Lifting Equipment for Construction Site Materials

Frederico Maio Henriques

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Extended Abstract

Jury

President: Prof.ª Doutora Ana Paula Patrício Teixeira Ferreira Pinto França de Santana
Supervisor: Prof. Doutor Luís Manuel Alves Dias
Member: Prof. Doutor Nuno Gonçalo Cordeiro Marques de Almeida

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1. INTRODUCTION
The construction sector in the European Union is a major component of the economy, with an output of about 1200 million euros per year (FIEC, 2012). In Portugal, as well as other countries, a general crisis in the sector is experienced currently, which reflects a significant reduction in domestic production, representing about 1.2% of EU production. This reduction can also drag the decrease in investments related to support equipment, in particular for elevation, and therefore compromise the safety and quality of construction work.

Regarding safety in construction and comparing to other EU countries, a serious problem has been observed in Portugal, where the indicators point to a high level of accidents in the sector. The cause generally aimed to justify this level of accidents, is often linked to the absence of technical safety regulations in Portuguese construction work sites. In statistical terms, the main causes of fatal accidents in the construction industry are derived 50% from high altitude falls, followed by crushing, comprising about 20% of all accidents, and 10% from burial and electrocution, while approximately 10% of the remaining accidents being associated with other causes.

Given these values, particularly in relation to high altitude falls and crushing, there is a link between these causes and the equipment. A lack of utilization and maintenance knowledge by users, may contribute to the occurrence of accidents due to dysfunction of support equipment in general, and in particular elevation.

It is in this context that the present study lends itself, in order to complement support techniques of managing construction with respect to the administration of equipment to ensure that adequate levels of safety and quality remain in the construction site.

The principal objective of this study is to present the main technical characteristics of the lifting equipment, specifically tower cranes, mobile cranes and construction hoists, as well as the procedures necessary for its entry into the European market and CE marking, taking into account the European Directive 2006/42/EC (Machinery Directive).

This study introduces key milestones that those responsible for construction should follow in order to correctly select the most suitable lifting equipment for each construction site. The receipt and control of equipment at a construction site, particularly in terms of maintenance and inspection are two aspects that were analyzed taking into account European standards regarding the equipment covered in this study.

2. TECHNICAL REGULATIONS APPLIED TO LIFTING EQUIPMENT
Regulatory documents were created in the European Union permitting the control of any action involving the manufacture, use and maintenance of machinery, in order to achieve positive results in terms of equipment quality and safety. Therefore, at the European level, legislative
directives emerged under the “New Approach”, which allow the free movement of products, particularly machinery.

In this study, the Machinery Directive (2006/42/EC) transposed into Portuguese law by Law-Decree 103/2008 was analyzed. This directive aims to ensure quality within the European Community with regards to design, manufacture and use of machinery, specifically lifting equipment and thus minimizing risks.

This Directive’s application targets principally all machines produced within the community, as well as all the machines from outside the community which had to undergo reconditioning processes. Thus, if all equipment (new or not) undergo tests and trials in accordance with all requirements of the Machinery Directive as well as the requirements of harmonized technical standards, it is clear that such machines meet the quality required for safety and health.

According to this Directive, a machine will be able to circulate and be used within the European Union, if it displays the CE brand. For this, it is necessary that the manufacturer ensures the following elements are obeyed:

1. Essential health and safety requirements relating to the design and manufacture of machinery, contained in Annex I of the Machinery Directive (2006/42/EC);
2. Technical process for machinery;
3. Instruction Manual for the machine;
4. Procedures for assessing the conformity of the machine;
5. CE declaration of conformity;
6. CE marking.

The essential health and safety requirements (1) are described in Annex I of the Directive, which is essentially composed of several clauses, of which the following are highlighted: integration of safety, ergonomics in order to minimize the discomfort worker, security and reliability of the equipment’s control systems, among others.

The technical process (2) conducted by the manufacturer shall be composed of elements that prove the technical quality of the machine, namely its description, schematic drawings, tests carried out, among others.

The instruction manual of the machine (3) is the most important document produced by the manufacturer and should contain all the information that identifies the machine and defines the main guidelines for its proper use and maintenance.
As for conformity assessment procedures (4), the manufacturer must apply one of three evaluation procedures presented below.

Whenever the machine is not listed in Annex IV of this Directive, the manufacturer applies the procedure for assessment of conformity with internal checks of the manufacturing of the machinery stated in Annex VIII of that Directive.

