



Certified Associate Constructor Exam

Official Study Guide



CERTIFIED ASSOCIATE CONSTRUCTOR (CAC) STUDY GUIDE

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American Institute of Constructors

19 Mantua Road | Mount Royal, NJ 08061

P: (703) 683-4999

info@professionalconstructor.org | <https://aic-builds.org>

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THE CERTIFIED ASSOCIATE CONSTRUCTOR

Congratulations on your decision to take the Certified Associate Constructors (CAC) Level 1 Exam! Those who sit and pass this exam set themselves apart as someone who has a solid foundation of construction knowledge and skills. Those with this certification can confidently show employers that they have a core competency and are ready to contribute meaningfully to the construction industry. Those who have earned the CAC certification bring value to any project as they have verified they have the skills and knowledge needed to succeed based on an ever evolving body of knowledge. In addition, each CAC certificate holder agrees to abide by the AIC code of ethics, ensuring they are professional and ethical member of the industry.

PURPOSE OF THE STUDY GUIDE

This study guide is intended to be used to help focus the study efforts of the test taker. The study guide is not intended to be a substitute for a 4-year building construction and management education and may not contain every concept covered in the exam. However, it does address all the major subject areas to verify an overall understanding and provide additional resources for the test taker to gain additional skills and knowledge. Questions are provided in the chapters for the test taker to gauge their level of understanding and where additional studying is needed.

HOW CERTIFICATION WORKS

Certification is a voluntary and non-governmental process to recognize the education and/or experience of an individual who meets certain criteria and standards. It is ongoing proof of commitment to ethics and professionalism and is something that is maintained throughout one's career. To become certified an individual must meet qualifying requirements, apply for an examination, and once approved, sit for the examination. Upon passing the examination and agreeing to the AIC Certificant Agreement, an individual is conferred the Certified Associate Constructor certification.

HOW TO QUALIFY FOR THE EXAM

To take the Certified Associate Constructor Exam a candidate must meet certain qualifying requirements. To qualify you must meet one of the below requirements:

- Have graduated from or is scheduled to graduate from an accredited 4-year Construction Management Degree Program.
- Have obtained 4 years of qualifying experience or education or a combination of the two.

Upon passing the Certified Associate Constructor Exam an individual will be awarded the Certified Associate Constructor (CAC) credential.

THE EXAM

The CAC exam is made up of 300 multiple choice questions, given during two 4 hour sessions on a single day. The exam is given twice per year, in the spring and fall at over 60 locations across the country. Over 50 University Construction Management Programs currently administer the AC exam, most require the exam as part of their program curriculum.

MAINTAINING THE CREDENTIAL

After being awarded the CAC credential you must participate in the Continuing Professional Development Program. This program ensures that each certificant keeps current on industry trends and education. Each individual certification is valid for two years, beginning the first full year after earning the certification. To keep the CAC credential in good standing an individual must pay a yearly CPD Fee, billed in November of the year before it is due. AIC Members have this fee waived. Note that CAC certification is not AIC Membership. Associate Constructors can only maintain their designation for 10 years, after which they must attempt the CPC examination if they want to maintain their professional certification.

CAC EXAM: STUDY GUIDE



CHAPTER 1

COMMUNICATION SKILLS

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ORAL COMMUNICATION

A manager's ability to lead and motivate people depends largely on his or her ability to effectively communicate orally. Oral communication is the exchange of understanding by verbal and often nonverbal means. The way in which a person verbalizes a conversation directly affects the meaning, perceived intent, and understanding of the conversation interpreted by the listener. The tone, volume, and speed in which one speaks all play an important role in how a message is understood. Additionally, because much of oral communication is done face-to-face, hand gestures, body language, eye contact, and appearance often play a major role in effective communication. The way information is transmitted is important because several studies suggest that how the information is presented directly affects how much of it the receiver retains. In general, people remember

- 10% of what they hear,
- 20% of what they read,
- 30% of what they see, and
- 50% of what they hear and see.

And the speakers (senders) remember

- 70% what they say and
- 90% what they say and do.

The following sections highlight several commonly used forms of oral communication in construction.

SPEAKING AND FORMAL PRESENTATIONS

In oral communications, a presentation occurs any time someone verbally presents a topic to an audience. Presentations may be formal (e.g., a sales presentation to a potential client) or informal (e.g., presenting new business at a weekly progress meeting) and comprise audiences ranging from one to any number of people. Regardless of the type of presentation or size of the audience, to be effective, the presenter should

- dress appropriately for the situation,
- maintain good personal hygiene,
- speak clearly and at a moderate pace,
- avoid speaking very softly or very loudly,
- pause between sentences and points,
- avoid space fillers such as “um” or “okay,”
- avoid excessive hand gestures,
- maintain eye contact with the audience,

- keep message short and on topic, and
- avoid presenting too much or extra information that may distract the audience from the message being presented.

LISTENING

In oral communication, effective listening is just as important as speaking. When listening, a person should

- make eye contact with the speaker;
- maintain good, attentive body posture by not slouching, rocking, or leaning back in the seat;
- turn off, close, and/or silence electronic devices;
- listen objectively with the intent to understand the speaker's perspective; and
- hold questions until the speaker finishes speaking.

TELEPHONE

Telephone conversations are one of the most widely used distant forms of communication in construction. To remain effective when communicating by telephone,

- speak clearly and at a moderate pace;
- avoid speaking very softly or very loudly;
- minimize background noise;
- avoid using speakerphones in loud, noisy, and easily interrupted areas and where the conversations can be easily overheard; and
- keep conversations short and on topic.

ORAL COMMUNICATION STUDY QUESTIONS

1. What percentage of conversations do listeners remember of what they hear?
 - A. 10%
 - B. 30%
 - C. 50%
 - D. 90%
2. What percentage of conversations do speakers remember of what they say and do?
 - A. 30%
 - B. 50%
 - C. 70%
 - D. 90%

3. When giving presentations, people should do which of the following?
 - A. present extra information beyond their primary goal to demonstrate their expertise
 - B. speak quickly to get in as much information as possible
 - C. speak as loudly as possible to ensure they can be heard
 - D. keep the conversation short and on topic
4. Which of the following should people do to effectively listen?
 - A. keep their mobile phone volume up so they do not miss a phone call
 - B. listen objectively with the intent to understand the speaker's perspective
 - C. ask questions as they think of them so they don't forget to ask them later
 - D. avoid eye contact with the speaker

WRITTEN CORRESPONDENCE

Construction is a complex process that often takes place over a long period of time. As a result, written correspondence is widely used to clearly communicate and document the exchange of information. Nearly all construction contracts and agreements require some form of written correspondence to document requests, directions, and changes.

All written construction correspondence should be well thought out so it accurately and completely communicates the desired message while being as brief as possible. Written correspondence should not contain emotional, explicit, or SMS language; slang; emojis; words written in all CAPS; and large, fancy, multicolored fonts. The following sections highlight several commonly used forms of written correspondence in construction.

LETTER OF TRANSMITTAL

A letter of transmittal, or simply transmittal, is a cover letter that accompanies other documents. It identifies the content of the document or items being sent and records the sent date. Letters of transmittal are commonly used when sending items such as submittals, shop drawings, samples, contracts, change orders. A typical letter of transmittal at a minimum should include the sender's name and address, the recipient's name and address, the project name and number, description of the items

sent, number of copies of the items, and notes or directions concerning the items.

For more information see Mincks & Johnston in the list of references.

BUSINESS LETTER

In construction, business letters are commonly used as formal correspondence to request information or action, respond to a request, state a position, or present an explanation. In general, letters tend to have more weight than e-mails or other less formal means of communication and are reserved for issues of great importance. Letters should be specific to a single project and address a single issue. All letters on a project should have a consistent format. A business letter should always include the sending company's name and address, the date of the letter, the recipient's name and address, subject, salutation, content or body, complimentary closing, sender's signature, sender's name and title, a list of any enclosures, and carbon copies. Figure 1-1 shows a typical format for a business letter.

For more information see Mincks & Johnston in the list of references.

MEMORANDUM

A memorandum, or memo, is a less formal type of written correspondence used to notify or advise the reader about a subject. Memos are often used internally to notify or provide clarification to employees about policy changes, procedures, or disciplinary issues. Externally, memos are often used to notify or remind subcontractors about important information or upcoming deadlines or meetings. A memorandum should include the date of the memo, the recipients, the senders, subject, content or body, and carbon copies.

FAX

Although their use has declined with the advent of e-mails, facsimiles, or simply faxes, are used as a method to quickly and securely send documents electronically. A fax machine scans 8.5 in. × 11 in. sheets of paper and transmits/receives them electronically by dialing a dedicated phone line. Faxes may contain both text and images, and although color fax machines do exist, faxes are typically transmitted in black and white.

Figure 1-1 Example of a Business Letter**G&J Construction**

2134 Lee Street
Busy City, SC 29876
(864) 555-5500
Fax: (864) 555-5501

July 20, 2015

PQR Plumbing
P.O. Box 123
Busy City, SC 29876
Attn: James Smith

RE: Closeout Documents
Big Office Building, Busy City, SC
G&J Project Number: 2015-012

Dear Mr. Smith:

Please be advised that the above referenced project is now substantially complete. Your firm is required to submit four (4) copies of plumbing as-built documents, warranties and operation and maintenance manuals in compliance with the project's closeout and warranty requirements. All warranties should begin on date of substantial completion, July 15, 2015. All closeout documents should be delivered to G&J Construction corporate office no later than July 27, 2015.

Please contact me if you have any questions regarding your required documents.

Sincerely,

Joe Joseph

Joe Joseph
Project Manager

C.C. File 3.1

CHAPTER 1 ► COMMUNICATION SKILLS

A fax may consist of a cover page and attached documents or be a stand-alone document such as a memo. A fax should include the date of the fax, the recipient's name and fax number, the sender's name and fax number, subject, number of pages being sent, and description of items sent and/or message.

E-MAIL

Electronic mail, or e-mail, is a versatile electronic message commonly used for personal and business correspondence. The message of an e-mail is often short but may be written in any length. Regardless of the length, e-mails should follow the same general guidelines as all written correspondence.

One of the main benefits of an e-mail is the ability to electronically transmit a wide range of documents via attachments. Attachments can vary in length, size, shape, and color and often include other forms of written correspondence and construction documents such as letters, memos, requests for information (RFIs), schedules, drawings, product data, and manuals. When attaching a document to an e-mail, it is important to note the attachment in the message of the e-mail to avoid the attachment's being overlooked.

Another important benefit of e-mails is that they are easily stored, providing convenient documentation of correspondence. Because of their frequent use, it is easy to become increasingly informal with how they are written. It is important to remember that they are a professional form of communication that potentially could have the same weight as a formal letter under the law. Care should be taken with tone, grammar, and thoroughness with all e-mails, especially to clients or other high-value recipients.

TEXTING

With the increasing use of smartphones, texting is becoming a frequently used form of communication for both personal and business correspondence. Texting is an informal form of written communication sent electronically, typically between mobile phones. Similar to e-mails, texting is instantly available and often incorporates short, abbreviated messages, with some phones limiting the length of any one text message. Because of the limited message length and nature of texting, there is often a tendency for senders to use SMS language and emojis. As with other forms of written

correspondence, when sending a business text, SMS language and emojis should be avoided.

Many phones also allow photos and short video to be sent via text message. Discretion should be used, and the sender should verify that the intended recipient is able to receive photos or videos before sending them in a text. Storing and documenting texts is often difficult. When receiving a direction to proceed, an RFI response, or any information that affects the schedule or scope, an e-mail or other formal written communication is a preferred means of communicating.

SOCIAL MEDIA

Social media is the newest form of business communication. Similar to a company's website, social media can be used in a variety of ways, from providing job site updates and notifications to advertising and connecting with owners and new clients. To effectively use social media, the same general guidelines for all written correspondence should be followed. The number of personnel authorized to modify and make public posts should be limited. Because most social media sites are open to the public domain, extra caution should be used when publishing information to ensure that no confidential, protected, or incriminating information is posted. As a general rule, social media should be used as a secondary means of information dissemination. A good practice is to use social media to provide general information on an issue but then direct the reader to a primary source such as a company's website, informational e-mail address, or contact person for the details. For example, use Twitter to inform subcontractors of the release of an addendum affecting the HVAC system, but ask them to "See Addendum #23 on the project's website for more information."

REQUEST FOR INFORMATION (RFI)

A request for information (RFI) is a formal type of written correspondence used by contractors to seek out and document clarification of items in the project documents that may be unclear, missing, or require further information. RFIs should include the sender's name and address, the recipient's name and address, and the project name and number and clearly state what information is being requested and what type of and when response is needed. It is often a good practice to present a potential solution to the problem, but care should be taken not to take on design liability.

For more information see Mincks & Johnston in the list of references.

CHANGE ORDERS

A change order is a type of formal written correspondence that modifies the contract or written agreement. Change orders can be categorized as either owner or subcontractor change orders. Owner change orders modify the contract between the owner and the prime contractor. Subcontract change orders modify the contract between the prime contractor and the subcontractor. Change orders may be issued by either side of the contracting parties depending on the terms of the agreement but are not fully executed until all parties have approved them. Change orders should include the following information:

- *Names and addresses of the contracted parties:* typically the owner and prime contractor for owner change orders, and the prime contractor and subcontractor for subcontractor change orders
- *Detailed description of the changes:* may consist of a narrative of the changes and/or reference other documents that detail the changes
- *Schedule impact of the changes:* indicates original project dates or durations, any adjustments due to the changes, and new dates or duration after execution of the change order
- *Cost impact of the changes:* indicates original or previous contract amount, cost impact of the changes, and the revised contract amount after execution of the change order
- *Signatures:* includes place for signatures of both contracting parties and any approving parties (i.e., owner change orders often must be signed by the owner, prime contractor, and architect or owner's representative)

For more information see Mincks & Johnston in the list of references.

WRITTEN CORRESPONDENCE STUDY QUESTIONS

1. Which of the following statements is true about texting and a subcontractor change order?
 - A. It is a good practice to text authorization of a change order to your subcontractors as long as you are sure they have a smartphone.
 - B. It is a good practice for your subcontractors to text you an RFI before proceeding with a change order request.
 - C. Texting your subcontractor that a change order is coming later in the day is a good practice.
 - D. Texting contract amendments is a good practice because it saves time and saves the changes in the cloud.
2. What does RFI stand for?
 - A. right for inclusion
 - B. response from institute
 - C. request for information
 - D. regular foam insulation
3. An owner-initiated change order should include which of the following?
 - A. expected duration of individual activities described in the change order
 - B. potential future cost impact of the change
 - C. reference to contract documents describing the change in detail
 - D. subcontractors to be used to complete the change

CONSTRUCTION REPORTS

JOB DIARY

A job diary, or journal, is an individual's personal record of daily conversations and events on a project (Figure 1-2). Diaries may be hand or electronically written and should be written and dated daily and maintained by each member of the project management team (project manager, assistant project manager, superintendent, assistant superintendent, foreman, etc.). Diaries are primarily used in disputes relating to specific conversations or events and should be written in clear, businesslike, factual, and accurate language.

DAILY REPORTS

A daily report, also commonly referred to as a daily log, is a snapshot record of the day's/shift's conditions and activities on the job site (Figure 1-3). Daily reports are often standardized preprinted or electronic forms that are completed daily and for each shift by the job-site superintendent, assistant superintendent, or foreman. Forms may vary by contractor and/or project and are typically used as an internal document for communication between the field and office personnel. Daily reports are often used in litigation and should be drafted with that purpose in mind. The following information is typically found in a daily report:

- **Date:** Reports often include calendar date, contract day/shift, and report number.
- **Project name and number:** Because the daily report is often an internal document, the contractor's project name and number should be used; however, the owner's, architect's, and/or other project names and numbers may also be included.
- **Individual completing the report:** The name of the person completing the report for the particular day/shift should be included.
- **Job-site weather and ground conditions:** Report should include the current and previous (since last report) weather and ground conditions of the job site such as the temperature at the start of work, end of work, and during major temperature-sensitive activities (e.g., concrete pours); daily high and low temperatures; amount and type of precipitation (if any); general weather conditions (e.g., cloudy, sunny, foggy, windy, raining, snowing); and general job-site ground conditions (e.g., wet, dry, icy, snow covered, standing water).

- **Job-site activities:** Include a brief description of work taking place on the job site during the report period.
- **Contractor's labor:** List contractor's workers/crews performing work on the job site during the report period. A brief description of work performed by and arrival and departure times of contractor's workers/crews should be included here.
- **Subcontractors:** List subcontractors' workers/crews performing work on the job site during the report period. A brief description of work performed by and arrival and departure times of subcontractors should be included here.
- **Equipment:** List equipment on the job site during the report period. Equipment arrivals and departures along with idle and in-use hours should be noted here.
- **Material deliveries:** List materials being delivered to the job site during the report period. The company delivering, unloading, and receiving the material; the time the material was received and unloaded; and a brief description of the material delivered should be included here.
- **Visitors:** List all visitors (e.g., owner's representatives, design professionals, building and code enforcement officials, trades not employed or currently working on-site) along with time of arrival and departure.
- **Occurrences:** Give a brief description of notable events that occurred on the job site during the report period that are not included under one of the preceding sections. Items in this section might include conflicts, accidents, owner/designer directives, and stop work orders.
- **Signature and date/time stamp:** All reports should be signed and dated by the person completing the report. Electronic reports should be printed, signed, and dated with a hard copy kept on file or electronically signed, time stamped, and locked/protected to prevent future manipulation.

For more information see Fisk & Reynolds in the list of references.

Figure 1-2 Example of Job Diary (Superintendent)

Monday, May 11, 2015

- 7:15AM: Arrived at job site, unlocked and walked building. Found puddle of water on floor below roof hatch located in storage room 208. Rain gauge shows 1.1 in. of rain received last night, emptied gauge.
- 7:30AM: Tool box talk held discussing ladder safety; our carpentry crew, PQR Plumbing rough-in crew, HotAIR Heating and Cooling ductwork crew, and Dry Roofing crew in attendance. AC Electrical rough-in crew not on-site.
- 7:40AM: Told Tony with Dry Roofing about water below roof hatch and reminded him that drywall is set to arrive later today and will be stocked in the first floor beneath that area. Tony said they had some final flashing to complete on the hatch and will be done by noon.
- 8:20AM: Called Dennis with AC Electric, asked where rough-in crew was. Dennis said they had several electricians call in sick today and are short a crew. I reminded Dennis that the electrical rough-in had to be completed tomorrow for Wednesday's inspection. Dennis said he understood the schedule and was working on getting a crew on-site and would call me back by 9:00AM with an update.
- 8:55AM: Dennis with AC Electric called and said that they could not get a crew on-site today, but is finishing another job today and would have a double crew on-site tomorrow to finish rough-in before Wednesday's inspection. I agreed to Dennis's alternate schedule and reminded him that he would be liable for delays if rough-ins were not completed tomorrow.
- 9:10AM: Emailed Joe at home office details about change in AC Electric's schedule.
- 10:15AM: Carpentry crew finished blocking on first floor, had crew begin framing walls on second floor.
- 11:30AM: Checked in with Tony with Dry Roofing and asked if flashing around roof hatch was complete. Jim said the flashing was done at hatch and should not leak anymore.
- 11:45AM: Gypsum board delivery arrived on-site. Drywall crew not on-site to unload.
- 11:50AM: Called Shima with White Drywall and told her that the gypsum board delivery was on-site and asked where her unloading crew was. Shima said the supplier was supposed to deliver the gypsum board at 1:00PM and that her crew was currently at lunch but would send them to the site as soon as they get back.
- 12:30PM: Drywall crew arrives on-site to unload gypsum board.
- 1:00PM: Carpenters discover discrepancy between second floor restroom 213 east wall framing and structural column C14. Framing plan indicates that column is to be outside of restroom, field layout of plan dimensions makes column inside restroom. Instructed carpenters to hold on framing wall and continue work in another area. Took picture of layout and e-mailed RFI 05 to Chris at XYZ Architecture, copied Joe at home office.
- 1:45PM: Chris with XYZ Architecture arrived on-site to review RFI 05. After reviewing, Chris stated that she would send a revised detail later today and left job site at 2:05PM.
- 2:15PM: Dark clouds forming northwest of job site. Checked radar and looks like heavy rain and wind may hit job site within next hour. Drywall crew still unloading gypsum board. Stopped carpentry crew and had them secure the building and loose materials on-site.
- 2:30PM: Light rain, drywall crew almost done unloading gypsum board. Site and building secure, had carpentry crew help drywall crew finish unloading gypsum board.
- 2:45PM: Gypsum board unloading complete.
- 3:00PM: Heavy rain and wind at job site. Checked roof hatch in 208, no leak apparent.
- 3:15PM: Received response to RFI 05 from Chris at XYZ Architecture. Reviewed revised detail with Tim, carpentry foreman, and determined that the revised detail would require additional cost to incorporate. Called Joe at home office and discussed changes and anticipated cost associated with RFI 05. Joe to review and discuss cost with owner and architect. Work at restroom 213 to remain on hold pending cost approval or further direction.
- 4:00PM: Last of the workers left job site. Walked building. Found reciprocating saw left out at plumbers' work area. Placed saw in job site office. Locked building. Rain gauge shows 0.5 in. of rain, emptied gauge.
- 4:15PM: Left job site.

