

Developing a Crane Safety Lab: A response to new OSHA guidelines on cranes which can be utilized by any Construction Management program

Bruce W. Smith, CPC and James Michael Hosey
Auburn University
Auburn, Alabama

Crane safety has changed for the construction industry since the new OSHA regulations were put in effect in November of 2010. As a result, teaching crane safety in construction management programs has become a more important part of the safety class. The authors, both authorized OSHA trainers for construction, wanted to create a lab for crane safety which could be shared with other construction management programs. The design of the lab included building a crane the students could use. The cost needed to be kept down to allow most programs to implement the lab. The storage space required also had to be kept to a minimum. The resulting derrick crane is capable of being set up by a small group of students. The lab can be run in an area about twenty-four feet square. The storage area is about four feet by twelve feet by two feet. The design of the lab took into considerations the desired learning outcomes, activities and assessment. This paper goes through reason for the lab, the educational response, the crane, the format of the lab, and the results from the instructors' and student's perspective. The lab was successful, easily replicable by other instructors, and had positive educational outcomes that could not take place in the classroom.

Key Words: Subpart CC, Crane Lab, Crane Safety

Introduction

OSHA's new crane rules became effective on November 8, 2010. There are significant changes and additions that impact the responsibilities of contractors using the equipment. The regulations also place additional responsibilities on the controlling contractor for several aspects of the crane operations. Ground conditions are the direct responsibility of the controlling contractor, as well as the need to verify subcontractors' compliance to regulations on assembly and disassembly of cranes, inspections, certification of operators (after November 2014), qualification of riggers and qualification of signal persons (OSHA 1926 Subpart CC 2013).

The additional OSHA requirements provide an educational opportunity for construction management students. Cranes vary in type and size, but there common elements to crane management. Having core knowledge of the process of crane assembly and disassembly, inspections, rigging, and signaling, would give construction management students valuable tools. A hands-on lab, in addition to the lecture on the OSHA requirements, could provide an opportunity for students to understand and appreciate the complexity of crane assembly, operations, inspections, and disassembly, and better prepare them for site management positions. Visiting a jobsite during the assembly was an option, but the coordination of field trips every semester is difficult. The assembly of a large crane takes time, and often the students would only see a small portion of the process. Also, the operation of the crane is not easy for visitors to fully appreciate.

The recent program review conducted by the department yielded feedback from the industry and students that additional lab experiences are beneficial. The safety class currently conducts a lab on scaffold erection. The decision was made to investigate the ability to develop a student lab project for cranes. The ultimate goal of the authors was to create a lab that could be used by any construction management program. The first challenge was the crane. Since a commercial crane was not an option, the authors examined the ability to build a small crane which would have the basic functions of a larger crane, without the initial cost, maintenance, and storage issues. Once built, the crane could be used each semester and easily stored when not in use.

The design and construction of the crane will be discussed later in the paper. The crane was designed, redesigned, built, rebuilt, tested, and was ready to be used. Students were part of the design, planning, of the crane and the lab exercise. The lab exercise was planned out and conducted. Finally, the students participating in the lab were questioned on the value of the lab exercise.

The Educational Questions

When developing a lab there are some guidelines that should be reviewed (Dickman, 1994, Vanderbilt, 2013). Reviewing these guidelines, the authors found there were some questions that needed to be answered to justify the use of resources.

1. Is the topic worthy of additional class time?
   - Cranes are heavily used in construction activities
   - Construction managers have defined responsibilities regarding cranes (OSHA 1926, 2013)
   - Almost 30% of fatal accidents in construction involve cranes (OSHA Final Rule, 2010)
   - The causes of crane accidents were the focus of the new crane rules (Smith, 2012, OSHA Final Rule, 2010)

2. Will the lab be constructed to allow students to understand the significance of the activity (Dickman, 1994)?
   - The lecture will be linked to the lab (Dickman, 1994)
   - The lab would use small teams (Dickman, 1994)
   - The lab activities would be linked to construction site activities

3. Will the students be able to apply the concepts learned to new situations (Vanderbilt, 2013)?
   - There needed to be a teamwork component.
   - There needed to be problem solving components
   - There needed to be real world application to the activity
   - There needs to be feedback to the students
   - There needs to be feedback from the students

The authors felt that the topic was worthy of more time and resources, the lab could be constructed to allow the students to understand the significance of the activity, and the concepts were applicable to new situations. It was decided to proceed.