When the machine in question is listed in Annex IV and is manufactured in accordance with the harmonized technical standards, the manufacturer applies one of three procedures of conformity assessment: procedure of conformity assessment with internal controls of machinery manufacture; procedure of CE-type examination and also internal controls of the manufacture of machinery for the production phase, or the procedure for total quality assurance.

Lastly, when the machine in question is listed in Annex IV of the Directive and is not manufactured in accordance with harmonized standards, the manufacturer must follow one of two procedures for conformity assessment: Procedure of CE-type examination and internal control of machinery production and the procedure for total quality assurance.

It should be noted that for practical purposes there are several machines within the Annex IV, however, among others, the main machines are: sawing machines, material molding or shaping machines and machinery for lifting persons or materials.

With regards to the CE declaration of conformity (5) should be performed after an examination of the machine and must specify that the machine complies with all provisions of the Directive.

Finally, the CE marking (6) is the symbol contained in the machine, which gives evidence that it meets the conformity requirements imposed by the community Directives, allowing it to become equipment which may be placed, or made available to circulate in EU community market.

**3. TECHNICAL CHARACTERISTICS OF THE LIFTING EQUIPMENT**

As described above, the present study concentrates primarily on the safety of key lifting equipment for construction work. Thus, the study focuses on three main types of lifting equipment:

- Tower cranes, designed, manufactured and used based on EN 14439;
- Mobile cranes, designed, manufactured and used based on EN 13000;
- Construction hoists for transportation of materials and persons, designed, manufactured and used based on EN 12159;
3.1. Tower cranes
The European technical standard EN 14439 defines this equipment as being a device comprising a spinning boom on top of a steel tower, which remains approximately vertical in the working position, this being a motorized machine equipped with the ability to lift and move loads through radial, rotary and/or direct motion.

In the present study, three main types of tower cranes were defined: cranes delineated by the type of rotary mechanism; cranes defined by the boom configuration, and cranes defined by their assembly and disassembly, being that there may be cranes which are a combination of types mentioned above.

With regards the rotation mechanism, this may be located in two different points: at the base (Bottom-Spinning); or located on top of the steel tower (Top-Spinning); The second type of tower cranes (depending on the configuration of the boom) can have a horizontal, inclined or articulated boom typology. The horizontal jib crane may be defined by the existence or omission of the top tower that supports the main jib, being that cranes without this element are named Flat-Top tower cranes. Finally, as far as assembly and disassembly, tower cranes may be assembled and disassembled manually (using a mobile crane) or automatically (self-erecting tower cranes).

Regarding the foundation of the tower crane, its design depends on various factors such as load level, terrain conditions, characteristics of construction work etc.. However, three types foundation typologies may be defined: fixed base (with concrete blocks, shoes and/or concrete columns); mobile base crane (currently associated with a rail system), and auto-erecting base (hydraulic platforms).

When building taller structures, it becomes clear that a slender element such as a tower crane can become laterally unstable due to various forces, particularly the wind. As such, there are two types of elements that ensure its stability. The first type employs steel shorings and braces which rigidly connect the tower of the crane to the construction structure. The second type consists in connection the crane’s tower to rigid elements situated on the ground with a steel cable system.

Regarding the safety of use of tower cranes, EN 14439 (2009) defines what components and devices the equipment must have. Among others, the main components are as follows: limiters and indicators of maximum load, anti-collision devices, anemometers, movement limiters.
3.1.1. Tower crane selection
The selection of an appropriate crane for a construction site is a complex task, and should take into account the combination of various criteria. This task will influence the smoothness of the work, time, cost, quality and safety of the site.

The main criteria to be taken into account in the selection of a tower crane, by the construction management, are (Shapiro et al., 2011):

- User preference;
- Availability of the crane;
- Power source;
- Reach and capacity of the crane;
- Cost;
- Efficiency;
- Construction site environment;
- The wind at the construction site area;
- Ease of erection and dismantling.

It is noteworthy that in regards to the reach and capacity of the crane, its load diagram should be consulted, which defines the maximum load in terms of its reach and capacity. Regarding wind variants, the map of Europe winds, defined by EN 14439 should be consulted.

3.1.2. Receiving and control of tower cranes
Upon selecting the most suitable crane for the given construction work, its location in the construction site should be defined. This location should be the most suitable in order to achieve the highest level of productivity, depending essentially on crane’s reach in order to obtain the largest coverage possible.

While receiving the equipment, the construction management shall carry out the acceptance inspection of tower crane, and the subsequent confirmation of the elements that identify the conformity of the crane, namely the CE declaration of conformity, the CE marking, and the instruction manual.

In order to guarantee smooth operation and site safety of the tower crane, the construction management should perform a proper examination of the equipment. This control is satisfied by the construction management who designates the correct personnel to execute the plan of inspection and maintenance of the crane.