Figure 1-3 Example of Daily Report

Daily Report G&J Construction							
Project No.: <u>2015-012</u>		Date: <u>Monday, May 11, 2015</u> (Calendar)		<u>68</u> (Day)	<u>1</u> (Shift)	Report No.: <u>50</u>	
Project Name: <u>Big Office Building, Busy City, SC</u>				Report By: <u>Greg Gregory, Superintendent</u> (Name/Title)			
Weather: <u>Overnight rain; cloudy, cool day; light rain (2:30pm); afternoon rain storm with wind gust (3:00pm-3:45pm); site wet/muddy with some standing water</u>							
<u>62</u> °F Day/Shift High <u>47</u> °F Day/Shift Low °F at _____ °F at _____ (Temp) (Time)	☒ Rain ☐ Snow ☐ Mist/Fog ☐ Hail/Size: _____	<u>1.1"</u> <u>0.5"</u> (Amt) <u>7:15am</u> <u>4:00pm</u> (Time)	☐ Sunny/Clear ☐ Partly Sunny/Cloudy ☒ Cloudy ☐ Calm ☒ Windy/Gust: <u>30</u> mph	☐ Dry ☒ Muddy ☒ Standing Water ☐ Snow/Amount: _____ ☐ Ice/Amount: _____			
Temperature		Precipitation		Sky/Wind Conditions		Ground Conditions	
Jobsite Activities: <u>Plumbing rough-in 1st floor restrooms, ductwork rough-in 1st floor column line B-G; blocking 1st floor; wall framing 2nd floor; roof flashing; stock gypsum board 1st floor</u>							
G&J Labor: Activities: <u>Blocking 1st floor walls, begin framing 2nd floor walls, secure site, assist w/gypsum board delivery</u>							
<u>1</u> Foremen	<u> </u> Cement Masons	<u>1</u> Apprentices					
<u>4</u> Carpenters	<u> </u> Concrete Finishers	<u>1</u> Laborers					
Subcontractors:				Workers:			
Company: <u>PQR Plumbing</u>				<u>3</u>	<u>Journeyman</u>		
Scope: <u>Plumbing/gas</u> Super/Foreman: <u>James Smith</u>				<u>1</u>	<u>Apprentice</u>		
Activities: <u>Rough-in water distribution & sanitary piping 1st floor restrooms</u>				<u>1</u>	<u>Laborer</u>		
Company: <u>HotAIR Heating and Cooling</u>				<u>4</u>	<u>Journeyman</u>		
Scope: <u>HVAC</u> Super/Foreman: <u>Jason Lucas</u>				<u>1</u>	<u>Laborer</u>		
Activities: <u>Ductwork rough-in 1st floor column lines B-G</u>							
Company: <u>Dry Roofing</u>				<u>2</u>	<u>Roofers</u>		
Scope: <u>Roofing</u> Super/Foreman: <u>Tony Wintz</u>				<u>1</u>	<u>Laborer</u>		
Activities: <u>Complete roof flashing</u>							
Company: <u>White Drywall</u>				<u>5</u>	<u>Laborers</u>		
Scope: <u>Drywall/Acoustic</u> Super/Foreman: <u>Shima Clarke</u>							
Activities: <u>Unload delivery/stock jobsite</u>							
Equipment:		<u>Genie Scissor Lift (GS-2046)</u>	<u>HotAir</u>	<u>6</u>	<u>2</u>		
		<u>Genie Scissor Lift (GS-2032)</u>	<u>HotAir</u>	<u>5</u>	<u>3</u>		
		(Item)	(Company)	(In-use)	(Idle)	(Delivered)	(Returned)
Deliveries:	<u>Gypsum board</u>	<u>Gyp Supply</u>	<u>White Drywall</u>	<u>11:45am</u>	<u>2:45pm</u>		
	(Item)	(From)	(For)	(Arrived)	(Completed)		
Visitors:	<u>Chris Piper, XYZ Architecture</u>	<u>Review RFI</u>	<u>1:45pm</u>	<u>2:05pm</u>			
	(Name/Company)	(Purpose)	(Arrived)	(Departed)			
Occurrences: <u>AC Electric no workers; will have double crew tomorrow per phone conversation with Dennis. Gypsum board delivery arrived early; White Drywall arrived early to unload. Wall/column conflict 2nd floor restroom 213, forwarded RFI 05 to XYZ Architecture. RFI 05 response received, forwarded to office for pricing</u>							

Signature: Greg GregoryDate: 5/11/2015

WEEKLY AND MONTHLY REPORTS

A variety of weekly and monthly reports are used in construction. Most weekly and monthly reports represent internal communication between the project team and a company's upper management on the progress of a particular project. However, monthly reports are often provided to the owner and design team on design builds or Construction Management (CM) projects.

Weekly and monthly reports often include general and detailed information about the project. Similar to daily reports, general information on weekly and monthly reports often include project identifiers (e.g., project name, number, location), names of the key members of the project team (e.g., project manager, superintendent), report period, report title/description, and name and signature of the individual preparing the report. Detailed information about the project commonly includes one or more of the following:

- *Overall project status:* This is a summary of the overall status of the project and progress since the last reporting period.
- *Schedule analysis:* This is a brief narrative and/or graphical analysis outlining the status of the project schedule, including a summary of activities completed since the last period, explanation of any significant changes in the schedule, identification of potential schedule risks, and plan of action and/or correction for schedule changes/risks.
- *Cost analysis:* This is a brief narrative and/or tabulated analysis outlining the project's current contract amount; costs to date; status of billings; and current/projected gains, losses, and/or profits. The cost analysis should also include an explanation of any significant changes, identify potential risks, and provide a plan of action and/or correction for cost changes/risks.
- *Labor, material, and/or equipment analysis:* This is a brief narrative and/or tabulated analysis outlining labor productivity, material accuracies, and equipment usage. The analysis should identify any issues, significant changes, and/or risks and include a plan of action to resolve them; it should also state upcoming requirements for labor, in-house tools, and equipment.
- *Subcontractor and purchase order management:* This is a brief narrative outlining the status of executed and pending subcontracts and purchase orders, including identification of any

issues, significant changes, and/or risks. A plan of action to resolve these items, including any concerns regarding subcontractor personnel; the schedule and compliance; and the status, timing, quantity, and quality of material deliveries, should also be addressed.

- *Changes in work:* This section highlights current pending and approved change orders along with any risk and other potential or directed changes, including pending, approved, or rejected requests for proposals (RFPs); contractor-initiated change proposals; owner change directives; and outstanding requests for information (RFIs).

For more information see Mincks & Johnston in the list of references.

CONSTRUCTION REPORTS STUDY QUESTIONS

1. A job diary should be maintained by whom?
 - A. superintendent
 - B. foreman
 - C. project manager
 - D. all members of the project management team
2. If a job has more than one shift, how often should a daily report be completed?
 - A. once a day
 - B. each shift
 - C. twice a day
 - D. once a week
3. Daily reports are primarily created by whom?
 - A. field laborers
 - B. project manager
 - C. superintendent
 - D. estimator

CONSTRUCTION MEETINGS

Meetings are an essential part of the construction process that allows for face-to-face conversations about the project to occur between multiple parties. Many important decisions are made during construction meetings, and accurate, unbiased written documentation of meetings is essential. In construction, the contractor is often responsible for planning for, providing leadership during, and documenting meetings. Several types of

meetings common to construction are described below.

Preconstruction Meetings

Preconstruction meetings are initial or project kickoff meetings typically held before the start of a construction project. On large projects, preconstruction meetings are also commonly held before each major phase of construction. Topics discussed often include project personnel, procedures, schedule, budget, safety, contracts, restrictions, requirements, and controls. Three common types of preconstruction meetings are listed below:

- *Contractor's preconstruction meetings:* These meetings are held in-house between members of the contractor's project management team, which often includes such people as senior project managers, project managers, assistant project managers, superintendents, assistant superintendents, foremen, estimators, and administrative assistants. Sometimes these meetings are referred to as, but may be separate from, transition meetings, where the project is transitioned from the estimating staff to the project management staff.
- *Project preconstruction meetings:* These meetings are between key project participants, which often include the owners or owners' representatives, key members of the design team, and members of the prime contractor's project management team.
- *Subcontractor preconstruction meetings:* These meetings are between members of the prime contractor's project management team and subcontractors and suppliers selected for the project. Depending on the size, scope, complexity, and time frame of the project, subcontractor preconstruction meetings may be held individually, in groups, or with all subcontractors and suppliers present.

Coordination Meetings

Coordination meetings are often held throughout the construction process and may be called at regular intervals or randomly as needed. Used to coordinate design and/or work activities of multiple parties, coordination meetings should occur prior to the start of all major or complex activities. The coordination of the mechanical, electrical and plumbing (MEP) trades in above-ceiling space is a common issue resolved at this type of meeting.

OAC Progress Meetings

Owner/architect/contractor (OAC) progress meetings are typically held at regular intervals throughout the project, commonly every week, biweekly, or once a month but may be more or less frequent depending on the complexity and duration of the project. They are used to update participants on the status of the project and any other issues or concerns. OAC progress meetings tend to focus on the big picture of the project as well as immediate concerns needing to be addressed to avoid cost and schedule impacts.

Regular participants of OAC progress meetings often include the owners or owners' representatives, key members of the design team, and members of the prime contractor's project management team. Depending on the project, key subcontractors and/or other project participants may regularly or occasionally attend progress meetings. Topics commonly discussed at each meeting include schedule, submittals, RFIs, change proposals, change orders, and old and new business.

Subcontractor Progress Meetings

Subcontractor progress meetings are typically held at regular intervals throughout the project, usually every week but may be more or less frequent depending on complexity and duration of the project. Similar to OAC progress meetings, subcontractor progress meetings are used to update participants on the status of the project and any other issues or concerns. Subcontractor progress meetings tend to review the overall project and focus more heavily on the day-to-day/week-to-week operations of the project.

Subcontractor progress meeting participants commonly include members of the prime contractor's project management team and any subcontractors, suppliers, and prime contractor's crew leaders who are getting ready to deliver material to or start on the project or who are currently working on or have just finished work on the project. Topics commonly discussed at each meeting include schedule, coordination, submittals, RFIs, change proposals, change orders, and old and new business.

Safety Meetings

Safety meetings are typically held at regular intervals throughout the project, commonly every day or each shift. Safety meetings are often short 5- to 15-minute meetings held at the start of each work period and focus on site-specific and daily safety topics. Participants should include all workers

performing work on the job site during the preceding work period.

Postconstruction Meetings

Postconstruction meetings are typically held in-house after the completion of construction projects or major phases of construction on large projects. The aim of postconstruction meetings is to perform comprehensive reviews of the projects in order to assist the contractors in improving their construction processes. Postconstruction meeting topics should include project strengths and weaknesses, schedule, safety, final cost, labor productivity, material efficiency, and subcontractor performance.

MEETING AGENDAS

For a meeting to be effective, it should be preplanned and well organized with a set of specific, realistic, and measurable objectives. A meeting agenda is a form of written communication used to organize and clearly communicate the intended content, objectives, and proposed discussions of a meeting.

Meeting agendas should be distributed at least one day prior to the meeting to remind participants of the meeting and allow them to prepare for it. Agendas should include

- title (type of meeting, meeting number, etc.);
- list of requested/required attendees;
- subject and/or purpose;
- project identifiers (name, number, etc.);
- date, time, and anticipated length;
- location;
- intended content, objectives, and/or proposed discussions; and
- instructions or notes indicating how and what participants need to prepare for the meeting.

An example of an agenda for a weekly subcontractor meeting is shown in Figure 1-4.

MEETING MINUTES

Meeting minutes are a written account of a meeting. They are not an exact record of all conversations that took place but rather a summary of the major points, decisions made, and discussions that occurred in the meeting. Another important aspect of meeting minutes is to document the assignment of action items, including identifying what action is to be completed and who is to complete the action and by when.

During the meeting, the note taker should make every effort to record detailed, unbiased, objective notes. After the meeting, notes should be edited, organized, written into minutes, and distributed to all participants of the meeting within 24 hours to allow for immediate feedback. If you are not the author of the meeting minutes it is important to thoroughly review them. Note takers may introduce bias or inaccurately record what took place in the meeting. If discrepancies exist, they should be documented and distributed to all parties immediately. Meeting minutes should include

- title (type of meeting, meeting number, etc.),
- project identifiers (name, number, etc.),
- date and time,
- location of the meeting,
- list of participants in attendance,
- list of participants absent, and
- content and discussions, including
 - approval of minutes from previous meeting,
 - project progress and schedule review,
 - submittals,
 - RFI,
 - RFP and change orders,
 - old and new business (summary of item, who is responsible, what is to be done, and when it should be completed), and
 - meeting adjourned and next meeting date and time.

An example of minutes for a subcontractor meeting is shown in Figure 1-5.

For more information see Mincks & Johnston in the list of references.

Figure 1-4 Example of a Meeting Agenda

G&J Construction
Weekly Subcontractor Progress Meeting
Agenda

To: James Smith, PQR Plumbing
Jason Lucas, HotAIR Heating and Cooling
Tony Wintz, Dry Roofing
Shima Clarke, White Drywall
Dennis Bausman, AC Electric

From: Joe Joseph, Project Manager
Greg Gregory, Superintendent

Project: Big Office Building, Busy City, SC

Project No.: 2015-012

Date: Thursday, May 14, 2015

Time: 10:00am

Location: Jobsite office

1. Approval of minutes from previous meeting
2. Project progress, schedule review
3. Submittals
4. Request for information (RFI)
5. Request for proposals (RFP), change orders
6. Old business
7. New business

Note: All meeting participants should come prepared with paper, writing utensils, and any paperwork relevant to the meeting.

Figure 1-5 Example of Meeting Minutes

G&J Construction
Weekly Subcontractor Progress Meeting
Meeting Minutes

Project: Big Office Building, Busy City, SC **Project No.:** 2015-012
Date: Thursday, May 14, 2015 **Time:** 10:00am
Location: Jobsite office

Attendees: James Smith, PQR Plumbing
 Jason Lucas, HotAIR Heating and Cooling
 Shima Clarke, White Drywall
 Dennis Bausman, AC Electric
 Joe Joseph, G&J Construction
 Greg Gregory, G&J Construction

Absent: Tony Wintz, Dry Roofing

1. **Minutes from previous meeting were approved without change.**
2. **Project progress, schedule review**
 Reviewed and distributed updated overall project schedule and two-week schedule (see attached).
3. **Submittals**
 Reviewed current submittal log.
 Outstanding submittals:
 Plumbing fixtures
 Electrical switchboard
 Acoustical ceiling tile samples
4. **Request for information (RFI)**

RFI #	Description	Date Sent	Responded	Status
01	Unsuitable soil	03/09/2015	03/11/2015	Complete
02	Foundation reinforcement	03/23/2015	03/27/2015	Complete
03	Pad size discrepancy	03/23/2015	03/24/2015	Complete
04	Column connection detail	04/07/2015	04/08/2015	Complete
05	Restroom 213 wall	05/11/2015	05/11/2015	Pricing
5. **Request for proposals (RFP), change orders**

RFP #	Description	Pricing Due	CO #	Status
01	Restroom 213 wall	05/18/2015	NA	Pricing
6. **Old business**
 05/07/2015 Rough-in inspection scheduled for 05/13/2015. Update: Inspection passed.
 Drywall installation began today.
7. **New business**
 05/14/2015 Restroom 213 on hold pending approved pricing.

Meeting adjourned at 10:45am, next meeting Thursday, May 21, 2015 at 10:00am in jobsite office.

CONSTRUCTION MEETINGS STUDY QUESTIONS

1. Meeting agendas should be distributed_____.
 - A. at least one day prior to the meeting
 - B. at the beginning of the meeting
 - C. about one day after the meeting
 - D. any time during the project
2. Meeting minutes should be distributed_____.
 - A. about one day prior to the meeting
 - B. at the beginning of the meeting
 - C. about one day after the meeting
 - D. any time during the project
3. Which of the following types of meetings is typically held at regular weekly or biweekly intervals throughout the project?
 - A. preconstruction meetings
 - B. progress meetings
 - C. postconstruction meetings
 - D. coordination meetings

ORAL COMMUNICATION ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | A. | 2. | D. | 3. | D. |
| 4. | B. | | | | |

WRITTEN CORRESPONDENCE ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | C. | 2. | C. | 3. | C. |
|----|----|----|----|----|----|

CONSTRUCTION REPORTS ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | D. | 2. | B. | 3. | C. |
|----|----|----|----|----|----|

CONSTRUCTION MEETINGS ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | A. | 2. | C. | 3. | B. |
|----|----|----|----|----|----|

CAC EXAM: STUDY GUIDE



CHAPTER 2

ENGINEERING CONCEPTS

ENGINEERING MATERIAL PROPERTIES	17
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MECHANICS AND STRENGTH OF MATERIALS	30
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ENGINEERING MATERIAL PROPERTIES

AGGREGATE

In construction, the term *aggregate* refers to the granular material, typically sand, gravel, and crushed stone, used in a variety of construction applications. Aggregate is commonly used in concrete, mortar, asphalt, plaster, drainage systems, erosion control, landscaping, as roof ballast, and as a base course for pavement and concrete slabs on grade.

Aggregate is classified by size and gradation using a series of sieves (Figure 2-1) and divided into two groups: fine aggregates and coarse aggregates. Numbered (No.) sieve sizes are based on the number of square openings per linear inch of sieve. For example, No. 30 sieve has 30 openings per linear inch, or 900 square openings per square inch. Fine aggregates include natural sands or crushed stone with all particles smaller than 3/8 in. and the majority of the particles passing through No. 4 (4.75 mm) sieve. Coarse aggregates include gravel or crushed stone with a majority of the particles retained on the No. 4 sieve and ranging up to 6 in. The American Society for Testing and Materials (ASTM) further defines fine and coarse aggregates and provides a variety of testing methods and technical specifications for aggregates.

Figure 2-1 ASTM Sieves for Gradation of Aggregate

Sieve Size	Sieve Opening
6 in.	152.4 mm
3 in.	76.2 mm
1 1/2 in.	38.1 mm
3/4 in.	19.0 mm
3/8 in.	9.5 mm
No. 4	4.75 mm
No. 8	2.36 mm
No. 16	1.18 mm
No. 30	0.6 mm
No. 50	0.3 mm
No. 100	0.15 mm

In concrete, the maximum size and gradation of aggregate that can be used vary depending on application. In general, the maximum size of aggregate should not exceed three-fourths of the clear space between reinforcing bars or one-third of the depth of slabs. Additionally, the gradation and percentages of fine aggregates and coarse aggregates within a concrete mixture should be considered. Excessive coarse aggregate can lead to separation or honeycombing, and excess fine aggregate can lead to concrete with a low density and high water content.

CONCRETE

Concrete is made of three key ingredients: aggregate, water, and hydraulic cement. Approximately three-fourths of the volume of concrete is made up by aggregate, with the remaining amount made up by a paste formed by the water and cement.

The most common type of hydraulic cement used in concrete construction is portland cement. Portland cement is made by grinding, mixing, and then heating materials containing lime, iron, silica, and alumina. The resulting mixture is then combined with small amounts of gypsum and crushed into a fine powder. A standard bag of portland cement in the United States contains 1 cu ft of cement and weighs 94 lb. ASTM designates eight types of portland cement:

- *Type I*: Normal; general-purpose cement
- *Type IA*: Normal, Air-Entraining; Type I with improved resistance to freeze-thaw cycles
- *Type II*: Moderate Sulfate Resistance; used when in contact with water that has higher than normal, but not severe, sulfate concentrations
- *Type IIA*: Moderate Sulfate Resistance, Air-Entraining; Type II with improved resistance to freeze-thaw cycles
- *Type III*: High Early Strength; provides high strengths at an early period, usually one week or less
- *Type IIIA*: High Early Strength, Air-Entraining; Type III with improved resistance to freeze-thaw cycles
- *Type IV*: Low Heat of Hydration; Used when rate and amount of heat during hydration must be minimized

- **Type V: High Sulfate Resistance;** used when in contact with water that has severe sulfate concentrations

Concrete cures (hardens) through a chemical reaction between the water and cement called hydration. The amount of water to cement in a concrete mix, or water/cement ratio, plays an important role in determining the strength and durability of the concrete. Too little or excessive water reduces the concrete's strength and durability. The amount of water in a concrete mix is specified by its mix design. Although some mix designs allow for additional water to be added at the job site to increase a concrete's fluidity, water should be added only if previously approved by the engineer and certain conditions have been met.

In addition to aggregate, water, and cement, other ingredients, called admixtures, are often added to alter the properties of concrete in various ways. A brief listing of some of the most common admixtures and their properties are listed below. For a more detailed listing of admixtures and their properties refer to Allen & Iano and Portland Cement Association in the list of references.

- ***Air-entraining admixtures:*** improve concrete's ability to resist freeze-thaw cycles and increase workability of wet concrete. Commonly used in cold-weather climates that are subject to freeze-thaw cycles.
- ***Water-reducing admixtures:*** increase the workability of wet concrete without the addition of water. Commonly used in concrete overlays and patching.
- ***Retarding admixtures:*** slow the curing time of concrete. Commonly used in hot weather to reduce the effects of high temperatures on curing.
- ***Accelerating admixtures:*** decrease the curing time of concrete. Commonly used to reduce setting time in cold-weather applications and to increase rate of strength development in tilt-wall construction.
- ***Superplasticizers:*** increase the fluidity of concrete without adding additional water. Commonly used for applications requiring very high slump, such as heavily reinforced structures.

Conventional concrete typically weighs 140 pounds per cubic foot (pcf) to 150 pcf and is naturally strong in compression but weak in tension and shear. Compressive strength of concrete is generally expressed in pounds per square inch (psi)

based on concrete that has been allowed to cure for 28 days. Compressive strength can range from 3,000 psi to 5,000 psi for general-use concrete and 6,000 psi up to 20,000 psi for high-strength concrete.

The specific formula and selection of materials that make up a concrete mixture is called the concrete mix design. In addition to compressive strength, the concrete mix design includes specifications for the amount and types of aggregate, consistency, unit weight, air content, water content, cement content, and admixture to be used in the concrete mixture. To ensure that the placed concrete meets the desired properties specified in the mix design, several on-site and laboratory tests can be performed. Concrete field tests typically measure consistency, unit weight, air content, compressive strength, and temperature to ensure the quality of concrete.

Cast-in-Place Concrete

Cast-in-place concrete is concrete that is placed in its fluid state and allowed to cure (harden) at its permanent location on the job site. Cast-in-place concrete may be mixed on site or delivered from an off-site mixing plant (ready mix). Ready-mix concrete is typically delivered by large specialty concrete trucks that slowly rotate the concrete mix to keep it from hardening during delivery.

Concrete should be placed as close as possible to its final resting location; avoid free fall and piling of the concrete. There are several types of specialty equipment used to place cast-in-place concrete, including chutes, belts, buckets, pumps, and buggies. If required, concrete should be moved from a high to low area by shovel. Vibrators should never be used to move concrete.

Cast-in-place concrete typically incorporates concrete reinforcement and may include structural and/or architectural embeds and elements. The placement, shape, and extent of cast-in-place concrete is controlled by formwork. Cast-in-place concrete is commonly used for foundations, structural walls, slabs, sidewalks, lightweight floors, and roof decking.

Precast Concrete

Precast concrete is concrete that has been cast prior to placement on the job site. The shape of precast concrete is determined by the mold or form in which the fluid concrete was cast. Similar to cast-in-place concrete, precast concrete commonly

incorporates concrete reinforcement, architectural elements, and structural embeds. Precast concrete may be used for structural or nonstructural applications and cast on- or off-site.

Most precast concrete is cast off-site at a precast manufacturing facility (precast plant). Precast plants are typically environmentally controlled and allow for the concrete process to be continually monitored. These factors, along with the ability to make identical pieces by use of reusable molds, can allow precast plants greater quality control and cost efficiencies over cast-in-place concrete. Plant cast precast concrete is typically delivered to the job site by truck and limited to the size and weight that can be delivered. Plant cast precast concrete is used in a wide variety of applications, including reinforced concrete pipe (RCP), manhole structures, equipment pads, vaults, septic tanks, piles, columns, beams, parking decks, load-bearing and veneer walls, planks, and lintels.