The Educational Response

There were four aspects of crane management that were the core for the development of the learning objectives:
1. Assembly and disassembly
2. Inspections,
3. Rigging
4. Signaling

Table 1
Learning Objectives/Activities/Assessment

Learning Objectives	Activities	Assessment
Understanding the assembly and disassembly process	Discuss the process for A/D	Ability to efficiently Assemble the crane
Recognize the hazards during assembly and disassembly	Conduct a hazard assessment	Team discussion
Evaluate the Assembly/Disassembly Plan	Go through the A/D plan	Questions to be answered

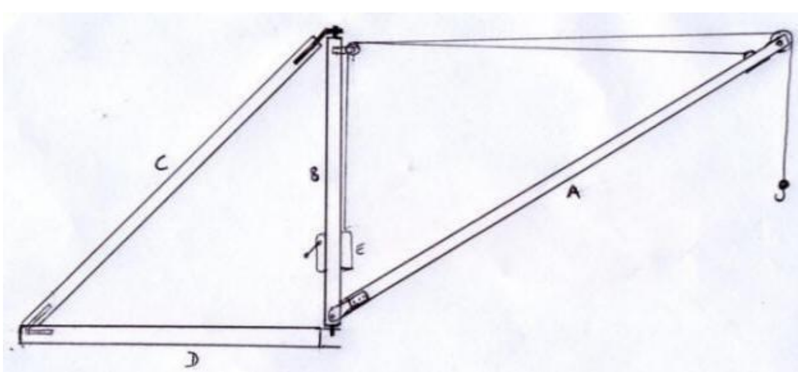
Manage the Assembly/Disassembly process	Team will have assigned roles and assigned and complete the assembly and the disassembly	Complete assembly and disassembly
Evaluate inspection documentation	Inspect the completed unit with a checklist	Complete checklist
Evaluate operations	Operate the crane to perform various lifts and complete operation team test	Complete lifts and complete obstacle course.
Evaluate the qualification of Riggers	Conduct rigging of loads	Use correct rigging terminology and correct rigging
Evaluate the qualification of Signalers	Conduct movement of loads and operation team test	Use correct signaling to move loads and complete obstacle course

The Crane

The next step was to determine which crane could be used. There were three options which could be used for our purposes: the jib style, the gantry, and the derrick crane. The three were evaluated based on the price to build, complexity, and flexibility. The derrick crane, known as a "scotch" derrick or a stiff-leg derrick was chosen (Figure 1). Help on the design came from *Cranes and Derricks* by Shapiro, Shapiro, and Shapiro (Shapiro 1999).

Safety is always an issue in any activity that involves students. There were two major risks in using a crane in a lab. The first hazard is a load coming loose and falling. This could be due to failure of the rigging, improper rigging, or a combination. The length of the boom, the angle of the boom, the minimum distance from the boom tip to the bottom of the block and hook, and the length of the sling limit all combine to limit the height of a load to around six feet off the ground at a maximum. The loads lifted in the lab do not get over two feet off the ground. When moving material from one location to another on the ground, it is not common practice to elevate the load any higher than necessary. The second hazard would be the failure of the crane. The capacity of the crane was set at 300 pounds, as that is the most the authors wanted to be lifted in the class situation. The unit needed to be tested at 125% of the design strength, or 375 pounds (OSHA 1926, 2013). Table 2 shows the components and their capacity. Setting the Load Capacity at 300# is well below the lowest capacity of a component. Capacity is discussed in more detail below.

In addition, the campus safety officer inspected the crane and reviewed the plan for the lab. With the exception of minor comments on the location cribbing used to level the sills (placing entirely under the counterweights) and the D rings used on slewing lines (heavier duty in case students used them for climbing), the safety office was pleased and wanted to be able to see the students complete the lab exercise.