The technical standards in question, specifically EN 14439 and FEM 1.007, define five levels of inspection: daily, frequent, periodic, thorough and exceptional.
In respect to daily inspections, they shall be made by certified operator of the crane, and target only a visual and general inspection of the equipment, performing only tests on key safety devices. About frequent and periodic inspections, those should be carried out by technical experts, being that some hydraulic and structural elements and also main accessories of the crane must be examined, these inspections must be performed monthly and semiannually. Regarding to thorough (at intervals of 2, 4, 10, 12 and 14 years) and exceptional inspections, these must be carried out by equipment specialist engineers. In the first inspection a rigorous analysis of the structure of the crane and its links is performed, whereas the second is performed after the occurrence of exceptional situations, such as collisions with the crane, storms or earthquakes.

3.1.3. Tower crane usage safety
As a security measure during the use of tower cranes, there must be a collection of the main risks and mitigation measures realized. The main risks and preventive measures are:

- The risk of imbalance, falling or collision of the crane and other objects;
- The risk of contact between the crane or load with power lines;
- The risk of imbalance or falling of the crane due to strong winds;

Relative to the first risk, this can be prevented if the safety components of the crane, such as limiters devices, are in good operating condition, and there is proper coordination at the site between the users of the equipment. To mitigate the risk of contact with power lines, they must, whenever possible, be removed or protected, otherwise there should be minimum safety distances set between the crane and the power lines, depending on their voltage. For lines with less than 50,000 volts the minimum distance is 3 meters, for values between 50,000 and 250,000, 250,000 and 500,000, and values greater than 500,000 volts, the distances may be 5, 8 and 10 meters respectively (Alves Dias, 2011).

Regarding the risk associated with imbalance or fall due to strong winds, this can be mitigated by placing the equipment out of service. Wind speeds referenced in the normalization, that may lead to placing the crane out of service, are 46 km/h if the crane is located in urban areas and 65 km/h if it is located in an open environment (near sea areas) (Alves Dias, 2011).

During the course of this study there have been referenced several checks to be carried out, usually by the operator, before, during and after placing the cranes in service each working day.

Before placing the crane in service, the main checks are:
- The correct operation of the safety devices;
- Check or estimate the weight of the load to be lifted, and consult the load diagram;
• Evaluate the wind conditions and their interaction with the shape of the load, being that it may be necessary to calculate the force given the area exposed to the wind.

During crane operation, the main checks are:
• Ensure minimum safety distances to power lines;
• Placing the crane out service if wind speeds are above indicated;
• Do not use the equipment for improper purposes.

After crane operation, the main checks are:
• Not leaving the load suspended on the hook and ensuring it is placed in the starting position;
• Turn off the crane’s power supply;
• Put the jib in a free state, unlocking the rotating point.

3.2. Mobile cranes
The European technical standard (EN 13000) defines the mobile crane as a jib crane with a built-in motor that is capable of moving by itself, and without the need for fixed paths, such as the rail type.

In the present study, two important groups of mobile cranes may be highlighted: mobile cranes defined by the structure of the base (crawler crane or truck tire crane) and mobile cranes designated by the coupled boom (lattice or telescopic). In both cases, the crane is comprised by a base resting on the ground and a rotating superstructure composed of the jib, counterweights, and operator’s cab, among others.

The crawler cranes may only move inside the construction site, being useful in rough terrain and unfinished surfaces, due to its high traction force. They are also characterized by a high load capacity, since they have a large base structure that offers them stability. In the case of truck tire cranes, these are characterized by moving in and out of construction site and are particularly useful in urban areas. The stability of the truck cranes, during action, is ensured by stabilizing structures (called outriggers pads or shoes) that articulate and are placed on the pavement in order to withstand the loads to be lifted. Both types of booms (lattice and telescopic) allow great reach, although the lattice boom weighs less than the telescopic boom.

Regarding the usage safety of mobile cranes, EN 13000 defines what components and devices constitute a mobile crane. The following are the main components and devices: limiters and indicators of maximum load; anti-collision devices; anemometers; movement limiters; superstructure rotation limiters; pressure devices and leveling shoes, among others.
3.2.1. **Mobile crane selection**

The selection of the most appropriate mobile crane for a construction site is a complex task, and must meet a number of factors and conditions, such as whether or not it is necessary to occupy public roads for lifting operations. In this study, the main criteria were analyzed and taken into account for the selection of this kind of equipment. Among the main criteria, the following are highlighted (Shapiro et al., 2011):

- User preference;
- Location of the construction site
- The wind at the construction site area;
- Reach, height and capacity of the crane;
- The type of geotechnical ground;
- Cost;
- Type and duration of work.