Although some large and/or remote job sites may cast a significant amount of on-site precast concrete, site cast precast concrete applications are generally limited to large or heavy custom components and tilt-wall construction. Tilt-wall construction uses a series of high-strength concrete wall panels that are formed and cast on-site atop a smooth casting slab. The casting slab may be temporary, often thin with no reinforcement, or a permanent part of the building, such as a floor slab. Once the panels have cured to an approved strength, they are tilted (lifted) into place and become part of the building's structure.

Concrete Reinforcement

Because concrete has little to no tensile and shear strengths, reinforcement is added to increase these strengths in concrete. The most common forms of concrete reinforcement follow:

- *Reinforcing steel bars or rebar:* hot rolled, ribbed, round rods of steel that are typically shipped in 60-ft lengths that are then cut, bent, and shaped into limitless configurations. In the United States, rebar is sized based on its diameter in eighths of an inch; for example, a #5 bar has a diameter of 5/8 in., and a #8 bar has a diameter of 8/8 in., or 1 in.
- *Welded wire fabric:* grids of wire spaced 2 in. to 12 in. apart, welded together, and fabricated into sheets or rolls for ease of use.

Sizing of welded wire fabric is designated based on its grid spacing in inches and wire size in cross sectional area of hundredths of a square inch; for example, a 6 × 6 W1.4/1.4 has a grid spacing of 6 in. and a wire cross-sectional area of 1.4 hundredths of a square inch.

- *Fiber reinforcement:* steel, fiberglass, synthetic, or natural fibers added in the concrete mix to increase strength, control cracking, and/or improve freeze-thaw resistance in concrete.
- *Pre- and post-tensioned concrete:* uses tendons (typically cables in plastic sleeves) to strengthen the concrete by putting the concrete member under a compression load. With pretension concrete the tendons are stressed at anchorage points before the concrete is placed. Once the concrete has set, the stress load at the anchorage points is transferred to the concrete, thus placing it in compression. Post-tensioned concrete is similar, but the tendons are stressed after the concrete has set.

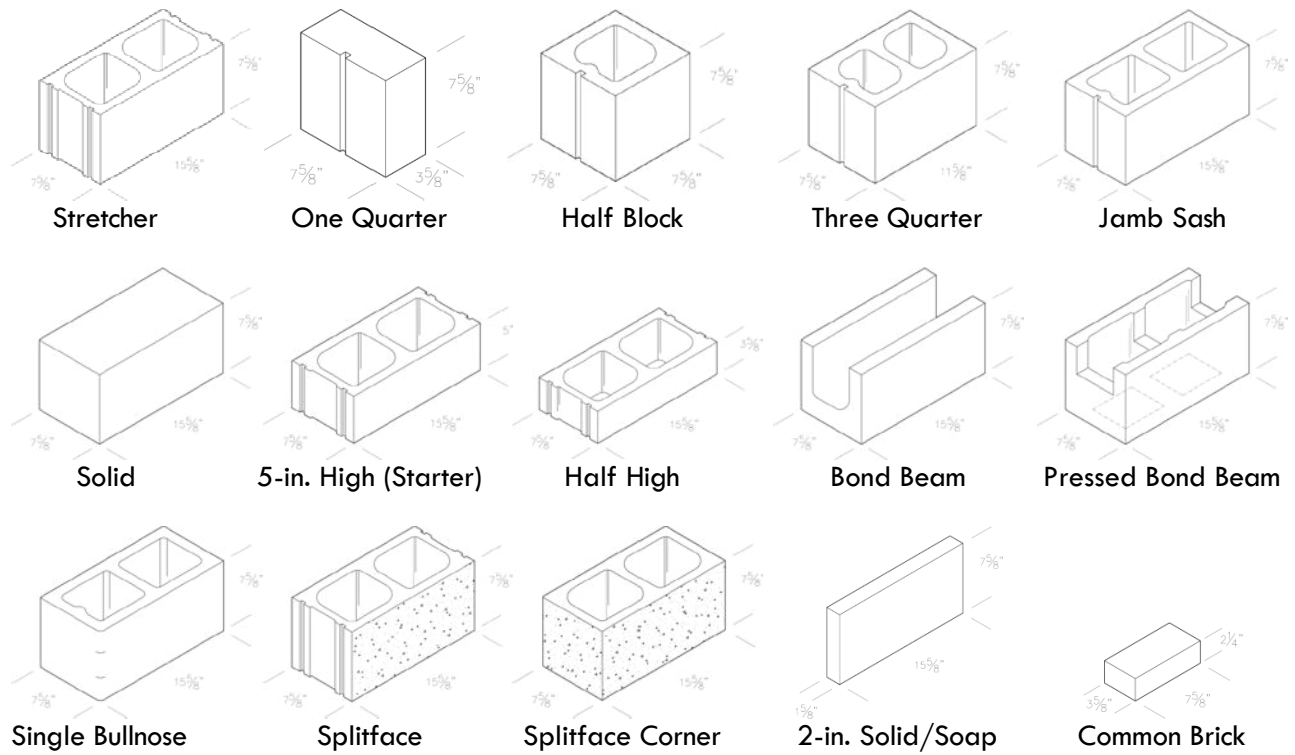
MASONRY

The term *masonry* refers to building materials consisting of brick, block, stone, or other masonry units held together with mortar. Masonry units can be either man-made or natural stone units. The two most common types of man-made masonry units are concrete masonry units (CMUs) and clay bricks. Masonry units come in an almost unlimited variety of shapes and sizes.

Concrete Masonry Units (CMUs)

Concrete masonry units (CMUs) come in a variety of standard shapes, sizes, and wall thicknesses (Figure 2-2). The most common size of CMUs is 8 in. × 8 in. × 16 in. nominal (7 5/8 in. × 7 5/8 in. × 15 5/8 in. actual) and has a 3/8 in. standard mortar joint. CMUs can be produced using normal weight (more than 125 pcf), medium weight (105 pcf–125 pcf), and lightweight (less than 105 pcf) concrete. CMU walls can be either load-bearing or non-load-bearing walls above or below grade. CMU walls are typically laid in either running bond or stacked bond pattern (Figure 2-3).

Figure 2-2 Common CMU Shapes



Reprinted Courtesy of Midwest Manufacturing, 2015

Figure 2-3 Common Masonry Bond Patterns

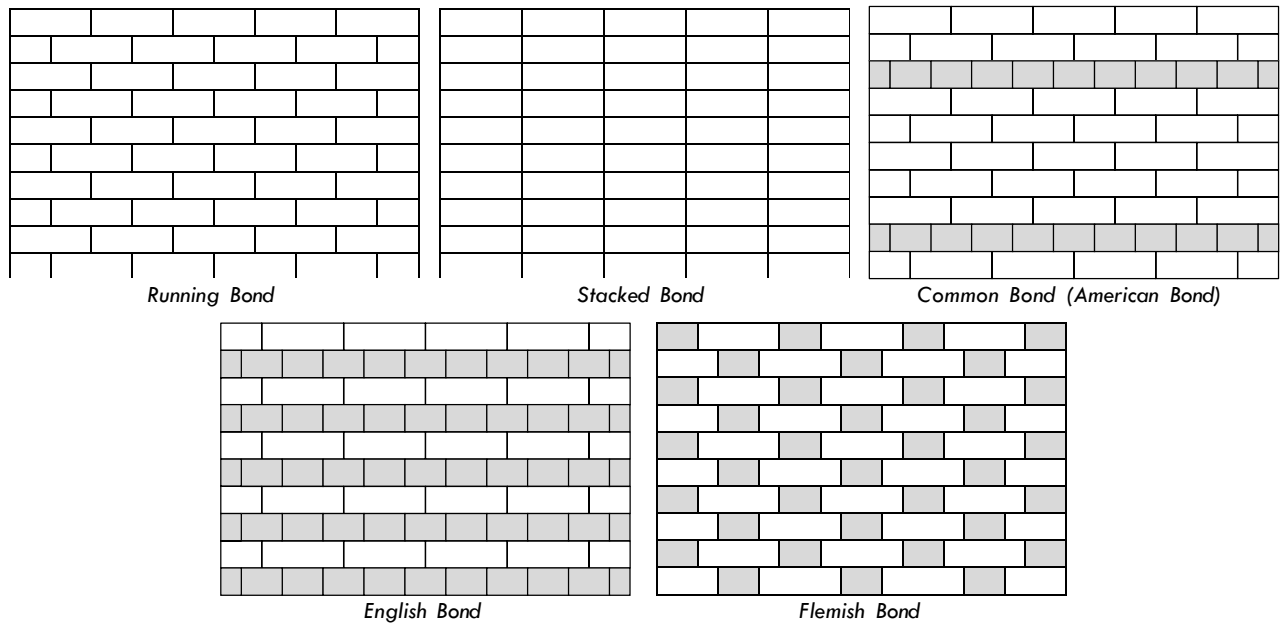


Illustration by author

To provide additional strength and/or increase performance, CMU walls may incorporate the following:

- *Joint reinforcement*: placed at horizontal joints to help control shrinkage cracks. Similar to welded wire fabric, typically constructed of two side rods connected by either straight (ladder style) or diagonal (truss style) cross rods.
- *Grout*: highly fluid mixture of cement, sand, and water used to solid fill CMU cores and bond anchorage and reinforcement to surrounding masonry. Also commonly used to increase fire rating, sound proofing, and thermal properties.
- *Vertical reinforcement*: used to increase resistance to tensile stresses and axial loads. Typically consist of rebar placed vertically in a series of cells and grouted in place. Vertical reinforcement is commonly installed the entire height of a wall or directly beneath an intended load.
- *Bond beam*: used for horizontal reinforcement to increase shear strength and distribute lateral loads. Bond beams are typically laid one course high and are grouted and contain one or more rows of rebar. Commonly placed at top of walls, floor levels, openings, and as required for additional shear strength.
- *Lintels*: typically steel or precast concrete installed above openings and used to transfer lateral loads around openings.
- *Core insulation*: used to increase the thermal properties of the CMU wall. Three commonly used types include rigid foam inserts, expandable foam insulation, and loose fill insulation.

Brick

There is no standard clay brick size in the United States; however, most bricks have a width of 3 1/2 in. or 3 5/8 in.; a length of 7 1/2 in., 7 5/8 in., 8 in., 11 1/2 in., or 11 5/8 in.; and a height of 2 1/4 in., 2 3/4 in., 3 1/2 in., or 3 5/8 in. The typical mortar joint thicknesses used for clay bricks is 3/8 in. or 1/2 in. Bricks may be manufactured as solid, cored, hollow, or frogged. Brick walls can be load-bearing or non-load-bearing and laid in various configurations for structural and visual purposes. Figure 2-4 illustrates common brick positions.

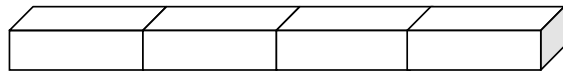
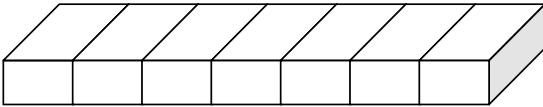
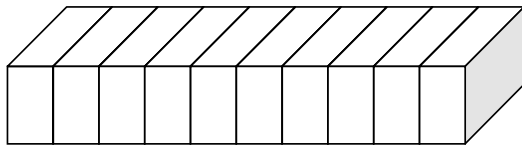
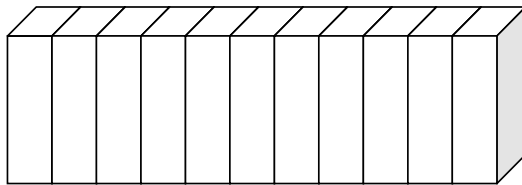
Thicknesses of brick walls are designated in terms of wythe, a vertical layer of masonry units one

unit thick. Multiple wythe walls are bonded together by altering layers of stretchers and headers. The four most common structural bonds used for load-bearing brick walls in the United States are running bond, common bond or American bond, English bond, and Flemish bond (Figure 2-3). A brick veneer wall is an exterior non-load-bearing brick wall, typically used for aesthetic purposes, that is anchored to a structural wall by metal ties or other anchoring methods. Masonry walls with multiple wythes of different types of masonry units are referred to as composite walls. Often, one wythe of a composite wall is for structural purposes and the other is decorative. A brick veneer over a CMU wall assembly is an example of a composite wall.

Mortar

Conventional mortar use in masonry construction is made up of four key ingredients: sand, water, portland cement, and hydrated lime. Several prepackaged masonry cements are also widely used for making mortar and vary by manufacturer but typically contain various admixtures to help increase one or more properties of the mortar. There are four main types of masonry mortar:

- *Type M*: high-strength mortar, typically used in high load areas and masonry below grade
- *Type S*: medium-high-strength mortar, typically used in severe weather exposure areas with normal compressive loads
- *Type N*: medium-strength mortar, most commonly used as mortar above grade
- *Type O*: medium-low-strength mortar, typically used only for non-load-bearing interior walls and partitions

Figure 2-4 Common Brick Positions**Stretcher Course****Header Course****Rowlock Course****Soldier Course***Illustration by author*

STEEL

Steel is a material composed mainly of iron and a small amount of carbon ($\leq 2\%$). The amount of carbon in steel determines the steel's properties. A high carbon content results in steel that is hard but brittle, and a low carbon content results in steel that is soft and relatively weak. Steel may also contain small additions of other elements or steel alloys. Steel alloys are added to improve one or more properties of the steel, such as tensile strength, corrosion resistance, hardness, and elasticity. Steel is the strongest building material used in construction and has a uniformly high tension and compressive strength and also is good in shear. Steel is used in a wide variety of construction applications, including structural steel beams, columns, angles, joists and girders; open web steel joists; metal decking; metal wall studs; concrete and masonry reinforcement and embeds; and fasteners. To shape structural steel, hot steel is passed through a series of rollers that squeeze the steel into the desired shape. Structural steel is sized based on the shape, size, and/or weight of the steel member; for example, for a W8 $\times$ 18, the W designates the shape as wide flange, the 8 indicates a nominal depth of 8 in., and the 18 is the weight per foot of length in pounds.

For more information see Allen & Iano, Dishong, and Wujeck in the list of references.

WOOD

Wood is a widely used natural construction material because of its ease of use and desirable aesthetic properties. There are two main classifications of wood: hardwoods and softwoods. Hardwood is wood harvested from broad-leaved deciduous trees, and softwood is wood harvested from narrow, needle-leaved coniferous trees. In general, softwoods are more abundant, less expensive, and typically used for most structural framing and sheathing, and hardwoods are used for furniture and high-end interior finishes. Both hardwoods and softwoods are used for moldings, paneling, and finish flooring. A variety of decay-resistant softwoods, such as cedar, are commonly used for shingles, exterior siding, and outdoor structures.

Wood is generally strong in compression and tension when forces are applied parallel to the grain but weak when forces are applied perpendicular to the grain. Wood has little shear strength as a result of its tendency to split along the grain. In its natural state, most wood is prone to fire damage and susceptible to deterioration by moisture and insects. To combat these weaknesses, a variety of chemical treatments have been developed. Chemical treatments can be surface applied but are more commonly impregnated into wood products by pressure treating.

The five most common types of wood products used in construction are lumber, wood panel products, laminated wood, structural composite lumber, and wood manufactured building components.

Lumber

Lumber is a solid wood product cut directly from the log of a felled tree. There are two common methods of cutting lumber: plain sawn and quarter sawn. In plain-sawn lumber, boards are cut from the log to achieve maximum yield. Plain-sawn lumber can result in varying grain orientations, which can cause boards to distort during seasoning. Structural wood framing is typically plain-sawn lumber. In quarter-sawn lumber, boards are cut so that the grain runs perpendicular to the face of the board. Quarter-sawn lumber tends to remain flat and is commonly used in wood flooring.

Nearly all lumber has one or more lumber defects. Lumber defects can be caused by the growth of the tree from which it came or from the manufacturing process. Common lumber defects include knots, knotholes, decay, insect damage, splits, checks, crooking, bowing, twisting, cupping, and warping. Lumber is graded based on appearance or structural strength. Common grades of structural lumber, rated in decreasing order, are Select Structural, No. 1, No. 2, and No. 3.

Most structural lumber is cut S4S, surfaced four sides, and sized based on its nominal dimensions. The nominal dimension of lumber represents its size prior to final sawing and smoothing, which results in the actual dimensions of lumber being less than its nominal dimension (Figure 2-5); for example, a common 2 in. × 4 in. board has the actual dimensions of 1.5 in. × 3.5 in.

Figure 2-5 Nominal Dimension vs. Actual Dimension of Lumber

Nominal Dimension	Actual Dimension
1 in.	3/4 in.
2 in.	1 1/2 in.
3 in.	2 1/2 in.
4 in.	3 1/2 in.
5 in.	4 1/2 in.
6 in.	5 1/2 in.
8 in.	7 1/4 in.
10 in.	9 1/4 in.
12 in.	11 1/4 in.
>12 in.	Nominal less 3/4 in.

Wood Panel Products

Wood panel products are manufactured by adhering wood veneers, strands, particles, and/or fibers together. Wood panel products are typically produced in 4 ft × 8 ft sheets and come in a variety of thicknesses. Five common types of wood panel products used in construction include the following:

- *Plywood*: made up of thin layers of wood veneers adhered together in alternating directions; typically used in floor, wall, and roof sheathing

- *Oriented strand board (OSB)*: made up of large strands of wood adhered together in layers of strands in alternating directions; typically used in floor, wall, and roof sheathing and is less expensive than plywood
- *Composite panels*: made up of wood fibers adhered together and sandwiched between outside layers of wood veneers; typically used in cabinet construction and other nonstructural applications
- *Particle board*: made up of wood particles smaller than those in OSB adhered together; typically used in shelving, plastic laminate countertops, and other nonstructural applications
- *Medium-density fiberboard (MDF)*: made up of wood fibers adhered together with resin; typically used in cabinets and moldings

APA—The Engineered Wood Association sets performance standards for structural wood panel products based on the products' structural applications, exposure ratings, and allowable uses. Structural wood panels are stamped with a grade stamp that identifies the panel's properties. Additionally, veneer panels are stamped with an A, B, C, or D veneer grade based on the number of defects found in the surface layer veneer; a veneer grade of A means the panels have very few to no defects, and a veneer grade of D means the panels have several defects, none of which are structural.

For more information see Allen & Iano and Breyer, Cobeen, Fridley, & Pollock in the list of references.

Laminated Wood

Laminated wood is manufactured by adhering together strips of wood to create large structural members. Laminated wood members are commonly referred to as glue-laminated wood, or glulam. Laminated wood members can be manufactured in almost any size and shape. Additionally, laminated wood members are stronger than standard lumber of the same size, because defects can be removed before the laminating process. Typical lamination thicknesses are 1 1/2 in. for straight members and 3/4 in. for curved members.

Structural Composite Lumber

Structural composite lumber is manufactured by adhering together wood veneers or strands to create structural members. Structural composite

lumber is manufactured in a way similar to that of plywood and oriented strand board except that all veneers or strands are oriented in the same longitudinal direction. Structural composite lumber has advantages over traditional lumber similar to those of laminated wood. The three most common types of structural composite lumber follow:

- *Laminated veneer lumber (LVL)*: manufactured by using sheets of wood veneers; looks similar to thick plywood.
- *Parallel strand lumber (PSL)*: manufactured by using narrow strips of wood veneers
- *Laminated strand lumber (LSL)*: manufactured by using large strands of lumber; looks similar to a thick OSB

Wood Manufactured Building Components

Wood manufactured building components are manufactured by combining and/or configuring standard lumber and/or wood panel products together to create efficient structural components. Common wood manufactured building components include the following:

- *Wood roof trusses*: typically manufactured with 2×4 s or 2×6 s joined together by metal plate connectors; use less wood, span greater distances, and allow for faster installation than stick built roof framing
- *Wood floor trusses*: commonly manufactured with 2×4 or 2×6 top and bottom chords and same sized webbing joined together with metal plate connectors or smaller sized webbing finger joined and adhered together; span greater distances and allow for ease of mechanical and electrical installation compared to conventional floor framing
- *Wood I-joists*: I-shaped members typically manufactured using solid lumber, LVL, or LSL top and bottom flanges with solid plywood or OSB webs; span greater distances, can come in long lengths, and are lighter than conventional floor framing
- *Wood panel components*: prefabricated floor, wall, or roof components constructed of dimensional lumber and/or wood panel products

ENGINEERING MATERIAL PROPERTIES STUDY QUESTIONS

- Which material is prone to fire damage and deterioration by moisture and insects?
 - concrete
 - masonry
 - wood
 - steel
- Concrete is strongest in _____.
 - compressive strength
 - tensile strength
 - shear strength
 - fluid strength
- Which of the following is a type of aggregate?
 - gravel
 - topsoil
 - water
 - cement
- Approximately what percentage (by volume) does aggregate make up in general-purpose concrete?
 - 25%
 - 50%
 - 75%
 - 90%
- What does a sieve size of No. 4 mean?
 - The sieve has 4-in. openings.
 - The sieve has four openings per square inch.
 - The sieve has four openings per linear inch.
 - The sieve has four openings per square foot.
- Which panel wood product is made up of thin layers of wood veneers adhered together in alternating directions?
 - plywood
 - oriented strand board (OSB)
 - particle board
 - medium-density fiberboard (MDF)
- The 10 in a W10 $\times$ 30 steel beam indicates what?
 - the nominal width of the flange in inches
 - the nominal depth of the beam in inches
 - the weight per foot of length in pounds
 - the length of the beam in feet

8. Which of the following mortar types has the highest strength?
- Type M
 - Type S
 - Type N
 - Type O

SOIL MECHANICS

SOIL COMPOSITION TYPES AND PROPERTIES

Soil contains three components: solid (weathered rock and decayed vegetation), liquid (water), and gas (air). Soils are commonly classified by category, type, and/or grain size. Three broad categories used in soil classification include the following:

- **Cohesive soils:** soils with very small particles that typically stick together, such as clay
- **Cohesionless soils:** soils that do not tend to stick together such as gravel, sand, and silt
- **Organic soils:** soils that contain organic material, such as peat

Soil type is typically used to classify soil and rock deposits in excavations based on their stability. OSHA standards classify four types of soil and rock deposits:

- **Stable rock:** natural, solid material that can be excavated with vertical sides and remains intact while exposed
- **Type A:** undisturbed cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (tsf) or greater
- **Type B:** cohesive soils with unconfined compressive strength greater than 0.5 tsf but less than 1.5 tsf; also include stable, granular, cohesionless soils; previously disturbed soils; and unstable rock
- **Type C:** cohesive soils with an unconfined compressive strength of 0.5 tsf or less, unstable soils, and saturated soils and rock

Soil grain sizes are used to identify the composition and properties of a soil sample. Grain sizes are determined by performing a sieve analysis and classified according to U.S. standard sieve numbers (Figure 2-6). Soils coarser than a No. 200 sieve size are considered coarse-grained soils, and soils finer than a No. 200 sieve size are considered fine-grained soils.