A = Boom, B = Mast, C = back stay or stiff legs, D = Sills, E = rough position of winches.
Figure 1 – Derrick Crane parts (Oily Hands 2004)

The design of the derrick was a crucial and difficult portion of the project. OSHA is very clear in Subpart CC (1926.1436 Derricks) about the construction, testing, and operation of the derrick. Table 2 identifies each component and its capacity. The capacity of each component exceeds the capacity of the crane. The design was relatively simple, as shown in Figure 1. The members were constructed of three 2x4 boards fastened together. The connections were constructed of ¼ inch plate steel and 1 ½ inch x 1 ½ inch "L" channel, except the connection between the boom and the mast, which has two 38mm stainless steel tubes with 3mm sidewall. The lifting for the line load and the luffing were performed by hand winches. Bolts were 3/8 inch galvanized. All welding was performed by a certified welder. The dimensions of the members, materials/ assembly, and capacity of each are in Table 2.

Table 2

Derrick Crane Dimensions, Materials/Assemblies, and Capacities

Component	Material/Assembly	Capacity	Reference
Mast – 8 ft.	3-2x4 SPF	5,517#	Ochshorn, 2008
Boom – 12 ft.	3-2x4 SPF	2,636#	Ochshorn, 2008
Sill – 8 ft.	3-2x4 SPF	5,517#	Ochshorn, 2008
Brace – 11'6"	3-2x4 SPF	2,858#	Ochshorn, 2008
Winch and Cables	Unit	1200 #	TEKTON, 2013
Sheaves	Gal. Steel	2000#	Grainger, 2013
Mast Connectors	Coil Thread Rod	Tension 9000# Shear 6000#	Masco, 2012
Leg Connectors	¼" x 2" Plate Steel	18,000 # Yield Strength 29,000# Tensile Strength	Sabel Steel
Boom Connector	38 mm stainless steel tube with 3 mm sidewall	22,000# yield strength 26,000# Tensile strength	Tube Methods, 2012
Bolts	3/8 inch Grade 2	Shear–4903#, Tensile –14,000 #	NUCOR, 2008
Single 3" Pulley	3 inch	650#	Tractor Supply Co.
Quick Links	3/8 inch	850#	Tractor Supply Co.

Figure 2 – Picture of completed Derrick Crane

Figure 2 shows the completed derrick crane. The crane cost about $700 to construct. The sills were made 12 feet long to allow an area behind the leg to place counterweights. A platform was built to hold the counterweights, which were in this case were bricks. OSHA requires that counterweights be of known weight and non-flowable (you cannot use sandbags) (OSHA 2013). The bricks were weighed at just over 3 pounds each, and each leg had 150 bricks on the counterweight platform. At the time of the picture, the boom angle indicator was not installed and the stencils were not on the boom indicating the capacity. Figure 3 shows the Derrick Crane stored. The area required is four feet by twelve feet by two feet. It is resting on the counterweight platforms. The crane could be stored outdoors.

The coating on the wood members is a wood stain for appearance only. Paint should not be used as it may mask flaws, cracks, or deterioration of the wood.

Figure 3 Crane Derrick in Storage

The Lab Exercise

The course where the lab was included was on construction safety, and the central portion of course was the OSHA 30 hour training for construction. All instructors in the course are authorized to teach the OSHA construction training and provide OSHA 30-Hour Construction Training cards for those students who successfully complete the requirements. One component of the course is crane safety.

It was important to the instructors that the lab be conducted in a two hour slot, so some preparations were necessary. Prior to the lab the students:

- Spent two hours in class on OSHA 1926 Subpart CC, Cranes and Derricks in Construction. Also prior to the lab
- Were divided into groups of seven to complete the lab.
- Received a sheet showing the hand signals and told to learn the signals
- Received a derrick diagram (Figure 2) and vocabulary sheet of terms used in the lab
- Received an overview of the lab along with the duties so that they could be assigned by the team prior to the lab. Duties change from A/D to operation.