It is worth mentioning that many of these criteria are similar to those already defined for the tower crane, given that the operation of both cranes, in terms of lifting and load, is similar.

For mobile cranes, it is also worth mentioning the importance of soil type and topography of the construction site, as this will determine which of the base types (crawler or tires) is better suited for the given situation. In regards to the capacity and reach of the crane, a load chart is also defined relating each point described by the radius and height limits given the crane's load capacity.

3.2.2. **Receiving and control of mobile cranes**

Depending on the type of work to be performed with the mobile crane as well as the type of soil or topography of the construction site, small ground leveling may be necessary, to ensure better stabilization of the equipment. During the action of receiving, the construction management should consult the documents that identify the crane, and if it is in conformity, including the CE declaration of conformity, the CE marking and the instruction manual. Then, there should be an equipment acceptance inspection, verifying the most important devices.

In order to increase proper control during possession of the crane on the construction site, the construction management shall designate the right persons to perform the inspection and maintenance plans. The EN 13000 states that it shall provide five levels of inspection: daily, frequent, periodic, thorough and exceptional content, which are similar to those defined for tower cranes in 3.1.2., with a main difference that in this case it applies to devices and constituents of the mobile crane.
3.2.3. Safety in use of mobile cranes

With regard to safety during the use of these cranes, this study referenced the potential risks and preventative measures associated with the use of mobile cranes. The main risks are as follows:

- The risk of the crane tipping;
- The risk of falling loads or any other object;
- The risk of contact with the crane and the power lines.

Relative to the first risk, tipping the crane, this may be caused mainly by the settlement of outriggers shoes, soil fault, imperfect ground leveling or by overload. The risk of falling objects or load, is mitigated, among others, by proper maintenance of cables and accessories, good control of maneuvers and proper site signaling. Finally, in regards to risk of contact of the crane with power lines, the same principles can be applied as in the case of the tower crane, therefore crane safety devices should be properly utilized and minimum safety distances mentioned in 3.1.3 should be guaranteed.

In terms of practical verifications before, during and after placing the mobile crane in service, there have been defined several checks. In addition to those already mentioned in the case of tower cranes in 3.1.3., the following presented below are highlighted:

Before placing the crane in service, the main checks are:
- Ensure proper ground leveling and horizontal placement of the outriggers pads;
- Make sure the surrounding area is clear;
- Ensure that the tires are not in contact with the ground, and stabilizing elements are well anchored to the ground.

During operation of the crane, the main checks are:
- Do not move the crane with a load;
- Do not drag loads;
- Avoid contact of the load with the crane’s superstructure.

After operating the crane, the main checks are:
- Park the crane correctly;
- Collect the boom, in case it is telescopic;
- Collect the outrigger pads.

3.3. Construction hoists

Construction hoists are utilized in construction as a means of transporting materials and/or persons.
The European technical standards applicable to this type of equipment, EN 12159 (2012) define construction hoists as temporary equipment serving various constructive roles of the construction phase. This equipment consists essentially of a transport platform or cabin, properly protected, which is coupled to a tower through steel elements, and with the aid of a mechanism it allows for vertical movement along a tower.

One objective of using construction hoists is related to the need to increase productivity during the finishing phase of building, thereby gaining an increasing demand in recent years in construction.

Two types of hoists were analyzed in the present study: cable hoists and rack hoists. The main difference between the two types of hoists is that the first type (cable) moves under tensile steel cables connected to the booth and spinning drum. The second type (rack) the booth has an electric motor that transmits the movement along the track. In any of the two types it is necessary to provide a rigid base, which binds both structures, thus absorbing reactions during movement. For elevators that reach higher heights lateral stabilization systems are provided, composed of collars and shorings that connect the lift to the rigid structure already constructed.

On safety issues, EN 12159 (2012) specifies the expected safety devices for construction hoists, especially the following: load indicators and limiters, devices that block the opening of the gate in inappropriate locations, speed limiters, among others.

### 3.3.1. Construction hoists selection

When it is necessary to select a hoist for a construction site it should begin by defining the objectives of the equipment and reflect on the selection criteria. The person responsible for equipment selection should take the following criteria in consideration (Adapted of Shapiro et al., 2011):

- Availability and user preference;
- Power source;
- Location of the construction hoist;
- Types of load to transport;
- Capacity;
- Hoist productivity;
- Cost;
- Safety.