Figure 2-6 U.S. Standard Sieves for Soil Grain Sizes

Sieve Size	Sieve Opening
No. 4	4.75 mm
No. 10	2.00 mm
No. 20	0.850 mm
No. 40	0.425 mm
No. 60	0.250 mm
No. 100	0.150 mm
No. 200	0.075 mm

The distribution of a soil's grain size can greatly influence the properties of the soil. Most cohesionless soils are coarse-grained soils, and their grain size distribution can be identified by sieve analysis. Cohesive soils, however, have particles that are too small to be determined by sieve analysis. The most common techniques for analyzing cohesive soils are the hydrometer method and the Atterberg limits method. A hydrometer analyzes particles by indirectly observing their settling velocities in a soil-water mixture. The Atterberg limits method defines soil consistency as four states: liquid, plastic, semisolid, and solid. There are three transition limits between each of these states:

- **Liquid limit:** transition between liquid and plastic states
- **Plastic limit:** transition between plastic and semisolid states
- **Shrinkage limit:** transition between semisolid and solid states

These limits are used to help classify the soils and determine their applications.

For more information see Liu & Evett in the list of references.

The amount of water and air, or void, within a soil also influences the soil's properties and characteristics. There are three phenomena related to water within soil:

- **Permeability:** the movement of water in soil through voids. Soils with large voids such as gravel and sand generally have greater permeability than soils with smaller voids, such as clay.

- **Capillarity:** the rise of water, against gravity, from a water source into the voids within a soil. Soils with high capillarity typically have a smaller grain size and higher permeability, such as silts and very fine-grained sands.
- **Frost heave:** the vertical expansion of soil due to the freezing of water within the soil.

SOIL INVESTIGATION TESTING METHODS AND SOIL BORINGS

Soil investigation generally begins with a preliminary soil survey that typically includes general geologic and topographical information obtainable from federal, state, and local governmental agencies. Subsurface soil exploration is the next step in soil investigation and consists of three steps:

- **Boring:** drilling or digging a hole in the ground. Common types of borings include auger borings, wash borings, test pits, and core borings.
- **Sampling:** removing the soil from the hole. Samples may be classified as either disturbed (auger and wash borings) or undisturbed (test pits and core borings).
- **Testing:** the process of determining the properties and characteristics of the soil. Testing may be done in the field or in a lab. The most common field test used in the United States is the standard penetration test (SPT).

For more information see Liu & Evett in the list of references.

The final step in soil investigation is the soil investigation report, or geotechnical report. The geotechnical report identifies the methods used for testing; provides a description of the site geology and subsurface conditions; and provides analysis, design, and construction recommendations. Also included in the geotechnical report is a map of test locations and boring logs, if boring is used. See Figure 2-7 for an example of a boring log. Boring logs indicate what type and at what depth different soil types and conditions can be expected. They should be reviewed early in the construction process and can assist a contractor in identifying the amount of available fill from excavations, type of excavation protection that will be required, locations of potential soil contaminants, extent of

any rock excavations, dewatering requirements, and other constructability factors.

TYPES OF FOUNDATIONS

There are two basic types of foundations: shallow foundations and deep foundations.

Shallow Foundations

Shallow foundations bear on suitable soil found at the base of a structure. Shallow foundations are typically less expensive than deep foundations. Common types of shallow foundations include the following:

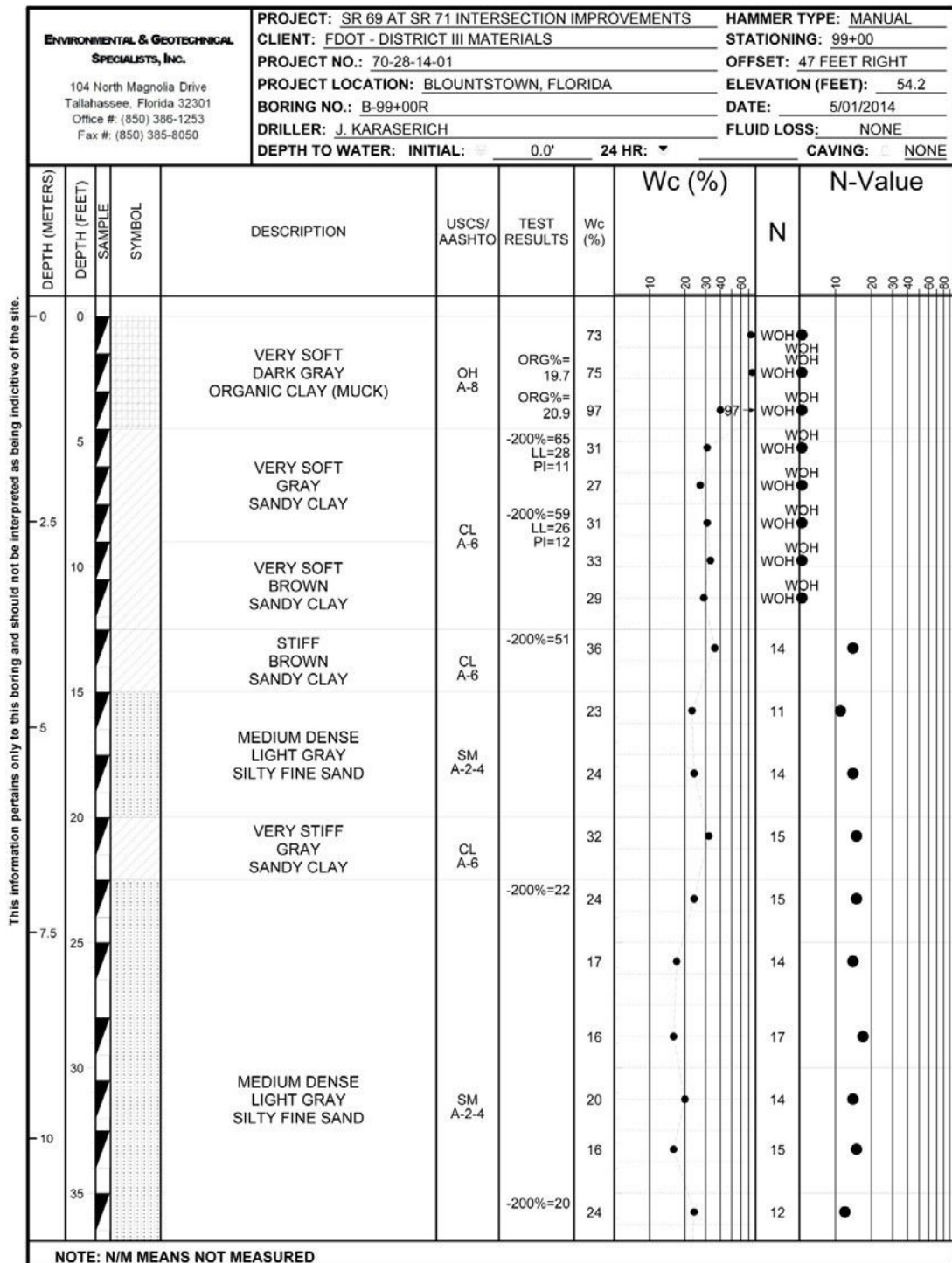
- **Isolated, single column or pad footing:** a pad of concrete that spreads a concentrated load from the building above.
- **Wall, strip, or continuous footing:** a continuous strip of concrete that supports a continuous load above, similar to a load-bearing wall.
- **Monolithic slab on grade:** a concrete slab with thickened edges at loads above. Least expensive type of foundation. Typically used in areas with little or no ground frost.
- **Crawl space or basement:** a foundation wall, usually concrete or masonry, set atop a concrete strip footing. Typically used in areas with deep ground frost, low water table, and/or grade changes.
- **Mat or raft foundation:** large, often thick, foundation that supports the entire structure. Often used when column footings become large enough that they overlap or are more economical to pour as one unit.

Deep Foundations

Deep foundations are used to penetrate upper layers of unsatisfactory soils to allow the structure to bear on satisfactory soils or rock deeper in the earth. Common types of deep foundations include the following:

- **Caisson:** a drilled or dug cylindrical shaft with belled end and, if required, filled with concrete. Used to transfer loads through layers of unsatisfactory soils to satisfactory soils or rock below.
- **Piles:** a material, typically timber, steel, or concrete, driven into the ground through unsatisfactory soil until a firm bearing layer (end bearing pile) or sufficient friction resistance (friction pile) is encountered.

Figure 2-7 Example of a Boring Log



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FIELD SOIL IDENTIFICATION METHODS

OSHA standards require at least one visual and one manual field soil analysis test be performed by a qualified person at the test site for classification of soil. The visual analysis requires the observation of soil conditions and properties of excavated materials to establish general soil classifications. Manual field tests are used to more accurately classify a soil by providing additional information and determining the soil's properties. OSHA standards require one of the following tests to be used for the manual field soil analysis:

- **Plasticity test:** requires the tester to mold a moist or wet sample of soil into a ball and attempt to roll it into threads as thin as 1/8 in. in diameter × 2 in. in length. The soil sample is then held by one end, and if the soil sample does not tear or break it is considered a cohesive soil.
- **Dry strength test:** used to determine the amount of strength and the presence of fissures in dry soils.
 - If the soil is dry and crumbles on its own or with moderate pressure into individual grains of fine powder, it is granular (any combination of gravel, sand, or silt).
 - If the soil is dry and falls into clumps that break up into smaller clumps, but the smaller clumps can be broken up only with difficulty, it may be clay in any combination with gravel, sand, or silt.
 - If the dry soil breaks into clumps that do not break into small clumps and can be broken only with difficulty and there is no visual indication the soil is fissured, the soil may be considered unfissured.
- **Thumb penetration test:** used to estimate the unconfined compressive strength of cohesive soils based on depth of thumb penetration (Figure 2-8). Test should be conducted on an undisturbed soil sample, such as a large clump of soil, as soon as practicable after excavation to keep to a minimum the effects of exposure to drying influences. If the excavation is later exposed to wetting influences (rain, flooding), the classification of the soil must be changed accordingly.

Figure 2-8 Thumb Penetration Level - ASTM Standard Test D 2488

Thumb Penetration	Unconfined Strength	Soil Type
1/4 in. or less	1.5 tsf	A
1/4 in.–1 in.	0.5–1.5 tsf	B
1 in. or more	0.5 tsf	C

- **Pocket penetrometer:** direct reading, spring-operated instruments used to determine the unconfined compression strength of saturated cohesive soils. Once pushed into the soil, an indicator sleeve displays the reading in either ton per square foot (tsf) or kilograms per square centimeter (kPa). Typically used on trench face or a large clump of soil. Penetrometers have error rates of +/–20%–40%.
- **Shear vane, or torvane:** hand-operated instrument used to determine the unconfined compression strength of soil. Soil strength is taken by pressing the instrument's blades into a level section of undisturbed soil and slowly turning a torsional knob until soil failure occurs. The direct instrument reading must then be multiplied by 2 to provide results in tons per square foot (tsf) or kilograms per square centimeter (kPa).
- **Drying test:** used to differentiate between cohesive material with fissures, unfissured cohesive material, and granular material. The drying test procedure involves drying a sample of soil that is approximately 1 in. (2.54 cm) thick and 6 in. (15.24 cm) in diameter until it is thoroughly dry. If the sample develops cracks as it dries, significant fissures are indicated. Samples that dry without cracking are to be broken by hand. If considerable force is necessary to break a sample, the soil has significant cohesive material content. The soil can be classified as an unfissured cohesive material and the unconfined compressive strength should be determined. If a sample breaks easily by hand, it is either a fissured cohesive material or a granular material. To distinguish between the two, pulverize the dried clumps of the sample by hand or by stepping on them. If the clumps do not pulverize easily, the material is cohesive with fissures. If they

pulverize easily into very small fragments, the material is granular.

VOLUME CHANGES AND COMPACTION

The type, water content, air content, and geographic location can all affect the volume of a soil. Some soils, particularly those with high plasticity, can swell and shrink significantly as a result of wetting and drying. In locations where the temperature falls below freezing, water within the soil can freeze and thaw causing the volume of the soil to expand and contract with changing temperatures. Soils closest to the surface of the ground are most susceptible to these types of volume changes.

Soil can decrease in volume by being compressed. Methods of soil compression include the following:

- **Consolidation:** the extrusion of water from voids within a soil as a result of increased loading. The grain size and permeability of a soil greatly affect the length of time the consolidation process takes to complete. In soils with high permeability (i.e., coarse-grain soils, such as gravel and sand), consolidation occurs within a short time period. In soils with low permeability (i.e., fine-grain soils, such as clay), consolidation occurs over a long period of time. In fine-grained soils, consolidation is the leading cause of settlement.
- **Compaction:** the tightly pressing together of soil particles by expelling air from void space. Soil compaction increases a soil's density and shear strength and results in a decrease in a soil's permeability and future settlement. Compaction can occur rapidly during construction and is most effective with unsaturated soils.

In construction, soil is commonly referred to as being in one of three conditions: bank, loose, or compacted. Bank soil is soil that is in its natural, undisturbed state. Loose soil is soil that has been disturbed from its natural state, creating voids, causing the soil to swell and increase in volume. Compacted soil is soil that has been compressed to reduce air in the soil, decreasing its volume. The amount a soil swells and can be compacted depends on the type, particle size/shape, and moisture content of the soil.

Soil is typically compacted in the field in layers, or lifts, by mechanical equipment. A common layer of soil consists of loose soil spread and compacted to a depth of 6 in. to 12 in. There are several common types of mechanical equipment used in soil compaction, including the following:

- **Tampers:** hand-operated devices that compact soil by delivering a series of vertical blows. Commonly used in areas with limited space not accessible by other types of compaction equipment.
- **Plate compactors:** hand- or machine-operated devices consisting of a flat, heavy metal plate that is vibrated up and down to compact soil. Commonly used in small or narrow areas, such as patios, small driveways, and trenches.
- **Smooth wheel rollers:** compact soil by use of heavy smooth metal rollers. Range in size from small to large. Small rollers are typically pulled by another piece of equipment, and large rollers may be pulled but are more commonly self-propelled with two or three rollers. Smooth wheel rollers are commonly used in compacting paving courses or to provide a smooth ground surface and can cover large areas quickly.
- **Sheepsfoot rollers:** compact soil by use of a heavy metal drum with projecting metal feet. The feet create a kneading action that is more effective in compacting fine-grained soils, such as clay, than are smooth wheel rollers. Typically self-propelled and used to cover large areas.
- **Pneumatic rollers:** compact soil by use of several highly inflated rubber tires. Pneumatic rollers are typically pulled by another piece of equipment. Commonly used for compacting clay and silty materials or granular material containing small amounts of fines.
- **Vibratory rollers:** compact soil by vibrating a roller up and down as it moves across the soil. Typically self-propelled and used in compacting granular materials, such as clean sands and gravels.

SOIL MECHANICS STUDY QUESTIONS

1. Which of the following is a type of deep foundation?
 - A. crawl space
 - B. strip footing
 - C. mat footing
 - D. caisson
2. Clay is what type of soil?
 - A. solid rock
 - B. cohesive soil
 - C. cohesionless soil
 - D. organic soil
3. Sand is what type of soil?
 - A. solid rock
 - B. cohesive soil
 - C. cohesionless soil
 - D. organic soil
4. Soil that has been excavated and stockpiled is considered to be in a _____ state.
 - A. natural
 - B. bank
 - C. loose
 - D. compacted
5. What is the purpose of a visual field soil analysis?
 - A. see how much work has been completed
 - B. establish general soil classifications
 - C. check for the presence of worms in the soil
 - D. develop an excavation plan
6. What is the correct order of subsurface soil exploration?
 - A. boring, sampling, testing
 - B. sampling, boring, testing
 - C. sampling, testing, boring
 - D. testing, sampling, boring
7. Fine-grained soils are soils finer than a _____.
 - A. No. 60 sieve
 - B. No. 100 sieve
 - C. No. 200 sieve
 - D. No. 400 sieve

8. Referencing the example of a boring log in Figure 2-7, at approximately what depth would you expect to find very stiff gray sandy clay?
 - A. 5 ft to 9 ft
 - B. 10 ft to 14 ft
 - C. 15 ft to 19 ft
 - D. 20 ft to 22 ft

MECHANICS AND STRENGTH OF MATERIALS

FORMWORK DESIGN

Formwork is used in concrete construction to mold and control concrete to attain a desired size, shape, placement, and/or finish of the cast concrete. Formwork may be a permanent or temporary component of the structure. Historically, formwork was constructed using lumber and used for one project. Today, a wide variety of materials and methods are used in formwork. Common formwork materials include dimensional lumber, plywood, engineered wood products, steel, alloyed aluminum, glass fiber reinforced plastic, rigid insulation, and fabric. Formwork may be custom constructed or prefabricated forms.

Prefabricated forms are manufactured reusable or single-use forms that a manufacturer commonly pre-engineers for a particular use. Following are common prefabricated forms:

- *Panel forms and systems:* reusable forms comprising a system of panels, hardware, and ties. Panels are typically manufactured in modular sizes, often 2 ft or 4 ft wide and ranging in height from 2 ft to 8 ft. The most common panel forming systems are unframed plywood panels, all-metal panels, and metal-framed plywood panels.
- *Tubular fiber column forms:* single-use one-piece form. Forms can be easily cut by saw to desired length and commonly range in diameter from 6 in. to 48 in.
- *Round glass fiber-reinforced plastic column forms:* reusable one-piece form that bolts or clamps along a single joint to allow the form to be removed after concrete has cured. Common diameters range from 12 in. to 36 in.
- *Round steel column forms:* reusable forms made up of sections connected by hardware with bracing built into the forms. Forms commonly

range in diameters from 14 in. to 10 ft and vertically from 1 ft to 10 ft in height.

- **Insulated concrete forms (ICFs):** single-use forms made up of interlocking modular units or panels of rigid insulation. Forms remain in place, becoming a permanent part of the structure with added R-value.
- **Metal deck:** single-use ribbed or corrugated sheets of steel that form, support, and reinforce cast concrete. Metal decking is most commonly used in concrete floor and roof slabs and comes in various gauges and styles. Once the concrete is placed, the metal decking becomes a permanent part of the structure.

The most critical aspect of formwork is its ability to safely support all loads applied to it during concrete placement. The way formwork is braced, shored, and reshored and the stripping of forms should all be considered prior to installation of the formwork. The most common loads encountered in formwork are vertical loads, lateral loads, and loads imposed by the lateral pressure of fresh concrete.

Vertical Loads

Vertical loads on formwork include dead loads—such as the weight of the concrete, reinforcement, and formwork—and live loads—such as the weight of workers, equipment, and stored materials. Vertical load is calculated in terms of pounds per square foot (psf) by adding together the dead and live loads.

Although the weight of concrete can vary greatly, the majority of concrete, with reinforcing steel, used in formwork weighs around 140 pcf to 150 pcf. The formwork often has little weight (typically 3–15 psf) compared to the weight of the concrete and live load. Because of this, a dead load of 150 pcf (or 12.5 psf per inch of slab thickness) is commonly assumed in formwork design.

The American Concrete Institute (ACI) recommends that formwork be designed with a minimum live load of 50 psf for the weight of workers and standard equipment and 75 psf if motorized carts are used.

Example: The minimum vertical load of formwork for a concrete slab 6 in. thick placed with standard equipment would be calculated as follows:

$$\begin{aligned}\text{Dead load} &= 12.5 \text{ psf/in.} \times 6 \text{ in.} \\ &= 75 \text{ psf}\end{aligned}$$

$$\text{Live load} = 50 \text{ psf}$$

$$\begin{aligned}\text{Total vertical load} &= \text{Dead load} + \text{Live load} \\ &= 75 \text{ psf} + 50 \text{ psf} \\ &= 125 \text{ psf}\end{aligned}$$

Lateral Loads

Lateral loads encountered in formwork include wind, movement of concrete equipment, dumping of concrete, and inclined forms. The ACI recommends a minimum lateral load for slab forms of 100 plf of slab edge, or 2% of the total dead load, whichever is greater. Wind loads are determined based on local code requirements but should be a minimum of 100 plf or 15 psf for wall forms. The lateral load placed on formwork by the movement of concrete equipment is based on the equipment's weight and the average acceleration or deceleration of the equipment.

For more information see Johnston in the list of references.

Loads Imposed by the Lateral Pressure of Fresh Concrete

Loads imposed by the lateral pressure of fresh concrete result from fresh concrete temporarily behaving like a fluid and creating hydrostatic pressure that acts laterally against vertical forms. The basic formula for calculating lateral pressure of freshly placed concrete is

$$C_{CP} = wh$$

where

C_{CP} = lateral pressure in pounds per square foot

w = weight of fresh concrete in pounds per cubic foot

h = depth of the concrete in feet

Example: Concrete with a fluid weight of 150 pcf placed to a depth of 4 ft has a lateral pressure of 600 psf.

$$150 \text{ pcf} \times 4 \text{ ft} = 600 \text{ psf}$$

Several other factors may also affect the lateral pressure on formwork including the rate of concrete placement, vibration, temperature, and the composition of the concrete mix.

Admixtures are another major influencing factor for lateral concrete pressures on formwork. In recent

years the ACI has expanded on the basic formula provided above to account for the effects of admixtures. These revised formulas can be found below.

$$C_{CPmax} = C_c C_w \left(150 + \frac{9000R}{T} \right)$$

for columns or walls ≤ 14 ft

$$C_{CPmax} = C_c C_w \left(150 + \frac{43,400}{T} + \frac{2800R}{T} \right)$$

for walls > 14 ft and walls with a rate of placement of 7 ft/h to 15 ft/h

where

C_c = chemistry coefficient

C_w = unit weight coefficient

R = rate of placement

T = temperature of concrete

For more information see Johnston in the list of references.

BEAM LOADS

In terms of structural design, a beam is any horizontal structural member that bears on reaction points and is subject to a force/load. Joists, stringers, purlins, lintels, headers, and girders are all types of beams commonly found in construction. A beam is typically subject to forces/loads applied perpendicularly to its longitudinal axis. These perpendicular forces will cause shear and bending in the beam.

- **Shear:** There are two common types of shear that may affect a beam: vertical shear and horizontal shear. Vertical shear is the tendency of one part of the beam to move vertically to an adjoining part of the beam, perpendicular to the beam's axis. Horizontal shear is the tendency of a beam's fibers to slide horizontally past one another, parallel to the beam's axis.
- **Bending:** A beam will have a tendency to bend when forces/loads are applied to the beam. The bending of a beam results in deflection. Deflection is the amount a beam bends when a force/load is applied. Deflection is typically measured in inches.