Duties for Team Members for Assembly and Disassembly

- A/D Director (In charge during A/D)
- 4 Iron workers for the erection
- 2 Counterweight handlers

Duties for Team Members During Operation

- Superintendent (In charge during operation)
- Operator
- 2 Riggers
- Signal person
- 2 Slewers (two people on ropes to move the boom left and right)

Lab Activity Plan

1. Team meets with the instructor to go through the instructions for the lab
2. The instructor goes through the plan for assembly and disassembly
3. The instructor will go through a hazard assessment and safety meeting for the lab.
4. The A/D director will provide Assembly duties for the team
5. Team will assemble the crane.
6. One person will go through the inspection checklist and sign off on the inspection and give the checklist to the A/D director
7. Team will rig, lift, move, and place:
   a. two steel beams (choker hitch)
   b. two 20 foot long steel pipes (two slings, with choker hitches)
8. Obstacle course which requires the team to move a load through defined path (Timed)
9. Disassemble
10. Meeting on
    a. lessons learned
    b. comments on the lab exercise
    c. how lab could be improve

The Results

The instructors felt that the lab went well. The tasks were completed in the time allotted, everyone was involved, there were teaching moments within the lab experience, the students learned something that could not be replicated in the classroom, and the students enjoyed the experience. It helped that the team members had designated roles during the lab. It was interesting that no one wanted to be the operator at first, but others wish they had the opportunity after the lab.

The schedule for the class goes about as follows:

- 10 minutes to go through the plan with the team.
- 25 minutes to erect and inspect the crane
- 25 minutes to go through the exercise
- 20 minutes to disassemble and store the crane.

The instructor for the lab was an Authorized OSHA Trainer for Construction, with 10 years of OSHA experience and over 20 years of construction experience. No load got over two feet off the ground. Team members were always aware of the location of the boom, and were only under the boom while rigging a load or unhooking a load. At no time were any team members under the boom when a load was suspended or under a suspended load. As mentioned before, the campus safety officer had also review the crane and the lab procedure and felt the students would be working in a safe manner.

The students were given a questionnaire to complete at the end of the lab. There were 14 questions to be answered numerically from 0 to 10, with 0 as disagree and 10 as agree. The results are shown in Table 3. There was also an area for additional comments, which are included.

Table 3

Results of Students' Evaluation on the Crane Lab

1.	The lab was too difficult for the time allotted.	0.1
2.	The lab was too easy for the time allotted.	4.3
3.	This was a good learning experience	9.0
4.	I would recommend that the lab be conducted in every safety class.	9.1
5.	There should be more rigging and lifting in the lab	7.1
6.	Team members should be allowed to change tasks in the lab, such as working as the operator or rigger.	7.6
7.	The lab should be expanded to allow the erection of the steel structure.	7.6
8.	Assembling the crane was easy.	8.0
9.	The crane should be bigger.	4.9

10.	Power winches would help in the lab experience	8.7
11.	Slewing the load by hand worked for the lab	9.4
12.	Power slewing would have advantages for the lab experience.	7.1
13.	More preparation for the lab was needed	2.1
14.	This lab could be divided into two labs: one for the erection and another for the operation	1.7

.
Students' Comments:

- This lab taught me a lot about the rigging of a crane
- Power winches would make the operation smoother, allowing for more complex movements
- Make a blind spot for the operator so they could only see the signaler
- Lab was actually pretty cool and fun
- Needed a harder obstacle course
- Maybe a small engine to slew the crane
- Obstacle course would be better if it were more difficult. It would tie it all together.

Authors' evaluation of the results showed:

- The preparation and the direction given were adequate for the lab.
- The assembly was very easy.
- The activities after the assembly needed to be more challenging
- It was a good learning experience
- The lab should be included in every safety class
- The team members wanted to change roles during the lab.
- The question about a bigger crane got a 4.9, which showed there was some desire for a bigger crane, but not strongly. They may see the difficulty in assembly of a larger crane.
- Power winches would be an improvement in that it could improve the operation of the unit and allow more operations.
- Slewing by hand worked well for the lab, but there could be an advantage to an automated solution.
- The required deliverables during the 90 minute lab were achievable.

