tower into the structure.

- with a telescopic tower

This construction is used only with small cranes. Hollow elements are telescopically inserted one into another.

- climbing cranes

This crane type has got invariable tower length. However, this crane type grows together with the construction.

Division of cranes according to their composition:

- assembly cranes

These crane types need for their composition another lifting mechanism which appears to be their main disadvantage. Their biggest advantage is that they cover a large area and their carrying capacity is high.



Fig. 5. An example *High-top-EC-H: builder* (Source: Liebherr 2006a, accessed February 13 2012).

- self-erecting cranes

These crane types do not require any other lifting mechanism to start working which is a big advantage. Nevertheless, their carrying capacity is small.



Fig. 6. An example *H Krane: builder* (Source: Liebherr 2006b, accessed February 13 2012)

Type of load chart for the tower crane:

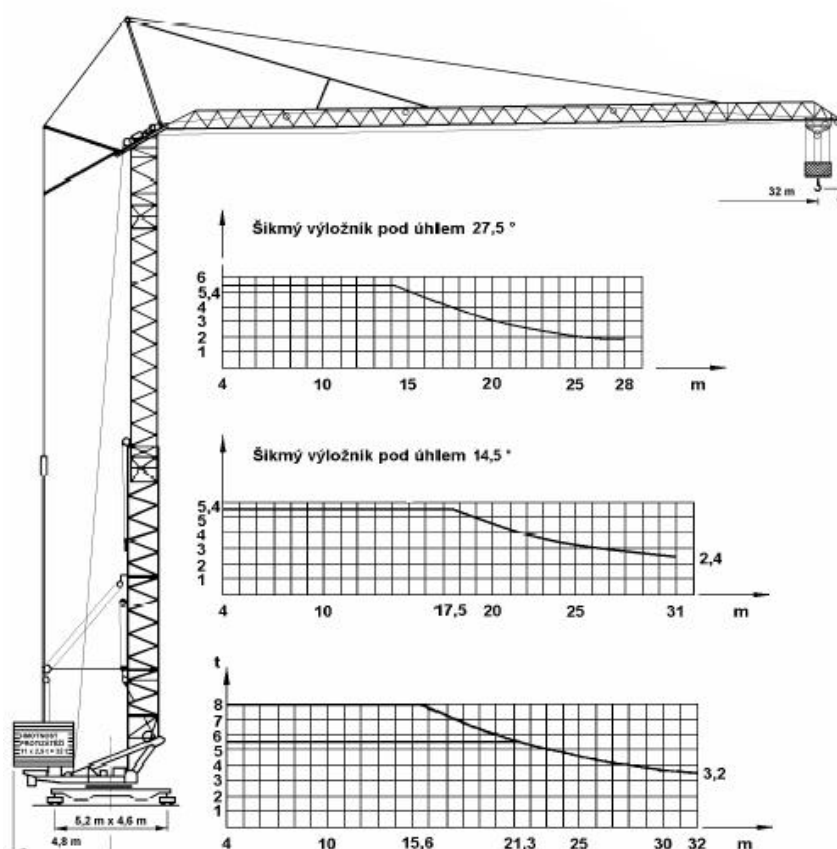


Fig. 7. An example *Load diagrams in relation to the position of the crane jib*
(Source: Craneservis 2008, accessed February 13 2012).

Contemporary methods used for lifting mechanism design in construction

In my opinion, basic methods that have been used for lifting mechanism design are relatively outdated. But these methods can be still applied. Their application is correct, nevertheless, the development of lifting mechanisms has accelerated so much that these methods have become only orientation and these methods cannot be relied upon. Such methods include for example:

Method that uses the indicator of the number of workers:

The number of necessary cranes is set according to the number of workers who need the crane for their work in the construction site. Authors of this method do not deal with the crane types and only exceptionally do they specify the relationship according to the type of the building construction. Usually from 10 to 20 workers are assigned to the construction site for one crane in action.

Method that uses the indicator of the enclosure in a unit of time:

This method relies on the number of cubic metres of the enclosure that can be built while supplied by one crane in a certain unit of time, for example one month. This method also does not consider the

crane type. One thousand cubic metres of the enclosure per month can be built while supplied by one crane.