Beams may have concentrated loads, distributed loads, or a combination of both. Beams with loads that are distributed evenly across the beam are considered to be uniformly loaded. In addition to the way a beam is loaded, the way a beam is supported plays an important role in

determining how forces/loads will affect a beam. Figure 2-9 illustrates common types of beam supports.

For more information see Beer, Johnston, & Mazurek, and Wujek in the list of references.

Figure 2-9 Common Types of Beam Supports

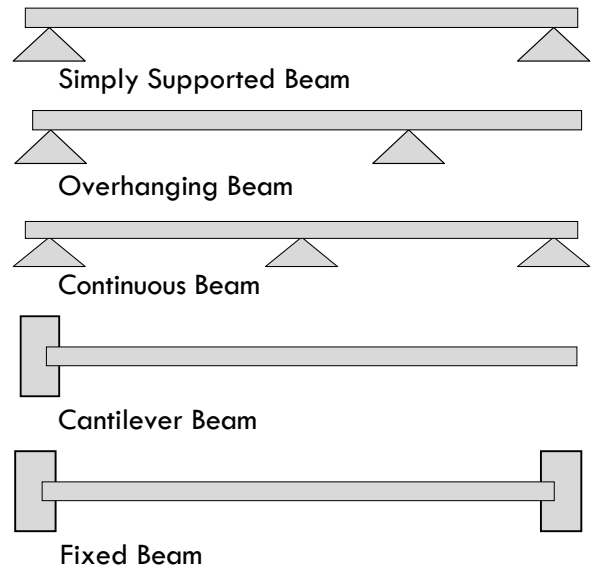


Illustration by author

MECHANICS AND STRENGTH OF MATERIALS STUDY QUESTIONS

1. Wood, steel, and rigid insulation are all used for _____.
A. concrete finishing
B. formwork shoring
C. strengthening concrete
D. concrete formwork
2. Deflection is a result of what type of stress?
A. bending
B. tensile
C. shear
D. axial
3. Which of the following is a type of multiuse form?
A. tubular fiber column forms
B. insulated concrete forms (ICFs)
C. panel forms
D. form release

4. Which of the following would be considered a dead load?
- A. workers
 - B. equipment
 - C. stored materials
 - D. formwork

AIR AND FLUID MECHANICS

PSYCHROMETRICS

Psychrometrics is the term used to describe the thermodynamic properties of air mixed with water vapor. In the HVAC field, there are seven properties of air that are considered:

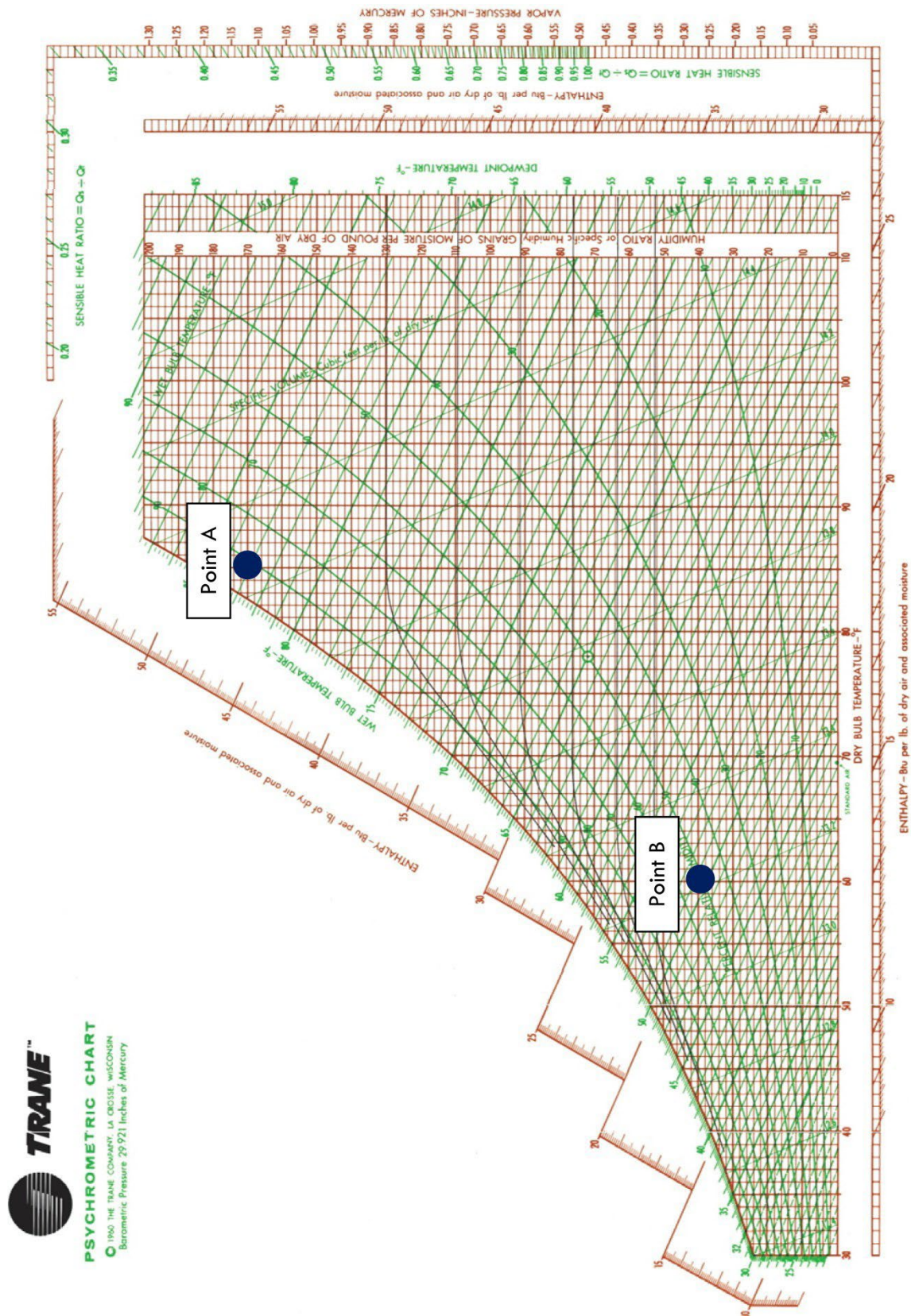
- *Dry bulb temperature* (DB) is the air temperature and is the measure of sensible heat.
- *Wet bulb temperature* (WB) is the air temperature measured with a thermometer with a wet cloth sock over it. As the water in the sock evaporates, the temperature on the thermometer is lowered through the latent heat of the evaporation process. Wet bulb and dry bulb temperatures are equal only when the air is 100% saturated (100% RH) and no evaporation can take place. When the air is not 100% saturated, the wet bulb temperature will always be lower than the dry bulb temperature. The wet bulb temperature is the lowest temperature that air can be cooled by the evaporation of water.
- *Dew point temperature* (DP) is the temperature at which the water vapor in the air begins to condense. At this point, the air is 100% saturated and cannot hold any more water vapor. Relative humidity (RH) is the ratio of moisture in the air compared to how much that same sample of air could hold and is expressed as a percentage. Air that is holding .008 lb of water but has the capacity of holding 0.10 lb would have a relative humidity of 80%.
- *Humidity ratio or absolute humidity* (W) is the amount of water in 1 lb of dry air. It is expressed as either grains of moisture per pound of dry air (gr/lb) or pounds of water per pound of dry air (lb/lb). A grain of moisture is 1/7,000 lb. This is a measure of latent heat in the air.
- *Specific volume* (v) is the physical size or volume of 1 lb of dry air. As air is warmed and humidified it gets larger. As it cools and dehumidifies, the same mass of air gets smaller.
- *Enthalpy* (h) is the total amount of thermal energy (sensible and latent) in the air. It is measured in BTUs per pound of dry air.

PSYCHROMETRIC CHART

The psychrometric chart is a graphical representation of the seven properties of air described above. If you have two properties of air you can locate a point on the chart and determine the remaining five air properties. See Figure 2-10 for an example of a psychrometric chart. All of the information provided on the chart is for 1 lb of air. In the HVAC industry it is usually the difference between two points that is of interest. For example, a technician may want to know the different air properties of inside and outside air. Points that move toward the right on the chart represent air that is being heated. Points that move up the chart represent air that is being humidified. Points that are moving to the right and up are being heated and humidified (Figure 2-11).

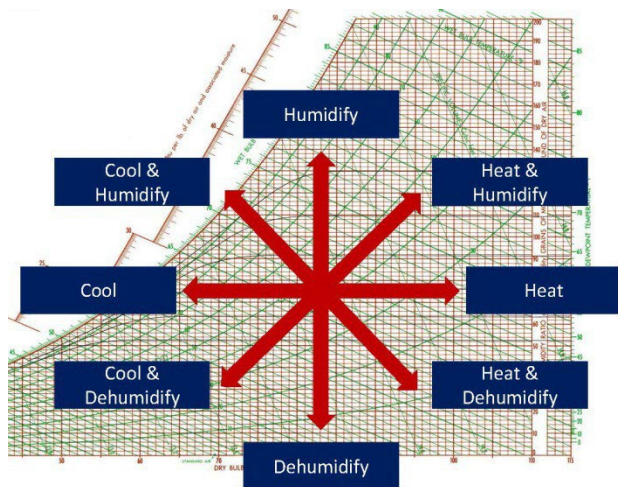
Example: Point A represents outside air on a hot, humid day and has a DB of 85° F and an RH of 92%. Point B represents the supply air of a building and has a DB of 60° F and 50% RH. Because Point B is lower and to the left of Point A we know that the air needs to be cooled and dehumidified. Using the dry bulb and relative humidity, you can find the remaining five properties of air on the psychrometric chart. See Figure 2-10 for air properties of both points. Notice that the difference in enthalpy is 26.6 BTUs/lb of dry air (47.0 – 20.4). That means that the HVAC system needs to remove 26.6 BTUs of energy for every pound of outside air it brings into the building.

Figure 2-10 Example of a Psychrometric Chart



Reprinted Courtesy of Trane U.S. Inc., 2015

Figure 2-11 Psychrometric Chart Temperature and Humidity Movement



Important Terms

- **Sensible heat:** heat added to the air without adding moisture. As sensible heat increases the points on the psychrometric chart move to the right.
- **Latent heat:** the hidden heat added to the air by adding moisture (approximately 1,000 BTUs/lb of water). As latent heat increases the points on the psychrometric chart move up.
- **British Thermal Unit (BTU):** a quantity of heat. It is the amount of heat needed to raise a pound of water 1° F. An MBH is 1,000 BTUs/hr.

For more information see Janis & Tao in the list of references.

AIR AND FLUID MECHANICS STUDY QUESTIONS

1. Which property of air is the best measure for latent heat?
 - A. dry bulb
 - B. relative humidity
 - C. enthalpy
 - D. humidity ratio

2. If you have an air sample with a dry bulb temperature of 80° F and an RH of 50%, what is its wet bulb temperature?
 - A. 31°
 - B. 67°
 - C. 77°
 - D. 80°
3. If you have an air sample with a dry bulb temperature of 60° F and an RH of 100%, what is its wet bulb temperature?
 - A. 30°
 - B. 60°
 - C. 90°
 - D. 120°
4. Using the psychrometric chart, if you have an air sample with a dry bulb temperature of 60° F and a humidity ratio of 23.0 gr/lb, what is its relative humidity?
 - A. 10%
 - B. 30%
 - C. 50%
 - D. 70%
5. Air sample A has a dry bulb temperature of 80° F and a relative humidity of 90%. Air sample B has a dry bulb temperature of 65° F and a relative humidity of 90%. Which of the following statements is true?
 - A. A has more sensible heat but the same latent heat as B.
 - B. A has less sensible heat but more latent heat as B.
 - C. A has more sensible and latent heat as B.
 - D. A has less sensible and latent heat as B.

ELECTRICITY

OHM'S LAW

Electrical energy is the flow of electrons through a conductor. Following are the basic units that describe electrical circuits:

- **Voltage:** the electromotive force (EMF) or potential difference that causes an electric current to flow. The unit of measure is the volt (E).
- **Current:** the flow of electrons, specifically the flow of 1 coulomb (6.24×10^{18} eee)

per second passing through a conductor. The unit of measure is the ampere (A).

- **Resistance:** the internal property of matter that resists the flow of current. The unit of measure is the ohm (R). Materials with low resistance are called conductors. Materials with high resistance are called insulators.

The relationship between voltage, current, and resistance is defined by Ohm's law:

$$\text{Voltage} = \text{Current} \times \text{Resistance} (E = IR)$$

CIRCUITS IN SERIES

Resistors in a circuit can be arranged to be either in series, parallel, or a combination of both. Circuits in series have the resistors in line (Figure 2-12). The total resistance can simply be added together.

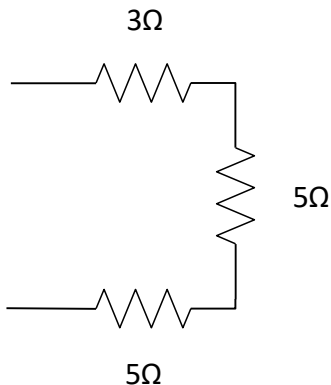
$$R_t = R_1 + R_2 + R_3 + R_n$$

Example: If you have a circuit with three resistors in series and one resistor has 3 ohms (Ω) of resistance and the other two resistors each have 5 Ω of resistance, what is the total resistance?

$$R_t = 3 \Omega + 5 \Omega + 5 \Omega$$

$$R_t = 13 \Omega$$

Figure 2-12 Circuit in Series



CIRCUITS IN PARALLEL

Circuits in parallel have the resistors side by side (Figure 2-13). The formula for calculating the total resistance follows:

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_n}$$

Example: If you have a circuit with three resistors in parallel and one resistor has 5 Ω of resistance and

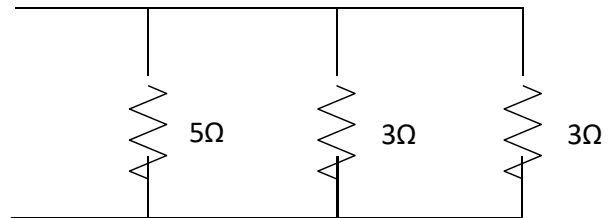
the other two resistors each have 3 Ω of resistance, what is the total resistance?

$$\frac{1}{R_t} = \frac{1}{5 \Omega} + \frac{1}{3 \Omega} + \frac{1}{3 \Omega}$$

$$\frac{1}{R_t} = 0.87$$

$$R_t = 1.15 \Omega$$

Figure 2-13 Circuit in Parallel



AC VS. DC

Direct current is the flow of electrons in a single direction. Batteries provide direct current because the electrons flow in a single direction from the negative to positive terminal. With alternating current the electrons alternate the direction of the current. In the United States the frequency (f) is 60 hertz (Hz), which means that the direction of the current changes 60 times a second. Building power is alternating current.

POWER

In single-phase AC circuits, power is the product of *Volts × Amperes*, which is referred to as *apparent power* and is the power available to use.

Single Phase

$$P_{\text{apparent}} = \text{Voltage (E)} \times \text{Amperes (A)}$$

Three Phase

$$P_{\text{apparent}} = 1.73 \times \text{Voltage (E)} \times \text{Amperes (A)}$$

The unit of measure for AC power is the watt (W) or kilowatt (1,000 W; kW). When the peak voltage and amperage align, the power is said to be *in phase*. In this case, *Watts = Volts × Amps*. However, many appliances, such as motors and computers, cause the peak voltage and amperage to be out of phase with each other. When they are out of phase, all of the power available (apparent power) is not used. The actual power used is called *real power* or *working power*. The *power factor* (PF) is a number from 0 to 1 and is a measure of how much of the available power is being used. When

CHAPTER 2 ► ENGINEERING CONCEPTS

the voltage and amperage are in phase, all of the apparent power is used, and the power factor is 1. When only some of the apparent power is used, the power factor will be less than 1.

Single Phase

$$P_{real}(\text{Watt}) = V \times A \times PF$$

Three Phase

$$P_{real}(\text{Watt}) = 1.73 \times V \times A \times PF$$

POWER VS. ENERGY

Power and energy are not the same. Power is the rate of energy transfer. In a building, power is how much electricity is being used at any given point in time. A 60 W lightbulb is consuming 60 watts per second. It's a rate of energy consumption. *Energy* is the ability to do work and is quantifiable. It's the rate of consumption multiplied by time.

$$\text{Energy} = W \times hr$$

Because the watt is relatively small, the kilowatt is typically used. If a 60 W lightbulb is on for 80 hr, then

$$\text{Energy} = 60 W \times 80 hr$$

$$\text{Energy} = 4,800 \text{ Whr or } 4.8 \text{ kWh}$$

Utility companies sell energy and charge by the kilowatt-hour.

For more information see Janis & Tao and in the list of references.

ELECTRICITY STUDY QUESTIONS

1. If you have 10 Ω of resistance and a voltage of 20 V, how much current is going through the circuit?
A. 0.5 A
B. 2 A
C. 10 A
D. 200 A
2. Which is the unit of measure for AC power?
A. volt
B. ampere
C. watt
D. coulomb
3. If you have three resistors in series and they each have 4 Ω of resistance, what is the total resistance in the circuit?
A. 0.75 Ω
B. 1.33 Ω
C. 4 Ω
D. 12 Ω
4. If you have three resistors in parallel and they each have 4 Ω of resistance, what is the total resistance in the circuit?
A. 0.75 Ω
B. 1.33 Ω
C. 4 Ω
D. 12 Ω
5. In the United States, alternating current is provided by utility companies at _____ hertz or cycles per second.
A. 1
B. 50
C. 60
D. 100
6. If a three-phase circuit has 240 V, using 100 A with a power factor of .5, what is the real power?
A. 0.24 W
B. 12,000 W
C. 20,760 W
D. 24,000 kW
7. If a single-phase circuit has 120 V, using 10 A with a power factor of .8, what is the apparent power?
A. 12 W
B. 1,200 W
C. 1,661 W
D. 2,076 W

ENGINEERING MATERIAL PROPERTIES ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | C. | 2. | A. | 3. | A. |
| 4. | C. | 5. | C. | 6. | A. |
| 7. | B. | 8. | A. | | |

SOIL MECHANICS ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | D. | 2. | B. | 3. | C. |
| 4. | C. | 5. | B. | 6. | A. |
| 7. | C. | 8. | D. | | |

MECHANICS AND STRENGTH OF MATERIALS ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | D. | 2. | A. | 3. | C. |
| 4. | D. | | | | |

AIR AND FLUID MECHANICS ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | D. | 2. | B. | 3. | B. |
| 4. | B. | 5. | C. | | |

ELECTRICITY ANSWERS:

1. B. $E = IR$; $20 = I \times 10$; $I = 2$
2. C.
3. D. $4 + 4 + 4 = 12$
4. B. $1/R = 1/4 + 1/4 + 1/4$; $R = 1.33$
5. C.
6. C. $1.73 \times 240 \times 100 \times 0.5 = 20,760$
7. B. $120 \times 10 = 1,200$

CAC EXAM: STUDY GUIDE



CHAPTER 3

MANAGEMENT CONCEPTS

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CONTRACT TYPES

ELEMENTS OF A CONTRACT

There are a variety of types of contracts used in construction. Three common types of contracts are lump sum, unit price, and cost plus. Contracts may be executed by formal documents, simple handshakes, or even unspoken agreement. Regardless of the contract type or method of execution, for a contract to be valid, four elements must be present:

- **Mutual agreement:** commonly referred to as an *offer and acceptance*. An *offer* is the proposed terms of the contract. The *acceptance* is the agreement to the offer. In a two-party contract, one party provides the offer and the other accepts it. A contract exists only when the offer is accepted without conditions. Conditional acceptance and a counteroffer are both considered offers and must have unconditional acceptance to create a contract.

Example: A contractor offers to install a handrail for \$5,000. The owner accepts the scope of work but asks whether the contractor will do the work for \$4,000. In this case the contractor's offer has been rejected, and the owner has proposed a new offer. No contract exists at this point.

- **Capacity:** both parties must be legally competent and able to enter into a contract.
Example: Minors, illegal aliens, convicts, those under the influence or mentally incapacitated may be legally restricted from making certain contracts.
- **Consideration:** the promise of exchange of something of value by one party for something of value by another party.
Example: A contractor promises to build an owner a building; in exchange, the owner promises to pay the contractor a set amount of money. In this case, the building and money are the consideration.
- **Lawful object:** the contract must be for legal purposes. A contract is not created if it requires a party to engage in illegal activity.

For more information see Collier in the list of references.

LUMP SUM CONTRACT

A lump sum contract is the most common type of contract. In a lump sum contract, the contractor gives the owner a single price, or lump sum, to complete the contracted scope of work. Changes in the scope of work are addressed by change orders. The

profitability of the contractor is dependent on the contractor's ability to complete the contracted work within the lump sum contract price. Additional funds are not given or taken away regardless of the contractor's final profit or loss. With this contract type, contractors have the highest amount of risk of costs and owners have the least.

UNIT PRICE CONTRACT

In a unit price contract, contractors provide a price for a unit of work such as square feet of sidewalks or cubic yards of concrete. The final price is based on the total number of units installed multiplied by the unit price. This contract type is typically used when exact quantities cannot be determined in advance. The unit price includes all labor, material, and equipment costs for one unit of work plus the contractor's overhead and profit. With this contract type, both the contractor and owner share the risk. The contractor has the risk of inaccurately estimating the unit cost, and the owner has the risk of an unknown quantity of work.

COST PLUS CONTRACT

In a cost plus contract, a contractor is paid for all direct costs, such as labor, material, equipment, subcontracts, and field supervision, plus an agreed upon fee. Cost plus contracts are typically used in cases where the scope of work is not easily defined. These contracts have the advantage for the owner of paying for only what the project needs without a contractor's risk premium. However, the owner is at risk because the final cost is not known until the end of the contract. Contracts may be based solely on *time and material*, which does not include any maximum price or have a guaranteed maximum price (GMP).

CONTRACT TYPES STUDY QUESTIONS

1. Which of the following is a fundamental element of a contract?
 - A. exchange of money
 - B. revised scope of work
 - C. time extension
 - D. mutual acceptance

2. Which of the following contract types is generally considered to have the most risk for the contractor?
 - A. lump sum
 - B. unit price
 - C. cost plus
 - D. cost plus with GMP

3. Which of the following contract types is best used if the scope is well defined but not the quantities of material?
 - A. lump sum
 - B. unit price
 - C. cost plus
 - D. cost plus with GMP

CONTRACT DELIVERY METHODS

There are several standardized families of contracts. Three well-known entities that offer standardized contract forms are the American Institute of Architects (AIA), the Engineers Joint Contract Documents Committee (EJCDC), and Consensus Docs. Five common delivery methods used in construction are traditional design-bid-build, design-build, construction management (CM) agency, construction management (CM) at risk, and integrated project delivery (IPD). In each of these contracts there are three primary parties: owner, architect, and contractor.