It is worth noting the productivity criterion, given that it affects the cost and schedule of the project which are real important factors. In general, the rack lifts are more productive than the cable, not only because of their maximum speeds, but also due to the simpler process of
assembly and disassembly. In regards to safety criteria, it is obviously that rack hoist perform better due to its type of structure, and the fact that this does not depend on steel cables, which require some level of maintenance (Lagares, et al., 2012).

3.3.2. Receiving and control of construction hoists

After receiving the equipment, the construction management should conduct an acceptance inspection, which includes only a general inspection of the equipment. The construction management should also review the entire set of documents that identify the equipment, particularly if the model and series corresponds to the one selected, the CE declaration of conformity, CE marking and the instruction manual.

In regards to the control, the construction management of the construction site should carry out the inspection and maintenance plans, at the appropriate time, while also designating the right people for each task. EN 12159 (2012) and BS 7212 (2006) define that the inspections conducted are of three types: daily, thorough and exceptional.

With respect to the daily inspections, these should be carried out by the operator of the hoist and target only a general verification of the equipment and safety devices. Regarding the thorough inspections, they must be made by specialist engineers semiannually, in order to verify correct installation (initial phase), detect degradation mechanisms of cables and other components, and check for possible changes or repairs needed to be performed. Finally, exceptional inspections have occasional frequencies, only in the case of something abnormal, such as storms, earthquakes, collisions, among others.

3.3.3. Construction hoists usage safety

Regarding safety while using construction hoists, the main risks and preventive measures associated with their use are:

- The risk of transporting persons when the elevator is used only to transport materials;
- The risk associated with the decline in free fall;
- The risk associated with the opening of the gates when the elevator is in motion or in inappropriate locations;
- The risk associated with cable breaks or ruptures (for the cable type only);
- The risk associated with the contact of the elevator with power lines;
- The risk associated with falling objects during elevation,

The project manager should be properly informed of these risks when opting for the installation of an elevator in the construction site. Some of these risks outlined above can be minimized
with some common sense, providing information to workers, and timely realization of inspection plans and maintenance, including of the structure, and if applicable, the cables.

According to BS 7212 (2006) and EN 12159 (2012), the elevator operator should carry out checks before, during and after the placement of the elevator in service, every single working day. Such main checks are highlighted below:

Before placing the construction hoist in service, the main checks are:
- Check the presence of maximum weight load indication plate;
- Check the operation of safety devices;
- Check for correct cable wrapping;
- Check the operation of the gate and access platform.

During operation of the construction hoist, the main checks are:
- Respect the maximum capacity;
- Check that the speed of the cabin does not exceed 25 km/h;
- Do not operate the elevator if wind speeds near 70 km/h.

After operation the construction hoist, the main checks are:
- Stop the elevator near the ground;
- Lock the cabin;
- Check the cables;
- Turn off the engine and electrical system.

4. CONCLUSIONS

One of the factors contributing to the high level of accidents in construction sites, is related to the existing support equipment at the construction site. These equipment are sometimes underestimated for inspection and maintenance, and often their instruction manuals are not followed. Sometimes, it is observed in practice that these inspection and maintenance plans are performed by persons not accredited to do so. In order to increase construction site safety, in particular related with support equipment, great importance is placed on the management of the construction site, especially to workers with sufficient qualifications and experience.

Thus, in the present study, site supporting equipment was analyzed, specifically lifting equipment like tower cranes, mobile cranes, and construction hoists (not only for material but also person transportation).

On the other hand, in order to contribute to better support of the project management, in terms of equipment, the main criteria that influence the selection of a elevation equipment was presented, as well as the receiving of such equipment at the work site. In the case of receiving
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the equipment at the construction site, it is essential to check the documents that prove the conformity with the European Directive 2006/42/EC (Machinery Directive) and European Norms. These elements are the CE declaration of conformity, CE marking and the instruction manual of the equipment.

In order to unify and apply the information described in this study, a future study, the statistical survey of some construction sites is suggested, as well as performing a verification of the conformity of the equipment present in these construction sites, analyzing the malfunctions and accidents involving this type of equipment.

The most important factors to evaluate in the future study of these construction sites, would be the existence or lack there of controls of the equipment, such as the construction management correctly designating the right people to undertake the inspection and maintenance plans of the equipment, as well as the daily checks before, during and after the operation of the equipment every working day. Finally, as an accessory to the analysis of some construction sites, it would be important to verify how those responsible for such sites conduct the selection and receiving of the equipment, and in fact if they take into account some of the various items described in the present study.

5. REFERENCES


FIEC, European Construction Industry Federation, Obtido em Maio de 2013 de web site: http://www.fiec.eu/