Method that uses the indicator of weight of the transferred material in a unit of time:

In this method it is crucial how many kilonewtons of material it is possible to transfer with the help of one crane in a unit of time, for example in a month. This method does not deal with the crane type. One crane can carry 3000 – 6600 kilonewtons of material per month.

Method that uses the indicator of volume or weight of material carried in a unit of time:

The design in this case uses volume or weight of materials carried in a unit of time. It is for example a cubic metre of concrete, square metre of casing and so on.

Method of crane design according to the time norms of crane operated processes:

Priority in this method is to find out the time norms of crane operated processes because the duration of all operations can be then determined. This duration is then divided by the required construction time and the result is the final number of cranes. Rounding up of final number to integer is necessary. The final number has to be corrected with the so called coefficient of idle time of a machine. This coefficient can rise up to 48 %.

Method of estimate of time that is necessary for crane operation:

This method assumes that 80 % of construction material in the construction site will be carried by the crane. That is why it is first necessary to determine the density of the building construction. This is determined on the basis of the enclosure [m^3] and relative weight [t/m^3]. Another precondition of this method is that the crane carries at the end of the crane jib 1 ton in one cycle of 6 minutes. Based on these facts it is then possible to determine the time that is necessary for the material transfer. However, coefficients of real possibilities have to be applied.

Methods for assessing the time utilization of lifting mechanism created at vut Brno

The latest solution of this matter is represented by two methods that deal with the design of lifting mechanisms. These two methods have been dealt with in VUT Brno. The first person who started to deal with this matter was Doc. Ing. Vít Motyčka, CSc. a his follower was Ing. Lukáš Klempa. Each of them started to solve the matter with the help of a different method. Doc. Ing. Vít Motyčka, CSc. solved the matter with the utilization of complete operation. Ing. Lukáš Klempa, on the other hand, solved the method with the usage of simulation model. These two methods are discussed further in this paper.

Method of complete operation

In order to assess the time utilization of the crane by this method, it is necessary to know the time schedule of the certain construction process, list of materials, layout of construction site facilities and also a certain crane type. It is possible to design the crane type by several methods. The easiest method is based on a certain element type. Such element has to have at least one of these prerequisites:

- Carried material causes the worst bending moment in relation to the allowable crane load.
- Carried material is transferred by the crane to the furthest horizontal or vertical distance.
- Carried material requires the longest time for crane operation.

The author has created a tabular and graphic summary of materials that form the most important components of the construction. The summary shows the number of necessary cycles or the material usage. Graphs show approximate numbers of required cycles in a period of time or an amount of carried material. Numbers gained from these materials are used for calculation of the crane utilization.

The calculated approximate numbers can then be used for any crane type with similar technical parameters.

The evaluation of machine performance efficiency does not take account of time loss. Time losses appear as a consequence of stopping the operation because of operating another activity in the same time. Based on this fact, the author decided to apply mathematical method of complete operation. This method enables to set the so called operation intensity of a certain system that is dependent on the number of incoming materials that require both the operation and the number of systems that serve their expedition, in this case cranes. The basic structure of this method is as follows:

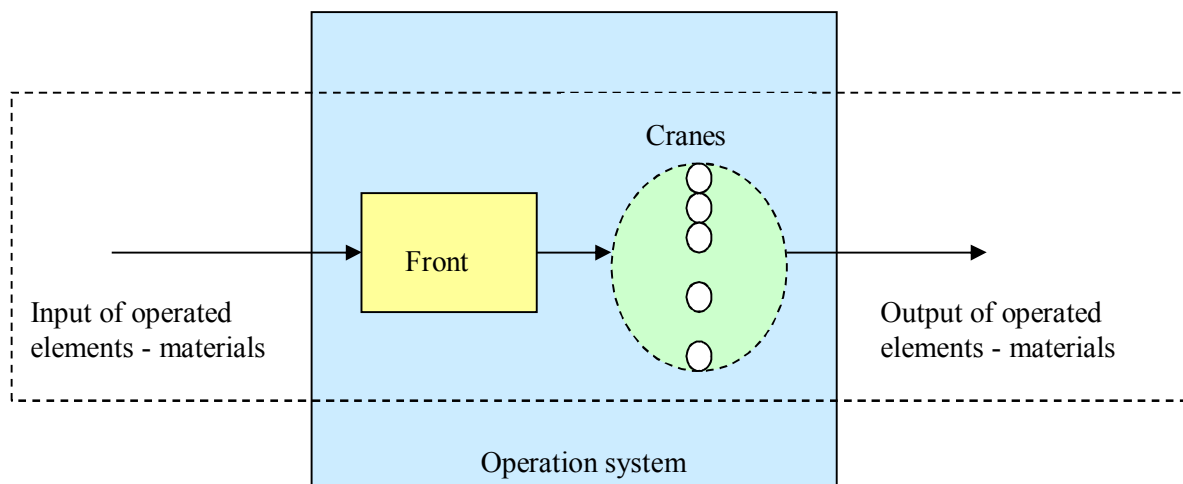


Fig. 8. An example *Basic structure of the complete operation system*

The exact simulation of all movements of cranes is necessary for the time appraisal of performance of the crane. This is not possible and that is why the author divided the construction processes into three basic groups that are as follows:

- A group of construction processes that requires full time capacity of the crane. In this case, the time of action without operation gets to zero and that is why it is possible to assume a zero value.
- A group that does not require full time capacity of the crane for the material supply. In this case unit amount of material is supplied in a certain time interval.
- A group that has unusual requirements for the crane operation. This group requires a minimum number of operation requests, usually less than once in two hours.

If all calculations indicate that the final values do not fit the time requirements for the work shifts or other required terms, it is necessary to find other possible solutions. There are several ways how this situation can be solved:

- Double shifts can be introduced in the construction site. This variant means the need of more workers.
- A time limit of the most risk activities can be extended. However, this will prolong the construction time which may result in financial sanctions.
- Stocking strategy may be applied in certain situations. It appears to be the best possible solution but it is possible to be used only in a small number of cases.

- A more powerful crane can be used. This solution appears to be the least negative and in comparison with other variants it is also the least expensive.

This method uses computer software. This enables fast calculations and in case of a mistake the correction is possible only in a certain part and there is no need to count everything over. The main disadvantage is a need of computer technology and at least a basic knowledge of it.

Method of simulation model

The basic prerequisite for the creation of this method was a summation of activities that require the crane operation. This method was created on a model of a monolithic ferroconcrete construction. Shuttering, bar setting, concrete work, removal of shuttering and setting were determined to be crucial activities for the crane operation.

Other input prerequisites in this method:

- The model is dependent on the time schedule of the construction
- The time schedule determines the time unit
- The quantity of work for each activity is calculated
- Concurrences of job performances are known
- Stockpiles and positions for material storage to the position of the crane are set
- An exact crane type is chosen

As soon as all the above mentioned criteria are applied, it is possible to compose the simulation model and then also the mathematical one.

The author introduced the simulation model in a following way:

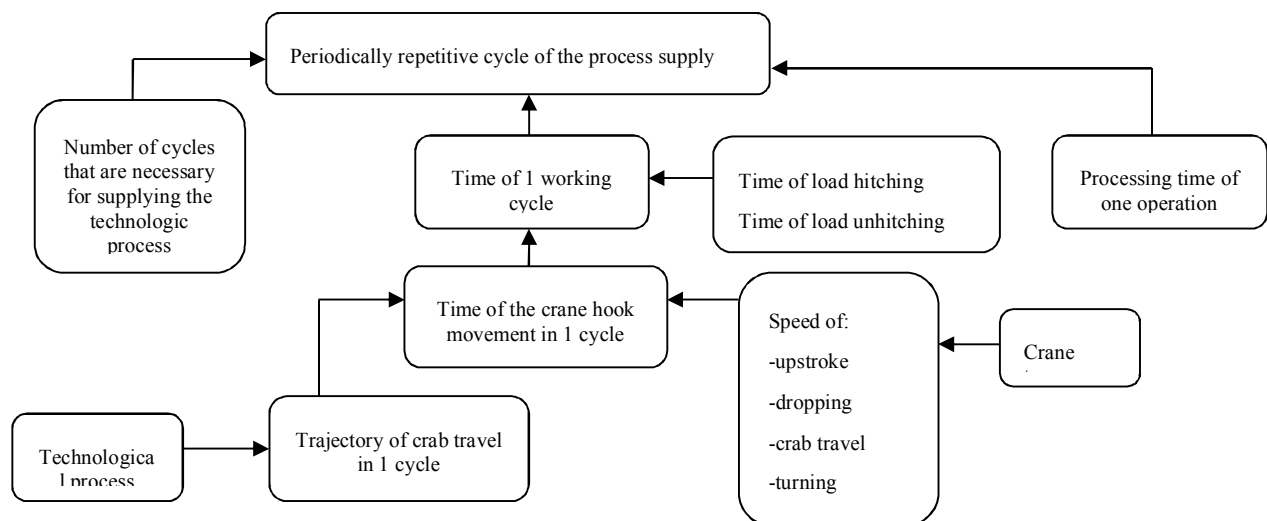


Fig. 9. An example *Simulation model*

Based on the model that is mentioned above it is necessary to calculate the values that are used in it. These values will be further used when the mathematic model is created.

The calculation of load movement in one working cycle is crucial. This calculation consists of the time that is necessary for the travel height and dropping, the time of slewing the crane jib and the time of the crane travel on a crane track. After the calculation it is possible to express the time of one working cycle of the crane. It can be done by adding the values of the load movement and the time that is necessary for hitching and unhitching of the load.

Another important step is to determine the number of cycles for single operations of the construction. These values can be gained by dividing the volume of the carried material and the volume of material that the crane carries in one working cycle. Then it is possible to determine the crane operation length in each construction process by the multiplication of the length of one working cycle with the number of finished cycles.

The author used a graph to exemplify the method of the mathematic model. Graphic representation is divided to the so called “steps”. One step represents according to the author the time after the first crane operated activity gets back to the beginning of the process.

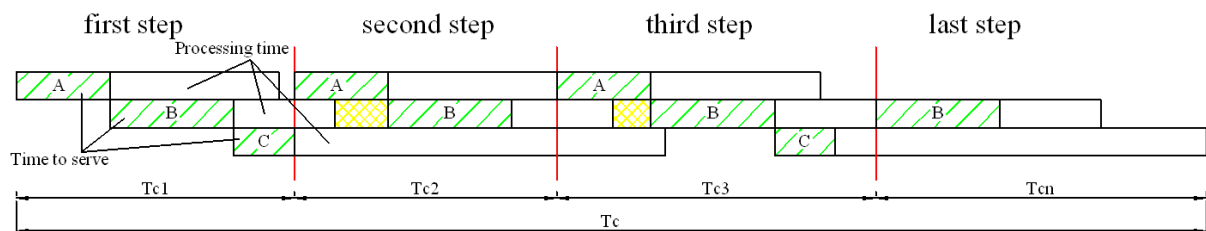


Fig. 10. An example *Division of the time interval into certain steps*

During the model composition it is necessary to include technological stops and there is also a possibility that new activities may enter the construction process. Furthermore, a division of activities on the basis of their priority is crucial. The activity of high priority is always preferred. It means that even in cases when it is put into the process later than others, its processing is preferred.

CONCLUSION – FURTHER DEVELOPMENT OF THIS MATTER

While considering the contemporary matter of lifting mechanisms, my supervisor and I have agreed that it is necessary to specify contemporary methods of proposing lifting mechanisms and take into account certain crane types. Our output should facilitate and specify the crane design or crane system in construction sites and it should be helpful to those who deal with the design of these mechanisms. The output should also lead to the financial savings for the maker. The savings can be reached by the correct proposal of these machines. Another part of our work will be a survey of input values of all actions that are commonly present in all typical construction sites that have been built recently. The aim of our work is that the method will show the most problematic parts during construction, for example the longest lasting phase when the crane will be used the most. This information will then enable to limit the crane operation time. Nevertheless, the planned period of construction should remain and the time of construction should not be prolonged in connection with the suggested machines.

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