TRADITIONAL DESIGN-BID-BUILD

The design-bid-build delivery method is commonly referred to as hard bid, stipulated sum, or fixed price. In this method, the owner has separate contracts directly with the architect and contractor (Figure 3-1). The architect designs the project, produces the construction document, and provides construction administration. Once construction documents are completed, the project is put out to bid, and a contractor is selected to build the project. The contract is largely awarded based on price; however, contractor qualifications may also be considered. The contractor is responsible for constructing the project in accordance with the contract documents. Both the architect and the contractor may subcontract out portions of their contracted work; however, they may remain solely responsible to the owner. For example, if a steel subcontractor installs a member incorrectly and causes a failure, the owner's recourse is against the contractor, not the steel subcontractor.

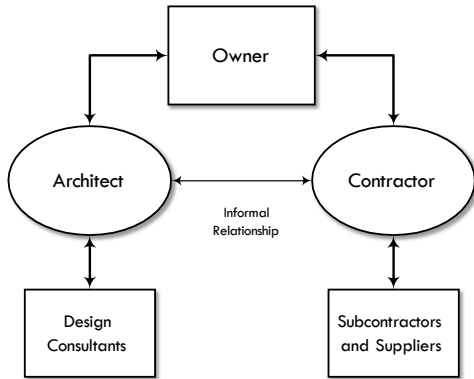
The contractor is generally considered to have the highest risk in this delivery method. Any mistakes in the bidding of the project are absorbed by the contractor, and there is no guarantee that the contractor will earn a profit on the project. The owner is generally considered to have the lowest risk because the owner has a fixed price for the work prior to starting construction. The exception to this is the potential for change orders. A poor design may necessitate the need for many changes in the work that are not priced in a competitive environment.

Advantages

- The process and the roles of each party are well known and understood.
- Projects typically involve competitive bidding, giving the owner the lowest price the market will allow.
- A set price for work included in the contract documents is known before construction begins.
- This method does not require the owner to be involved in the day-to-day construction processes.

Disadvantages

- The contractor has the highest risk from cost overruns, such as labor inefficiencies, cost inflation, or nonperforming subs.
- This method can result in significant added cost to the owner on projects for which the scope is not clearly defined.
- It requires a longer schedule because design and construction phases are done in series.
- The contractor is not involved during preconstruction.
- The relationship between the owner, architect, and contractor is more an arms-length relationship.

Figure 3-1 Design-Bid-Build Delivery Method**DESIGN-BUILD**

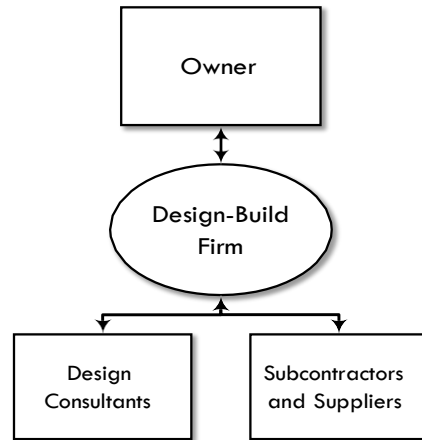
In the design-build delivery method, the owner contracts with a single entity for both design and construction services (Figure 3-2). Entities may be a single design-build firm with in-house design and construction employees or a temporary partnership between design and construction firms commonly through a joint venture or subcontract. Because one entity is responsible and liable for both the design and construction of the project, the design-build firm has the highest risk of any of the delivery methods.

Advantages

- Good communication between design and construction teams
- Allows for expedited, fast-track design and construction schedule
- Allows for easier incorporation of changes in work
- Does not require owner to be involved in the day-to-day designer and construction communications or processes
- Allows for value engineering and constructability reviews during preconstruction
- Single point of fault from owner's perspective for building failures

Disadvantages

- In fast-tracked projects, owner may have limited time to make decisions without affecting cost.
- There are fewer checks and balances than in the design-bid-build method. The owner must rely on the quality and ethics of the firm.

Figure 3-2 Design-Build Delivery Method**CONSTRUCTION MANAGEMENT (CM) AGENCY**

In the construction management (CM) agency delivery method, an independent agency acts as the owner's representative and coordinates work between the design and construction teams. In this method, the owner contracts directly with the designers, contractors, and construction manager (Figure 3-3). The CM agency does not hold any subcontracts and is purely in a consulting role with the owner. Because of this, the CM agency has the lowest risk of any of the delivery methods. With these projects, the owner may contract directly with multiple designers, contractors, and subcontractors. During construction, the construction manager provides the construction administration for the owner.

Advantages

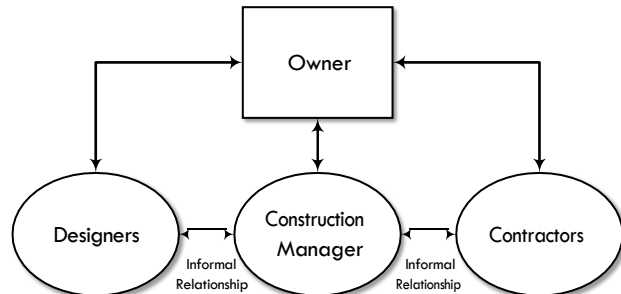
- Good communication among the owner, designer, and construction teams early in the project
- Allows for value engineering and constructability reviews during preconstruction
- Allows the owner to have control of multiple contracts directly and avoid a middle-man administration fee
- Allows for easier incorporation of changes in work

Disadvantages

- Early contractor selection and involvement may increase cost over competitively bid design-bid-build projects.

- In fast-tracked projects, the owner may have limited time to make decisions without affecting cost.
- The owner is responsible for cost overruns.

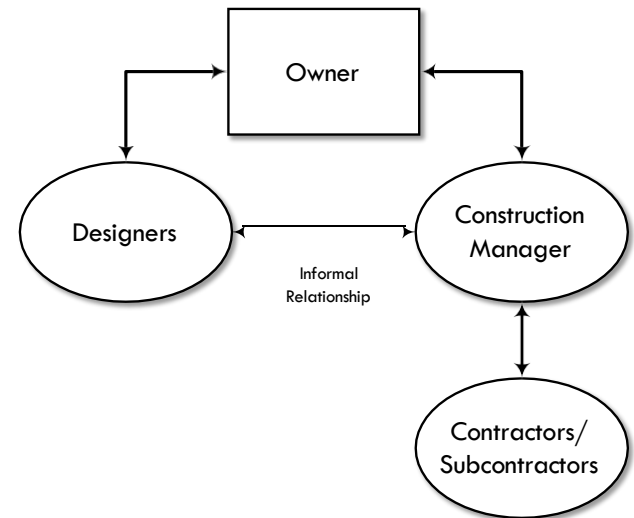
Figure 3-3 Construction Management (CM) Agency Delivery Method



CONSTRUCTION MANAGEMENT (CM) AT RISK

In the construction management (CM) at risk delivery method, the contractor acts as the owner's representative and coordinates work between the design and construction teams in a manner similar to that of the CM agency. In this method, the owner contracts directly with the designers and construction manager (Figure 3-4). With this delivery method, however, the CM at risk is responsible for the work and contracts directly with the contractor/subcontractors. The CM at risk delivery method is a cost plus contract, so the owner pays for the cost of the work plus the CM's fee. However, the CM provides a cap on how much the owner could pay for the work, which is referred to as a *guaranteed maximum price*, or GMP. Costs incurred on the job that exceed the GMP are paid by the CM. The GMP is why the CM is at risk.

Figure 3-4 Construction Management (CM) at Risk Delivery Method



Advantages for Contractors

- Good communication among owner, designer, and construction teams early in the project
- Allows for expedited, fast-track design and construction schedule
- Allows for value engineering and constructability reviews during preconstruction
- Allows for easier incorporation of changes in work

Disadvantages

- Early contractor selection and involvement may increase cost over competitively bid design-bid-build projects.
- In fast-tracked projects, the owner may have limited time to make decisions without affecting cost.

INTEGRATED PROJECT DELIVERY (IPD)

The integrated project delivery (IPD) delivery method is the most recently developed of the delivery methods discussed here. With this method, a collaborative multiparty contract aligns each of the major parties' goals with the success of the project (Figure 3-5). Typically, the contract provides a financial reward pool that is shared equally with all parties. The more successful the project is, the more of the reward pool is shared with all parties. Conversely, if the project is not successful, the financial pool would not be shared but instead used to improve the project. This shared risk/reward delivery method is intended to promote collaboration and encourage project-focused

decision making. On IPD projects all major parties, including subcontractors, are selected and involved early in the project, which intensifies the design and allows for collaborative decision making. A successful IPD project will reduce individual risk, increase project efficiency, reduce waste, and maximize value to the owner.

For more information see Levy in the list of references.

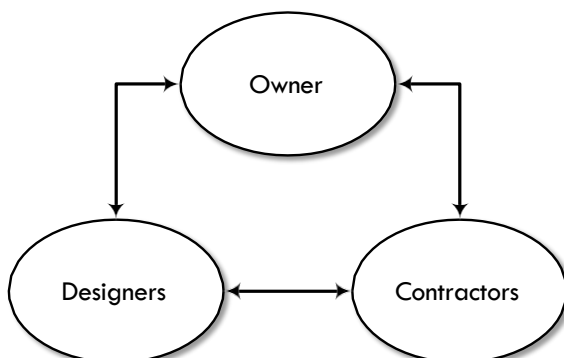
Advantages

- Good communication among owner, designer, and construction teams early in the project
- Improves collaboration and aligns all parties' goals with the success of the project, thus creating a win-win construction/design environment.
- Open-book bidding and change orders, which reduces the risk of cost overruns
- Fewer claims and disputes, which reduce costs from reduced liability
- More efficient design and building process
- Negotiated pricing rather than bidding

Disadvantages

- Typically requires a higher level of owner involvement
- Newer and less tested delivery method
- Little to no case law in the event of disputes
- More risk associated with construction for owner and designer and more risk associated with a poor design for contractor
- Little experience with delivery method for most major players
- Difficulty changing thought process from self-serving to community risk sharing

Figure 3-5 Integrated Project Delivery (IPD) Delivery Method



CONTRACT DELIVERY METHODS STUDY QUESTIONS

1. In which delivery method is the construction administrator most like a consultant?
 - A. lump sum
 - B. CM agency
 - C. CM at risk
 - D. integrated project delivery
2. Which statement is true about the design-build delivery method from the owner's perspective?
 - A. Design is complete when contractor is hired.
 - B. Fast tracking is difficult with this delivery method.
 - C. There is a single source of fault for building system failures.
 - D. Design Build firms are rarely temporary joint ventures.
3. Which delivery method has the most risk for the contractor?
 - A. design-bid-build
 - B. design-build
 - C. CM at risk
 - D. integrated project delivery
4. Which of the following is a major difference between a CM agency and a CM at risk?
 - A. manages construction on the owner's behalf
 - B. has a contract with the designer
 - C. provides a lump sum price for construction services
 - D. caps the construction costs the owner is required to pay

BUSINESS ENTITIES

SOLE PROPRIETORSHIP

Sole proprietorships are companies owned, operated and managed by a single person. The company may have any number of employees, but only one owner, the sole proprietor. This type of business entity is the simplest form of ownership, and can be started and terminated without formal documentation. Sole proprietorships are taxed at the individual level based on personal income and earnings. The disadvantage of a sole proprietorship is that the owner of the company is personally liable for all losses. Any debt that exceeds the company's

assets must be paid for with private funds by the owner.

For more information see Halpin & Senior and Gould & Joyce in the list of references.

PARTNERSHIPS

A partnership is a business entity owned by two or more people. The amount of ownership each partner has within the company is determined by legal agreement. The way the legal agreement is set up varies depending on the partnership and may be based on the amount or percentage of money, hard assets, and/or skills each of its partners brought into the company. The legal agreement outlines how the partnership may be terminated. If a partner dies, the partnership is legally terminated unless prior terms for such an event were included in the legal agreement.

Similar to sole proprietorships, partnerships are taxed at the individual level based on personal income and earnings and may have any number of employees, and the owners of the company are personally liable for any losses. The amount of liability each individual partner has is based on the percentage and type of ownership.

For more information see Halpin & Senior and Gould & Joyce in the list of references.

CORPORATIONS

Corporations are independent legal business entities. To form a corporation, a company must file documentation with and pay fees to the state in which the company will do business. Once incorporated, the company must hold formal meetings for all major decisions regarding company matters. Individual owners of a corporation are referred to as stockholders. The percentage of ownership of corporations is determined by the amount of stock or number of shares a stockholder has. The number of shares a stockholder has also reflect the amount of voting power that person has within the company. The greater the percentage of shares, the greater the voting power of the stockholder.

Unlike sole proprietorships and partnerships, stockholders of a corporation are not personally liable for company losses. Only assets that belong to the corporation may be used in settlements. The corporate shield can be pierced, however, in cases of extreme negligence or illegal activity.

Additionally, if an individual stockholder dies, the company is not terminated, and the stock passes to the heirs of the deceased stockholder. A disadvantage of corporations is that profits are taxed twice: once at the corporate level and again when distributed as dividends at the individual level. Large corporations with many stockholders may also face challenges in making decisions that must be approved by all stockholders because often the greater the number of stockholders, the slower the process.

For more information see Halpin & Senior and Gould & Joyce in the list of references.

LIMITED LIABILITY COMPANY (LLC)

Limited liability companies (LLCs) are a hybrid type of business similar to a corporation in that individual owners have limited liability and similar to sole proprietorships and partnerships regarding tax and operational benefits. Individual owners of LLCs are called members. An LLC may have one or more members. To form an LLC, members must file a document called articles of organization with the state in which they will do business and pay associated fees. LLCs are taxed only once at the individual level.

JOINT VENTURES

A joint venture is an agreement between two or more individuals or companies formed to complete a single business enterprise. Joint ventures may be a new business entity or a collaborative agreement. By partnering in a joint venture, parties combine strengths and share assets, revenues, expenses, and risks.

In the construction industry, joint ventures are often temporary arrangements. A small local contractor may partner with a large national firm on a particular project. The local relationships of the smaller company coupled with the financial strength of the larger company may improve both companies' chances of winning a project. Design-build firms are often joint ventures between designers and contractors.

BUSINESS ENTITIES STUDY QUESTIONS

- Under which legal structure are the least total taxes paid for the goods and services provided by the company?
 - sole proprietorship
 - federalist
 - corporation
 - joint venture
- In the construction industry, which legal entity is often a temporary arrangement?
 - sole proprietorship
 - partnership
 - limited liability corporation
 - joint venture
- Which is an advantage of forming a corporation?
 - Shareholders have reduced personal liability.
 - The corporation's value can't go down from its initial purchase price.
 - Less taxes are paid than in a limited liability corporation.
 - Quick decision making is possible, especially for large companies.

ACCOUNTING AND FINANCIAL RATIOS

ACCOUNTING PRINCIPLES

Demand for construction is influenced by a variety of factors, including national, regional, and local economies; government policies; social trends and demographics; technology; and changing customer needs and expectations.

Income is generally recognized in the same period in which the expenses are incurred. There are two main methods of recognizing income:

- Completed contract method:** All revenue, expenses, income, and/or losses are recognized in the fiscal period the project is completed.
- Percentage of completion (accrual method):** All revenue, expenses, income, and/or losses are based on measurement/estimate of completed progress.

Because most projects are constructed over more than one fiscal period, the percentage of

completion method is more often used for most commercial construction companies.

FINANCIAL REPORTS AND RATIOS

Balance Sheet

The balance sheet indicates the financial position of a company at a particular point in time. It incorporates the income statement and indicates resources the company has and/or limitations in its future operations. A balance sheet comprises three parts:

- Assets:** include current assets, such as cash, accounts receivable, inventory, cost-in-excess, and prepaid expenses; fixed assets, such as buildings and equipment; and other assets, such as investments and goodwill.
- Liabilities:** include current liabilities, such as accounts payable, notes payable, billings-in-excess, accrued payments, and current maturity of long-term debt, and long-term liabilities, such as long-term debt
- Owner's equity (net worth):** includes paid-in-capital and retained earnings

$$\text{Total Assets} = \text{Total Liabilities} + \text{Net Worth}$$

Income Statement

The income statement indicates the results of a company's financial operations over a period of time. It is critical to understanding a company's current operations, estimating future operations, and indicating profitability. Following are the main components of an income statement:

- Net sales (revenue):** how much revenue the company has earned over a specific period of time
- Direct costs:** all costs directly attributable to performance of work, such as project labor, material, subcontract, and equipment cost
- Gross profit:** Revenue – Direct Cost
- Indirect costs:** all costs not directly attributable to performance of work, such as overhead, general, and administrative costs
- Net profit:** Gross Profit – Indirect Cost

Statement of Cash Flow

The cash flow statement indicates cash generated and used during a specific period of time and a firm's liquidity.

Current Ratio

The current ratio indicates a company's ability to pay its current obligations with its current assets.

$$\frac{\text{Current Assets}}{\text{Current Liabilities}}$$

Quick Ratio

The quick ratio is similar to the current ratio but uses current assets with greater liquidity.

$$\frac{(\text{Cash and Equivalents} + \text{Accounts Receivable})}{\text{Current Liabilities}}$$

Days Receivable

Days receivable indicates the average number of days a company takes to receive payment.

$$\frac{365}{\frac{\text{Revenue}}{\text{Trade Receivables}}}$$

Days Payable

Days payable indicates the average number of days a company takes to make payments.

$$\frac{365}{\frac{\text{Direct Cost}}{\text{Accounts Payable}}}$$

Working Capital

Working capital measures available funds for investment in operations to generate future revenue and profit.

$$\text{Current Assets} - \text{Current Liabilities}$$

Fixed/Worth

Fixed/worth is the ratio that measures the amount in which the owner's equity is invested in fixed assets.

$$\frac{\text{Net Fixed Assets}}{\text{Tangible Net Worth}}$$

Debt/Worth

Debt/worth is the ratio of capital contributed by creditors and the capital contributed by the owners.

$$\frac{\text{Total Liabilities}}{\text{Tangible Net Worth}}$$

Return on Investment (ROI)

ROI measures the effectiveness and rate of return on invested capital.

$$\frac{\text{Net Profit before Taxes}}{\text{Tangible Net Worth}} \times 100$$

Return on Assets (ROA)

ROA measures the effectiveness of asset utilization.

$$\frac{\text{Net Profit before Taxes}}{\text{Total Assets}} \times 100$$

ACCOUNTING AND FINANCIAL RATIOS STUDY QUESTIONS

1. A company has \$10,000 in cash, \$20,000 in equipment, and \$20,000 in accounts payable. The tax rate is 13%. What is the current ratio?
A. 0.5
B. 0.67
C. 1.3
D. 1.5
2. What is the return on assets assuming a net profit before tax of \$15,000 and \$30,000 total assets?
A. 0.5%
B. 2%
C. 50%
D. 200%
3. A company has \$50,000 in equipment, \$20,000 in cash, and \$30,000 in accounts payable. How much working capital does it have?
A. (\$10,000)
B. \$10,000
C. \$20,000
D. \$40,000

MANAGEMENT SYSTEMS

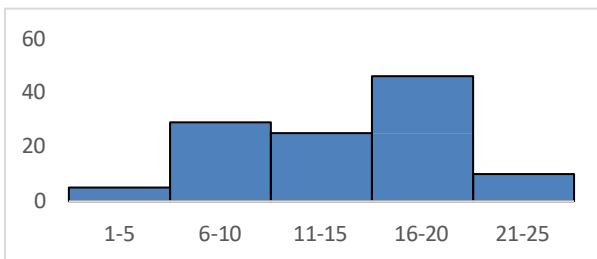
PROJECT CONTROLS

Project controls are generally defined as the collecting of data, organizing the data so it can be analyzed, and analyzing the data to provide useful information and then using that information to the benefit of the project. An effective way of communicating large amounts of data is through charts; several types of charts are used in the industry to present data and trends effectively.

Histogram

A histogram is a chart used to show the relative frequency of an observation. The width of the bar is proportional to the size of the category or bin, and the height of the bar corresponds to the distribution of the observations. Histograms are often used when tracking differences in frequency and magnitude of the grouped data (Figure 3-6).

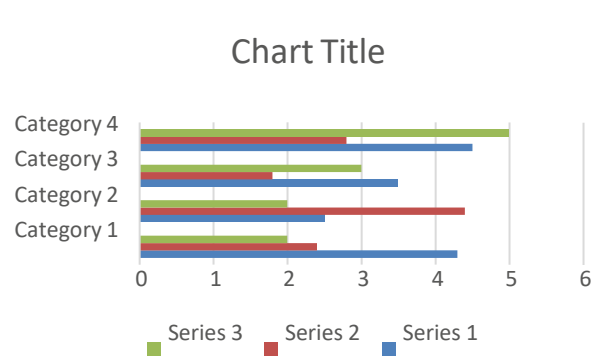
Figure 3-6 Example of a Histogram



Bar Chart

A bar chart uses rectangular bars over a category to show the magnitude or frequency of grouped data. These charts are best used to compare differences between grouped data (Figure 3-7).

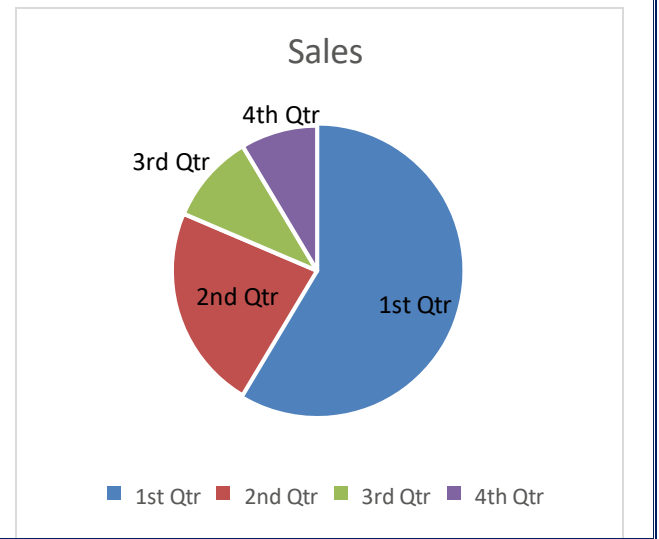
Figure 3-7 Example of a Bar Chart



Pie Chart

A pie chart is a circular graph in which sections or slices represent a portion of the whole. The area of the section is proportional to the frequency or magnitude of the data being represented. The whole area of the chart includes all data in the set. These charts are best used when comparing parts of the whole (Figure 3-8).