Conclusions

The authors agreed that the lab was beneficial to the students and gave added value to the course. The time to build the crane and develop the lab was a worthwhile effort, and there would be little preparation required in future classes. The students said they appreciated the lab.

The lab exercise worked well. There will need to be some changes in the activities after the crane is assembled. Additional rigging needs to be acquired. Lifts could be made on small air handlers, rebar, trusses, pipes, etc., which would require the use of different rigging and spreader bars. The specific operations conducted by the crane during the lab could be a varied as the instructors' imaginations. The obstacle course needed to be improved and (at the suggestion of students) timed for each team. The smallest team size would be four, but should not go above seven.

One of the primary goals of the authors was to develop a lab that could be shared with other construction management programs. The cost would be about $700 for the crane, which would require minimal maintenance, and could be stored in a small area. The space needed to set up the crane and run the lab would be about 24 feet by 24 feet. The labs would be easy to replicate by other faculty members with a minimum of instruction.

The crane worked well, but a few changes have been suggested since the use of crane began. Adding a boom tip of steel that included the sheaves and eye bolts that attached to the boom would be a good addition. The overall size of the crane could be increased. This would be an easy change as all the connections could be re-used, even with the change to 2x6 members. Going to a 12 foot mast and a 16 foot boom could be a large improvement. Increasing the size also increases the weight, and the plan was to be able to erect the crane by hand. The winches could be replaced with electric models that would be easier to operate.

The counterweights used were bricks. The authors would like to obtain some other type of counterweight that has defined weights and can be moved more quickly. Using solid 4x8x16 blocks would require less time to move and a smaller platform.

The proposed changes noted in the crane and the lab activities are typical of any educational experience. Teachers are always changing and improving. They are always looking for new ways to get students involved. The authors are very pleased with the results of the lab and the reaction of the students, and hope that the experience can become valuable to others.

References

Dickman, Alan PhD (1994), Teaching Laboratory Classes, Teaching Effectiveness TEP Program [WWW Document] URL http://tep.uoregon.edu/resources/librarylinks/articles/lab.html

Grainger (2013) Sheave [WWW document] URL. http://www.grainger.com/Grainger/Sheave-5RRT3?Pid=search

Masco Masons Supply (2012) Coil Bolts [WWW document] URL. http://masco.net/web/index.php?option=com_content&task=view&id=86&Itemid=60#coilrod

NUCOR Fastener (2008) Technical Data Sheets [WWW document] URL. http://nucor-fastener.com/Files/PDFs/TechDataSheets/TDS_013_Shear_Strength.pdf

Ochshorn, Jonathan (2008), Structural Elements for Architects and Builders, Elsevier, Oxford, UK [WWW document] URL https://courses.cit.cornell.edu/arch264/calculators/example7.1/index.html

Oily Hands (2004) [WWW Document] URL http://www.oilyhands.co.uk/home_made_derrick_crane.htm

OSHA 1926 (2013), *29 CFR 1926 OSHA Construction Industry Regulations*, Mancomm Communications, Davenport, Iowa, Jan. 1, 2013

OSHA Final Rule (2010). Department of Labor, Occupational Safety and Health Administration, 29 CFR Part 1926, Cranes and Derricks in Construction: Final Rule, Federal Register / Volume 75, No 1952, Monday, August 9, 2010 / Rules and Regulations

Sabel Steel, (2013), 749 North Court Street, Montgomery, AL 36103

Smith, Bruce W., (2012), Changes in OSHA Crane Rules: A Preliminary Look at the Economic Impact on Individual Construction Operations, *48th ASC Annual International Conference*, San Luis Obispo, CA

TEKTON (2013) Winches and Hoists [WWW document] URL. http://www.tektontools.com/All_Products/5552

Tube Methods, Inc. (2012) Mechanical Properties - Stainless Steel Tubing [WWW document] URL. http://www.tubemethods.com/mpss.htm

Vanderbilt University (2013), Teaching Laboratory Classes, Center for Teaching, Vanderbilt University [WWW Document] URL. http://cft.vanderbilt.edu/teaching-guides/teaching-activities/lab-classes/