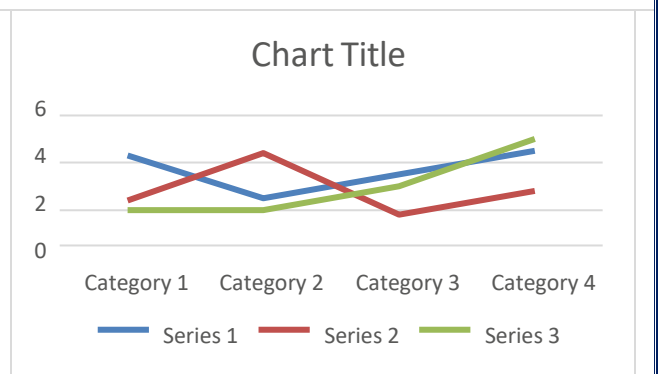
Figure 3-8 Example of a Pie Chart



Line Chart

A line chart shows data points on a graph at the intersection of the data descriptors shown on the x-axis and y-axis. Points are connected by lines to represent trends in the data points. They are commonly used to track trends in data (Figure 3-9).

Figure 3-9 Example of a Line Chart



CURRENT CONCEPTS AND TECHNOLOGY

Building Information Modeling (BIM)

Building information modeling is the process of using computer software to collect and manage building component information in the virtual environment. Contractors often use BIM to build a project in the virtual world before building it in the real world so that conflicts can be identified early and resolved at low cost. Facility managers use BIM software as a way to manage and maintain their facilities.

Lean Construction

Lean construction is a management system derived from the Toyota Production System (TPS). Lean principles were made mainstream by Jeffrey Liker in his book *The Toyota Way*. In this book he identified 14 principles that made Toyota successful and unique among its competitors. The system focuses on providing value to the owner by removing waste within the production system. The 14 principles, which include leveling the work flow, using only proven technology, and continuous improvement, all support the goal of eliminating waste.

For more information see Gould & Joyce in the list of references.

ISO 9000

The International Organization for Standardization produced the ISO 9000 in 1987. It is a family of standards that provides management concepts and guidelines primarily for the manufacturing and service industries. It focuses on quality to ensure the companies meet their customers' needs.

For more information see Gould & Joyce in the list of references.

Six Sigma

Six Sigma is a management tool developed by Motorola in 1988 and incorporated into General Electric's operational strategy in the mid-1990s. The core concept behind Six Sigma is that if product defects are quantified they can be systematically removed. The goal is a zero defects product line.

Total Quality Management (TQM)

Total Quality Management is a management system that grew widely in the late 1980s as a way to create an environment in which companies could provide higher-quality products and services to their customers. The core of the system is to focus on improved quality as a means to increase business and market shares.

For more information see Gould & Joyce in the list of references.

MANAGEMENT SYSTEMS STUDY QUESTIONS

- Which chart would be the most appropriate to show the percentage of fall protection safety violations compared to all safety violations?
 - histogram
 - bar chart
 - pie chart
 - line chart
- Which of the following is a management system used to improve customer satisfaction?
 - TQM
 - Six Sigma
 - Lean
 - All the above
- Which management system was developed based on Toyota's Production System?
 - TQM
 - Six Sigma
 - Lean
 - ISO 9000

BUSINESS ETHICS

AIC CODE OF ETHICS FOR CONSTRUCTORS

The construction profession relies on a system of ethical competence, management excellence, and fair dealing in undertaking complex works to serve the public with safety, efficiency, and economy. The members of the American Institute of Constructors are committed to the following standards of professional conduct:

- A Constructor shall have full regard to the public interest in fulfilling his or her responsibilities to the employer or client.
- A Constructor shall not engage in any deceptive practice, or in any practice which creates an unfair advantage for the Constructor or another.
- A Constructor shall not maliciously or recklessly injure or attempt to injure, whether directly or indirectly, the professional reputation of others.
- A Constructor shall ensure that when providing a service which includes advice, such advice shall be fair and unbiased.
- A Constructor shall not divulge to any person, firm, or company information of a confidential

nature acquired during the course of professional activities.

- A Constructor shall carry out responsibilities in accordance with current professional practice, so far as it lies within his or her power.
- A Constructor shall keep informed of new thoughts and development in the construction process appropriate to the type and level of his or her responsibilities and shall support research and the educational processes associated with the construction profession.

For more information see the “Mr. Ethics” blog on the AIC website at

<http://www.professionalconstructor.org/>

BUSINESS ETHICS STUDY QUESTIONS

- Which of the following should a construction professional provide when delivering services to his or her clients based on the AIC code of ethics?
 - adjustable ethics based on clients' preferences
 - management excellence
 - minimum industry standards
 - complete transparency to everyone on every task

CONTRACT TYPES ANSWERS:

- D.
- A.
- B.

CONTRACT DELIVERY METHODS ANSWERS:

- B.
- C.
- B.
- D.

BUSINESS ENTITIES ANSWERS:

- A.
- D.
- A.

ACCOUNTING AND FINANCIAL RATIOS ANSWERS:

- A. $\$10,000/\$20,000 = 0.5$
- C. $\$15,000/\$30,000 \times 100 = 50\%$
- A. $\$20,000 - \$30,000 = (\$10,000)$

MANAGEMENT SYSTEMS ANSWERS:

- C.
- D.
- C.

BUSINESS ETHICS ANSWER:

- B.

CAC EXAM: STUDY GUIDE



CHAPTER 4

MATERIALS, METHODS, AND PROJECT MODELING AND VISUALIZATION

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CONSTRUCTION EQUIPMENT

PILING EQUIPMENT

Piling equipment varies based on the method of installation and type of piling being installed. Piles may be made of steel, concrete, or composite materials and are commonly driven, water or air jetted, drilled and poured, or vibrated into place. Piling equipment may be specialized stand-alone pieces of equipment or mounted to/used in conjunction with other pieces of equipment, such as a crane or excavator.

Pile Drivers

Steel and precast concrete piles are commonly installed by pile drivers. A pile driver is a mechanical piece of equipment that drives a piling into the ground by striking the head of the piling. Following are three common types of pile drivers:

- *Drop hammer pile driver*: simplest type of pile driver. A drop hammer pile driver consists of a heavy weight that is raised by cable along a guided track and then dropped freely onto the head of the pile.
- *Mechanical hammer pile driver*: uses a mechanical actuated piston and hammer to drive pile into the ground. The piston may be powered by internal combustion, steam, compressed air, or hydraulics.
- *Vibratory hammer pile driver*: rapidly vibrates the head of the pile in up-and-down cycles while placing downward pressure, which causes the soil and piling to expand and contract, relieving friction and driving the piling downward. Typically, this is the fastest type of pile driver; however, the vibration from this equipment may disturb adjacent soils, especially those of nearby open excavations.

Pile Jetting Equipment

Pile jetting uses pipes to deliver concentrated jets of water or air to loosen the soil directly beneath the piling, relieving friction and driving the piling downward. Pile jetting equipment may be used with or separate from other pile driving equipment and can be used to install most wood, steel, or precast concrete piles. Specialty metal and precast piles may also be manufactured with built-in piping for pile jetting.

Pile Drillers

Cast-in-place concrete piles are often drilled using pile drillers. Pile drillers utilize a large steel auger to bore a hole into the ground that can then

be filled with concrete. Steel or composite casing may also be placed using pipe drillers for soils incapable of maintaining the bored hole without collapse or where risk of the soil contaminating the concrete is high.

For more information see Andres, Andres, Smith, & Woods in the list of references.

SHEET PILINGS, COFFERDAMS, AND TIEBACKS

Sheet pilings, cofferdams, and tiebacks are commonly used in construction to stabilize the sides of open excavations and work areas.

Sheet Pilings

Unlike pile foundations, which are intended for vertical loads, sheet piles are designed to stabilize the sides of open excavations by resisting the lateral pressure of soil and water. Sheet piles are typically used in a system or series of interconnecting piles. Sheet piles interlock to one another along their vertical joints and are installed in a manner similar to that used for other piles, often by pile driver. The depth and length of the sheet pile are determined by the amount of the pressure to be resisted. Sheet piles may be installed temporarily or designed to remain permanently in place.

Cofferdams

Cofferdams are temporary enclosures primarily used to hold back water for activities requiring a dry work area. Commonly used in bridge construction, cofferdams may be large or small and constructed in a variety of ways. Earthen embankments are the simplest method of constructing a cofferdam but are often limited in use because of the large area required and susceptibility of deterioration caused by moving water. Cofferdams are more commonly constructed using sheet piles with structural bracing or a combination of earthen embankments with sheet pilings.

Sheet piling cofferdams are constructed by driving sheet piles through water or mud and into stable soil below, forming a watertight, boxlike or circular structure. Once sheet piles are in place, they are structurally braced, and the water is pumped out. If needed, stone and/or concrete can be placed in the bottom to provide additional lateral support and/or a firm working surface.

Tiebacks

A tieback bracing system is an external bracing system that uses metal rods or wires anchored into rock or soil outside of an excavation to support the face of an excavation. The main advantage of tieback bracing systems is that they provide larger clear work areas within the excavation than internally braced systems do. Tiebacks are typically installed at an angle and are either driven or drilled and grouted into place. They may individually anchor metal plates or wood sheets, be used in rows with wales and planks or sheeting, or be used to provide support for other protection systems, such as sheet piling and concrete slurry walls. Tieback bracing systems are commonly used in urban areas where excavation for a building extends to the edge of the property.

Dewatering Equipment

Dewatering is the process of removing ground- or surface water so that construction activities can take place. Dewatering is especially important when excavating because water can accumulate in trenches, which may make placing concrete or utilities or performing other activities impossible. The water is removed by using pumps. Positive displacement pumps create a vacuum internally and are used for low-volume applications. Centrifugal pumps are commonly used for open water with high concentrations of debris and trash. Hydraulic submersible pumps use hydraulics to power the pumps and are ideal when the pump can't be physically placed near the water source. An important consideration when creating the site logistics plan is where the water will be discharged. Often the water will have silts, clays, and other contaminants, requiring that it must be treated before it can be returned to the water table. Treatment may include filters, buffers, or temporary settlement ponds. The location of the filtering area should be included in the site logistics plan. The contractor should also take care not to create excessive soil erosion with the discharge water.

EXCAVATION EQUIPMENT

Excavator

An excavator is a piece of heavy construction equipment commonly used in the excavation of soils (basements, footings, trenches, pits, etc.), demolition, and material handling. Excavators may be track or wheel mounted and generally consist of an undercarriage, a housing, a cab, a two-part articulated arm (boom and stick), and a bucket. Most modern excavators are hydraulically

powered (Figure 4-1), but they may also be cable operated. Excavators are manufactured in a large variety of sizes and typically have easily removable buckets that can be interchanged with a variety of bucket sizes and attachments based on the project's needs.

Figure 4-1 Hydraulic Excavator



Reprinted Courtesy of Caterpillar Inc.

Dozer

A dozer is a tractor-like piece of construction equipment equipped with a front-mounted blade (Figure 4-2). Dozers may be wheel mounted but are most often track mounted and commonly used in clearing and leveling of a job site and in pushing/spreading large quantities of materials.

Figure 4-2 Dozer



Reprinted Courtesy of Caterpillar Inc.

Grader

A grader is a wheeled piece of equipment with a center-mounted angled blade (Figure 4-3). Graders are primarily used to finish level grade.

Figure 4-3 Grader

Reprinted Courtesy of Caterpillar Inc.

Loader

Loaders may be wheel or track mounted and have a wide front-mounted bucket that can be raised, lowered, and dumped. Although able to excavate loose materials, loaders are more commonly used for landscaping, material handling, and loading of stockpiled materials into trucks to be hauled. There are three common classifications of loaders: skid steer loaders, wheel loaders, and track loaders. Because of their smaller size, versatile use (some with interchangeable bucket attachments), and greater affordability, skid steer loaders are the most widely used type of loader. Figure 4-4 shows an example of a skid steer loader.

Figure 4-4 Skid Steer Loader

Reprinted Courtesy of Caterpillar Inc.

Scraper

A scraper is a multipurpose piece of equipment designed to excavate, load, haul, and discharge soil (Figure 4-5). Typically consisting of large wheels and a center-mounted blade, scrapers may be self-propelled or towed behind another piece of equipment. Scrapers are commonly used to quickly excavate large areas.

Figure 4-5 Scraper

Reprinted Courtesy of Caterpillar Inc.

Backhoe

A backhoe is a tractor-like piece of equipment that consists of a two-part articulated arm and bucket, similar to those of a small excavator, mounted to the back and a loader bucket equipped on the front (Figure 4-6). Backhoes are a multipurpose piece of equipment and are commonly used in shallow and narrow trench excavations, utilities, and material handling.

Figure 4-6 Backhoe

Reprinted Courtesy of Caterpillar Inc.

Dragline and Clamshell

Two common uses of cranes in excavation are draglines and clamshells. A dragline excavates material by using a dragline (cable) to pull a bucket toward the crane. The depth of the excavation on a dragline is controlled by adjusting the tension of a hoist cable. One advantage of a dragline is that excavation equipment (crane, trucks, etc.) is often able to remain outside of the excavation. Because of this, draglines are commonly used in excavation of ditches, canals, and other excavations containing water.

A clamshell bucket is a hinged bucket used to vertically excavate material. To excavate, an opened bucket is dropped straight down into the soil being excavated and then closed by bringing the bucket's jaws toward each other. Material is then lifted out of the excavation by the crane and dumped by reopening the bucket. The opening and closing of the bucket is operated by a closing line controlled by the crane. Clamshell buckets are commonly used in excavations below the surface of water, such as cofferdams after sheet piling is installed.

COMPACTION EQUIPMENT

Soils are compacted to increase their density and shear strength and to decrease permeability and future settlement. In construction, compaction typically occurs rapidly and is performed by equipment. The method of compaction and type of equipment used highly depend on the accessibility and type of material to be compacted. Several types of compaction equipment and their uses are outlined in the following sections.

Tampers

Tampers are hand-operated devices that compact material by delivering a series of vertical blows. Because of their small size and ease of maneuverability, tampers are typically used for the compaction of soils and aggregates in areas with limited space that are not accessible by other types of compaction equipment. Following are two types of tampers commonly used in construction:

- *Manual tamper*: often a simple pole with a flat, heavy metal plate affixed to the end (Figure 4-7A) that compacts material by manually delivering vertical blows
- *Rammer tamper*: also commonly referred to as a *jumping jack*; typically a stand-alone piece of equipment powered by a gasoline engine (Figure 4-7B) that compacts material by

mechanically delivering vertical blows and is self-propelled in that each blow moves the tamper slightly ahead to contact new material

Figure 4-7 Tampers



A. Manual Tamper



B. Rammer Tamper

Reprinted Courtesy of A) The AMES Companies, Inc., 2015; and B) Northern Tool + Equipment, 2015

Plate Compactors

Plate compactors, also commonly called plate tampers, are hand- or machine-operated devices consisting of a flat, heavy metal plate that is vibrated up and down to compact material. Plate compactors are commonly used for compacting a wide variety of materials, including soils, aggregates, and asphalt in small or narrow areas, such as patios, sidewalks, small driveways, and trenches.

Hand-operated plate compactors are stand-alone compactors that are typically powered by gasoline-engines and roughly resemble a bulky push mower without its wheels (Figure 4-8A). Machine-operated plate compactors are typically mounted to the end of another piece of equipment, such as an excavator, and are commonly powered by connecting into the host equipment's hydraulic system (Figure 4-8B).

Figure 4-8 Plate Compactors**A. Hand Operated****B. Machine Operated**

Reprinted Courtesy of A) Northern Tool + Equipment, 2015; and B) Caterpillar Inc.

Smooth Wheel Rollers

Smooth wheel rollers compact material by use of heavy smooth-metal rollers and are often used to cover large areas quickly. Small rollers are typically pulled by another piece of equipment and used to provide a smooth ground surface, and large rollers may be pulled or self-propelled and are commonly used in compacting paving courses or to provide a smooth ground surface.

Self-propelled smooth wheel rollers may have one or more smooth wheels that are either pushed/pulled by other wheels that are part of the equipment or used to propel the equipment. Smooth wheel rollers are also commonly combined with other types of rollers, such as pneumatic and vibratory rollers. Figure 4-9 shows a vibratory roller with a front smooth wheel roller and rear pneumatic rollers.

Pneumatic Rollers

Pneumatic rollers compact material by use of ballast, typically heavy weights, placed over several highly inflated rubber tires. Pneumatic rollers may be self-propelled or pulled by another piece of equipment. Pneumatic rollers may be combined with other types of rollers and are commonly used in compacting asphalt courses, clay and silty materials, or granular material containing small amounts of fines.

Figure 4-9 Vibratory Roller with Smooth Wheel and Pneumatic Rollers

Reprinted Courtesy of Caterpillar Inc.

Sheepsfoot Rollers

Sheepsfoot rollers compact material by use of a heavy metal drum with projecting metal knobs or feet (Figure 4-10). The feet create a kneading action that is more effective in compacting fine-grained soils, such as clay, than are smooth wheel rollers. Sheepsfoot rollers are commonly used to cover large areas and may be self-propelled or pulled behind another piece of equipment. Similar to smooth wheel rollers, self-propelled sheepsfoot rollers may have one or more knobbed wheels that are either pushed/pulled or used to propel the equipment and may be combined with vibratory rollers.

Figure 4-10 Sheepsfoot Roller

Reprinted Courtesy of Caterpillar Inc.

Vibratory Rollers

Vibratory rollers compact material by vibrating a roller up and down as it moves across the surface of the material. Typically self-propelled, vibratory rollers have either smooth, pneumatic, sheepsfoot,

or a combination of differing types of rollers. Vibratory rollers are commonly used in compacting asphalt courses and granular materials, such as clean sands and gravels.

For more information see Allen & Iano in the list of references.

CRANES AND LIFTING EQUIPMENT

Material handling is a key component of job-site efficiency. Proper selection of equipment to be used to move and lift materials around the job site can increase project profitability, worker productivity, and job-site safety. There is a wide variety of different types of lifting equipment used in construction. For simplicity, this section highlights a few of the larger and most widely used types of lifting equipment, including cranes, forklifts, and aerial work platforms.

Cranes

Cranes are a widely used and versatile piece of construction equipment. When selecting a crane for a project, there are several critical aspects that must be considered:

- **Activity:** The type of activity to be performed often limits the type of crane that can be used. Cranes are commonly used for
 - lifting, moving, and placement of large, bulky, and/or heavy items;
 - steel erection;
 - concrete placement;
 - excavation; and
 - pile driving.
- **Type:** There are two basic types of cranes used in construction:
 - *Stationary cranes* are erected and fixed to a single location on the job site. Typically erected early in the project and not disassembled until all major lifting activities are completed, stationary cranes are most effective on sites that require a great amount of lifting activities around a central location. One of the most common types of stationary cranes used in construction is a tower crane. Cranes can be fairly large and should be identified in the site logistics plan. How the crane is erected and accessed is an important consideration.
 - *Tower cranes* are often erected and disassembled in sections by mobile cranes. They may be supported at the ground level by a concrete foundation or by the

structural frame of the building. The crane foundation can be very large and should be included in the site logistics plan. The size of the foundation may even make the use of the crane impossible if it prevents the installation of critical building foundations and utilities. Tower cranes move loads by use of a fall block and hook that can be raised/lowered and moved in/out along a horizontal jib that rotates around a central mast or tower. One of the main advantages of a tower crane is that the cab is located high above the job site, giving the operator an unobstructed view of the site. Figure 4-11 shows a typical layout and common components of a tower crane.

Figure 4-11 Diagram of a Typical Tower Crane

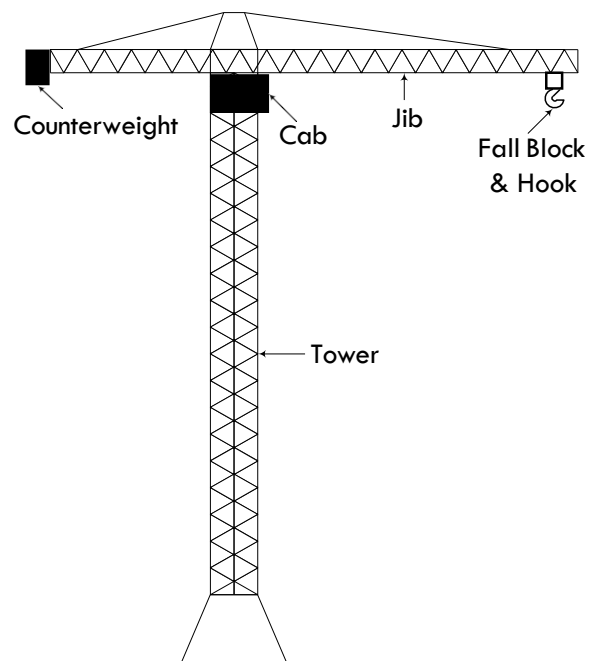


Illustration by author

- *Mobile cranes* are capable of moving from one place to another without being disassembled (although some are assembled on-site). Mobile cranes include many different types of cranes, including crawler cranes, vehicle-mounted cranes, aerial cranes, and floating cranes, and may range in size and capacity from very large to relatively small. Mobile cranes typically have either a lattice/truss style boom or telescoping hydraulic boom that can be raised, lowered, and rotated around the base of the crane. A fixed or telescoping jib may be added to the end of the boom for greater radius and boom clearance.

Two of the most common types of mobile cranes used in construction are crawler cranes and vehicle-mounted cranes. With any type of mobile crane, the crane access must be considered. Where the crane can move on-site, the limits to its reach, location of overhead utility lines, and access to the crane should all be included in the site logistics plan.

Most crawler cranes are equipped with steel tracks that allow them to move around the job site at slow speeds. Crawler cranes are typically large in size and often have a lattice/truss-style boom. Crawler cranes usually require on-site assembly and often must be dismantled and hauled from one job site to another. Crawler cranes are most effective on sites that require crane usage for an extended period of time or have significant lifting or multiple crane position requirements.

Vehicle-mounted cranes have rubber tires and often an additional cab that allows them to be driven from one job site to another. Vehicle-mounted cranes may have a lattice/truss-style boom that requires some on-site assembly or a telescoping hydraulic boom. Vehicle cranes are most effective on sites with fewer lifting requirements and that require limited or noncontiguous crane usage.

- Capacity is critical in selecting a crane that can safely lift and move its intended load. A crane's capacity is dependent on the activity and type of the crane, length of the crane's boom and/or jib, counterweight of the crane, weight of the load, distance of the load from the crane's pivot point, and speed and direction in which the load is moved. Wind speed, soil conditions, and a crane's position will also affect its capacity. In general, the heavier and farther from the crane the load is, the less the crane's capacity.

To safely determine a crane's capacity, a load-rating chart is provided by the manufacturer. A load-rating chart often provides general information about a crane, such as size, weight, and available configurations, and detailed information, including the crane's operating range and load capacity. Figure 4-12 shows an example of a load-rating chart of a vehicle-mounted crane. In this example, the crane has a telescope boom with various extensions denoted by letters A–D. With each extension, the chart provides the

boom length and ranges from 29 ft to 77 ft (not including jib). To read the chart, first identify the length of the boom and its angle. Using the range diagram, find the intersection of the boom length arch and the angle of the boom, and then follow the vertical line straight down to determine the operating radius. The operating radius is shown on the x-axis of the diagram. Once the operating radius is known, use the load chart to find the maximum load at the intersection of the operating radius and boom length.

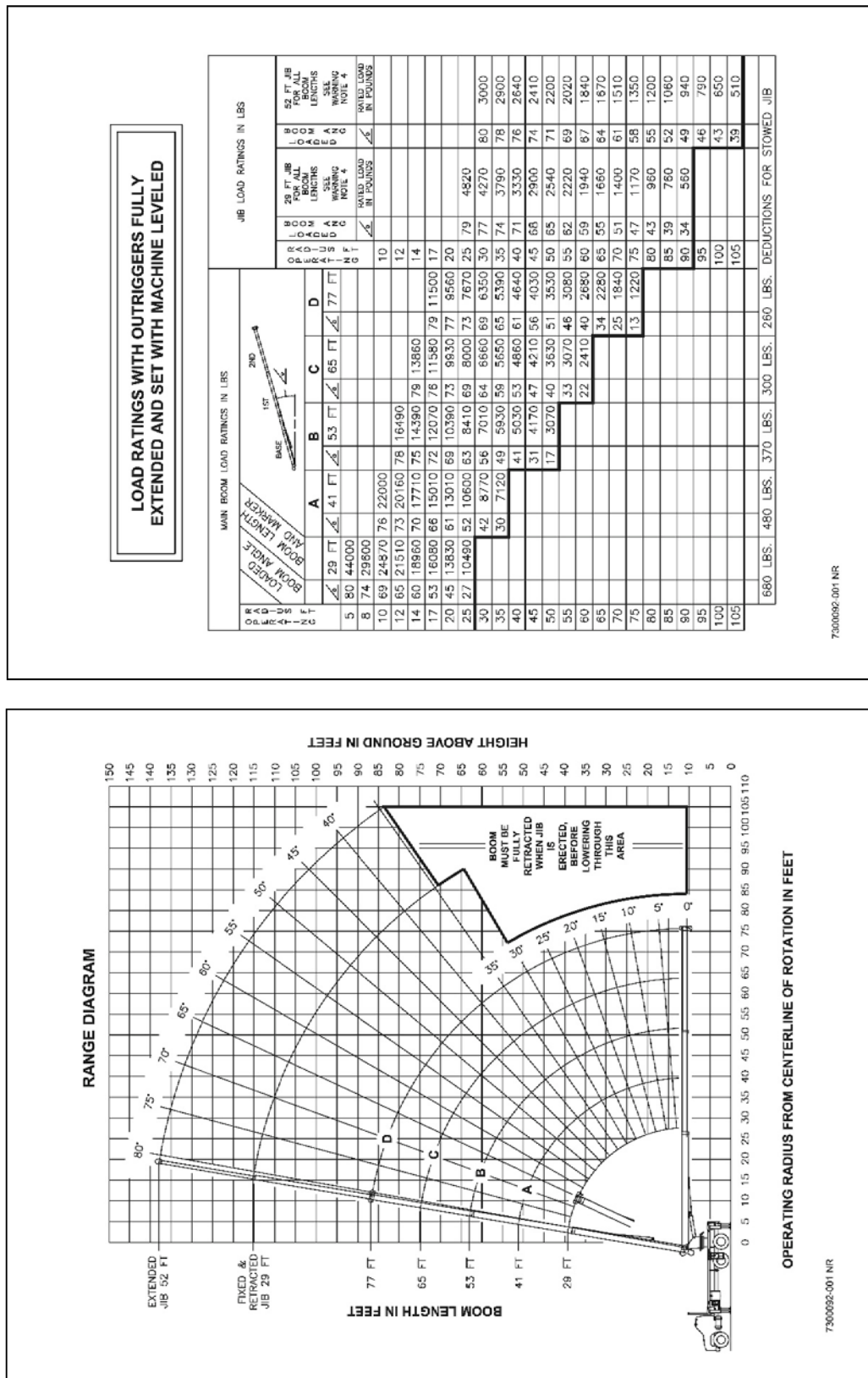
For more information see Andres, Andres, Smith, & Woods in the list of references.

Forklifts

Forklifts are used in construction primarily for job-site material handling. Following are three common types of forklifts used in construction:

- *Industrial forklifts* are able to move and lift loads vertically. They are equipped with small, smooth wheels and are able to be used on only smooth, level surfaces. They are commonly used at material supply yards.
- *Rough terrain straight mast forklifts* are able to move and lift loads vertically. Straight mast forklifts are equipped with larger rough terrain tires and are able to be used over semi-rough terrain. They are commonly used for loading and off-loading deliveries at a job site.
- *Rough terrain shooting boom forklifts* are able to move and lift loads vertically and horizontally. Shooting boom forklifts have a telescoping and tiltable mast, are equipped with rough terrain tires, and are able to be used over semi-rough terrain. They are commonly used for material handling at job sites.

Figure 4-12 Example of a Load-Rating Chart



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Personnel and Material Hoists

Personnel and material hoists, often referred to as temporary elevators or buck hoists, are common pieces of equipment used to transport workers and material vertically in a multistory building. These pieces of equipment are generally rented from a vendor and secured to the side of the building. The construction of the hoists is similar to that of common elevators in that they have a cab for the workers and equipment and counterweights to offset the load. Unlike elevators, most temporary hoists do not have an enclosed shaft but ride along a rail or tower that is secured to the building structure. Depending on the manufacturer, the rail will support one or two cars. The contractor should take great care in determining the number and location of the hoists because these factors can significantly affect the productivity of the crews. This is an important consideration when developing the site logistics plan.

Aerial Work Platforms

Aerial work platforms are used to create an elevated work area to lift workers and their tools and equipment and light materials to be installed. A wide variety of aerial work platforms are available:

- *Scissor lifts* are able to lift workers vertically. A scissor lift's work platform is located directly over its wheels and is raised and lowered by a cross-supported scissoring mechanism. Scissor lifts may have smooth wheels (slab scissor lift) or be equipped with rough terrain tires (rough terrain scissor lift) and are able to be used on only level surfaces. They are typically electrically powered and able to be moved while in use and maneuvered in tight spaces. They are commonly used for installation of overhead MEPs.
- *Manlifts* are able to lift workers vertically at a horizontal distance away from and rotate around the main body of the lift. There are two main types of manlifts: straight boom manlifts and articulating boom manlifts. *Straight boom manlifts* raise and lower workers in a basket connected at the end of a straight boom where articulating boom manlifts raise and lower workers in a basket connected at the end of a multijointed boom. Manlifts may be self-propelled or towable. They are often equipped with rough terrain tires and used in outdoor applications but may have smooth wheels for indoor applications. They are commonly used

for work on the exterior façade of buildings and where work must take place over other objects, such as landscaping, furniture, and equipment.

- *Mast boom lifts* are able to lift workers vertically. A mast boom lift raises and lowers workers in a basket connected to a retractable mast. They are point-of-use lifts and unable to be moved when in use. Mast boom lifts are typically smaller than other types of aerial work platforms and commonly used where space is limited and work can be completed at a single location (e.g., wiring an electrical fixture).

CONSTRUCTION EQUIPMENT STUDY QUESTIONS

1. Which of the following is not a type of pile installed by pile driving?
 - A. cofferdams
 - B. precast concrete pile
 - C. cast-in-place concrete pile
 - D. metal pile
2. Which of the following types of equipment is most suitable for excavation of a standard residential basement?
 - A. excavator
 - B. loader
 - C. scraper
 - D. dragline
3. Which of the following types of excavation equipment is most suitable for removing and stockpiling on-site 2 ft of soil from 1 acre of excavation area?
 - A. excavator
 - B. loader
 - C. scraper
 - D. dragline
4. Which of the following types of excavation equipment is most suitable for final grading of a roadway?
 - A. dozer
 - B. grader
 - C. loader
 - D. backhoe

5. Which of the following types of compaction equipment is most suitable for compacting the granular base of a large parking lot?
 - A. tamper
 - B. plate compactor
 - C. smooth wheel roller
 - D. sheepsfoot roller

6. A sheepsfoot roller is most suitable for compaction of which type of soil?
 - A. clay soils
 - B. gravel
 - C. sandy soils
 - D. topsoil

7. What is an advantage of a tower crane?
 - A. It is easily moved from one location to another on the job site.
 - B. Its operator has an unobstructed view of the site.
 - C. Several mobilizations and demobilizations per project are common.
 - D. Its setup time is fast.

8. Which of the following types of aerial work platforms is most suitable for installing fire sprinkler piping inside a building?
 - A. slab scissor lift
 - B. rough terrain scissor lift
 - C. straight boom manlift
 - D. mast boom lift

9. Using Figure 4-12, what is the maximum load of a crane if the boom is at an angle of 40° and extended 53 ft?
 - A. 4,640 lb
 - B. 5,030 lb
 - C. 13,010 lb
 - D. 80,000 lb

SPECIFICATIONS

The specifications make up the bulk of the project manual and provide detailed descriptions of the material and equipment to be installed in a building. The drawings provide the geometry of the building, and the specifications are used to define the nature of the materials, the procedures, and the minimum installation standards. Both are needed to know the design intent of the project.

CSI 16-Division Format

The specifications are typically divided by CSI (Construction Specifications Institute) divisions and sections. The CSI divisions are a standardized arrangement of construction activities and scopes of work. For many years a 16-division format was used and is provided in Figure 4-13. The divisions are further broken down into sections. Sections are more specific areas of scope within the divisions. For example, Division 02, Site Construction, includes specific sections for demolition, site utilities, earthwork, and paving. Division 09, Finishes, includes sections on drywall, carpeting, acoustical ceilings, and painting. Division 15, Mechanical, covers all mechanical systems, specifically including sections on fire protection, plumbing, and HVAC. Although the 16-division format is still used, it is being phased out by the newer 50-division format.

Figure 4-13 CSI 16-Division Format

Division 00: Procurement/Contracting Req.
 Division 01: General Requirements
 Division 02: Site Construction
 Division 03: Concrete
 Division 04: Masonry
 Division 05: Metals
 Division 06: Wood and Plastics
 Division 07: Thermal and Moisture Protection
 Division 08: Doors and Windows
 Division 09: Finishes
 Division 10: Specialties
 Division 11: Equipment
 Division 12: Furnishings
 Division 13: Special Construction
 Division 14: Conveying Systems
 Division 15: Mechanical
 Division 16: Electrical

CSI 50-Division Format

In 2004, the 16-division format was updated to 50 divisions (Figure 4-14). CSI made the change to better define the scope between the trades, especially in mechanical, electrical, and civil work. The 50-division format has been widely accepted by the industry and is the most common method of construction scope organizations.

Figure 4-14 CSI 50-Division Format

Specification Subgroups Sections

Procurement and General Requirements Subgroup

- Division 00: Procurement/Contracting Req.
- Division 01: General Requirements

Facility Construction Subgroup

- Division 02: Existing Conditions
- Division 03: Concrete
- Division 04: Masonry
- Division 05: Metals
- Division 06: Wood, Plastics & Composites
- Division 07: Thermal & Moisture Protection
- Division 08: Openings
- Division 09: Finishes
- Division 10: Specialties
- Division 11: Equipment
- Division 12: Furnishings
- Division 13: Special Construction
- Division 14: Conveying Equipment
- Division 15: Reserved for Future Expansion
- Division 16: Reserved for Future Expansion

Facility Services Subgroup

- Division 20: Reserved for Future Expansion
- Division 21: Fire Suppression
- Division 22: Plumbing
- Division 23: Heating, Ventilating & Air Conditioning
- Division 24: Reserved for Future Expansion
- Division 25: Integrated Automation
- Division 26: Electrical
- Division 27: Communications
- Division 28: Electronic Safety & Security
- Division 29: Reserved for Future Expansion

Site and Infrastructure Subgroup

- Division 30: Reserved for Future
- Division 31: Earthwork
- Division 32: Exterior Improvements
- Division 33: Utilities
- Division 34: Transportation
- Division 35: Waterways & Marine Construction
- Division 36: Reserved for Future Expansion
- Division 37: Reserved for Future Expansion
- Division 38: Reserved for Future Expansion
- Division 39: Reserved for Future Expansion

Process Equipment Subgroup

- Division 40: Process Integration
- Division 41: Material Processing & Handling Equipment
- Division 42: Process Heating, Cooling & Drying Equipment
- Division 43: Process Gas & Liquid Handling, Purification & Storage Equipment
- Division 44: Pollution Control Equipment
- Division 45: Industry-Specific Manufacturing Equipment
- Division 46: Water & Wastewater Equipment
- Division 47: Reserved for Future Expansion
- Division 48: Electrical Power Generation
- Division 49: Reserved for Future Expansion

Notice in Figure 4-14 that many sections are reserved for future expansion, giving the new format room for growth and making it unlikely to change in the future. It isn't necessary to memorize all 50 divisions; however, it is highly recommended to know Divisions 01–14, 21–23, 26, and 31–33 because these are very common systems included in most building construction projects.

Differences between CSI Formats

There are a number of differences between the 16- and 50-division CSI formats. However, for most commercial construction projects the most significant changes are in Divisions 02, 15, and 16. Each of these divisions was subdivided. The trades in Division 02 under the 16-division format are now in sections 02 and 30–39. The mechanical systems in Division 15 are now sections 20–23. The electrical

system previously in Division 16 is now distributed among sections 25–28.

Three-Part Specification Format

Another contribution CSI made to the construction industry is its introduction of the three-part technical specification format. Most specifications are divided into three parts: general, products, and execution. The standardized three-part format makes it much easier to locate specific information within a product's technical specifications. The description of each part is found below:

Part 1, General, provides a description of the work, the submittals required, and any inspections or testing needed to be performed by the contractor.

Part 2, Products, provides the technical specification of all of the material or equipment described in the section.

Part 3, Execution, provides clarification on how material and equipment are to be installed. Minimum workmanship standards are provided along with approved installation procedures.

An example of a technical specification is provided in Figure 4-15. Notice that it is section 03 1513. The 03 indicates that it is in Division 03, Concrete, because it pertains to the waterstops installed in a concrete wall. You can also see that it is divided into the three parts described above.

For more information see Fisk & Reynolds in the list of references.

UniFormat

An alternative to the CSI divisions is the UniFormat standard for classifying building components and systems. UniFormat was created by the AIA and GSA in the early 1970s and breaks down the various components into seven categories found below. The seven categories (A–G) are subdivided into five additional levels (1–5). Because this system combines different trades into common systems more inclusively than the CSI format does, this system has some advantages when doing conceptual estimating as well as with BIM modeling.

- A. Substructure
- B. Shell
- C. Interiors
- D. Services
- E. Equipment and Furnishings
- F. Special Construction and Demolition
- G. Building Sitework

SPECIFICATIONS STUDY QUESTIONS

1. In which CSI division is information about structural steel located?
 - A. Division 01
 - B. Division 05
 - C. Division 10
 - D. Division 15

2. Which CSI technical specification part would contain information about which submittals were required?
 - A. Part 1
 - B. Part 2
 - C. Part 3
 - D. Part 4
3. Which CSI division significantly changed with the 2004, 50-division format change?
 - A. Division 01
 - B. Division 05
 - C. Division 10
 - D. Division 15

CONSTRUCTION DRAWINGS

Construction drawings, also referred to as drawings, plans, and blueprints, are the graphical representation of what the contractor is to build. The drawings are only one part of the contract documents but are the part most used by the contractor on a day-to-day basis. The drawings contain different views, sections, schedules, and notes to describe the design intent of the structure. Although there is a great deal of consistency in style and format in drawings from designer to designer, each set of drawings is unique and will have a unique way of showing the design intent. Plan reading is a skill and, like any other skill, requires practice to master.

Plan Views

The *plan* view shows the building as if someone were viewing the building from above it. Plan views commonly provide overall dimensions of the build, wall types, room dimensions, and locations of sections. Site plans, footing layout, and life safety plans are typically provided in plan view. Sheet A101 in the sample set of plans provided at the end of this chapter is in plan view.

Figure 4-15 Example of a Technical Specification

Clemson University
Freeman Hall Expansion
SC #H12-9891-SG

03 1513-1
WATERSTOPS

SECTION 03 1513 WATERSTOPS

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes: Waterstops for construction and control joints in cast-in-place concrete.
- B. Install waterstops of the type specified herein in the following locations, whether or not the drawings indicate the presence of waterstops in such locations:
 - 1. Construction and control joints in footings.
 - 2. Construction and control joints in foundation walls.
 - 3. Construction and control joints in elevator pit slabs and walls.
 - 4. All other construction and control joints that are below grade, other than basement slabs.
- C. If other portions of the contract documents indicate PVC or rubber waterstops to be employed in construction and control joints, obtain instructions from the Architect before proceeding.
- D. Section Does Not Include: Waterstops for expansion joints.

1.02 SUBMITTALS

- A. Product Data.
- B. LEED Documentation: Submit information required by Section 01 3531 for the following targeted credit:
 - 1. Credit MR 5: Materials and Resources - Regional Materials.
- C. Submit final certification in the form included at the end of this section.

PART 2 PRODUCTS

2.01 SUBSTITUTIONS

- A. Refer to Section 01 6000 - Product Requirements.

2.02 WATERSTOPS

- A. Adcor ES; W.R. Grace & Co.
- B. Henry HF302-Hydro-Flex Waterstop; Henry Company.
- C. Volclay Waterstop-RX"; American Colloid Company.
 - 1. RX 101": 1 inch x 3/4 inch flexible strip of compounded bentonite and butyl material.
 - a. Use in concrete at least 8 inches thick with 2 rows of reinforcement.
 - 2. RX 102": 3/4 inch x 3/8 inch flexible strip of compounded bentonite and butyl material.
 - a. Use in vertical concrete at least 5 inches thick with 1 row of reinforcement.
 - b. Use in horizontal concrete at least 4 inches thick.
- D. Fasteners: Concrete nails with washer heads as recommended by manufacturer.
- E. Adhesive: Manufacturer's standard product.

PART 3 EXECUTION

3.01 EXAMINATION

- A. Verification of Conditions:
 - 1. Ensure that joint surfaces are dry and clean and free of debris, dirt, and rocks.
 - 2. Correct any voids or projections using concrete repairs methods specified elsewhere.

LAS 10091-00

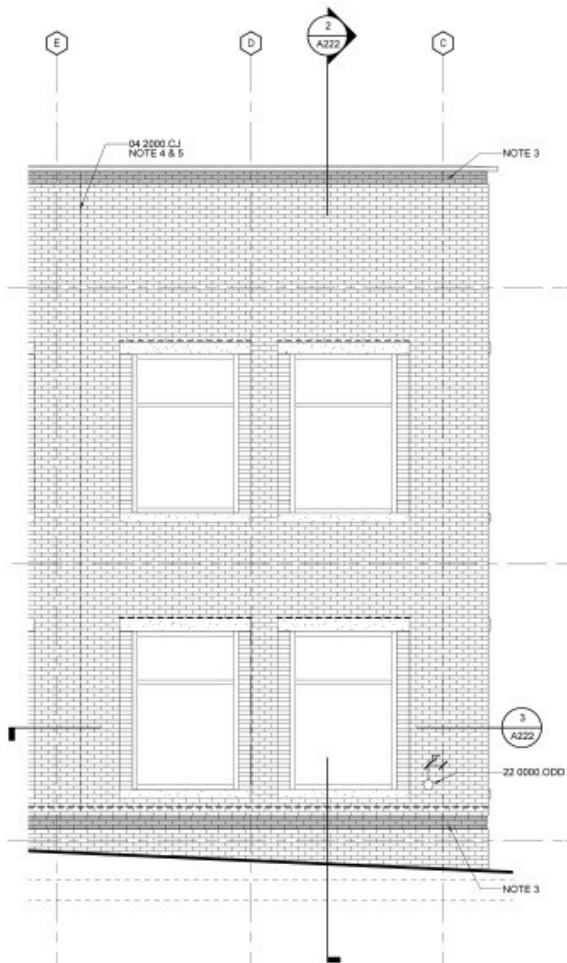
April 4, 2014
100% Construction Documents

Specification courtesy of Lord Aeck Sargent, Inc. 2015

Elevation

The building view, shown as if someone were looking toward the horizon, is referred to as an elevation. Elevations can be of the interior or exterior of the building. Elevations give the dimension of height, which is not provided in the plan view. Exterior windows and cabinets are commonly shown as an elevation. Exterior elevations are commonly named by their compass directions or relation to the front of the building, such as west elevation or rear elevation. Figure 4-16 below is the north elevation of the sample set of drawings provided at the end of this chapter.

Figure 4-16 Example Elevation



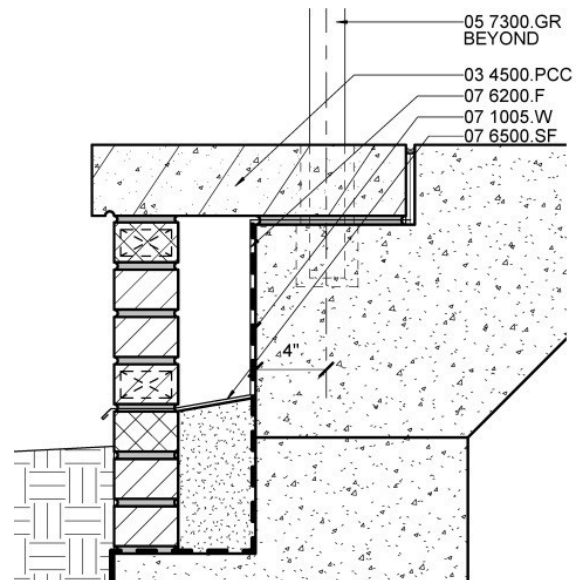
Reprinted Courtesy of Lord Aeck Sargent, Inc., 2015

Section

A section is a type of view provided where a section of the building is cut away to expose the hidden areas. The cutting plane is typically vertical

to the building. Window details and rebar in a footing are commonly shown in section view. The location of the cutting plane should always be provided to the reader either on the floor plan, in the elevations, or in other sections. The location of cut sections is provided in sheet A101 in the sample set of drawings provided at the end of this chapter. See Figure 4-17 for an example of a cut section. Notice also that a section cut is provided in the elevation shown in Figure 4-16.

Figure 4-17 Example of a Cut Section



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Isometric Drawings

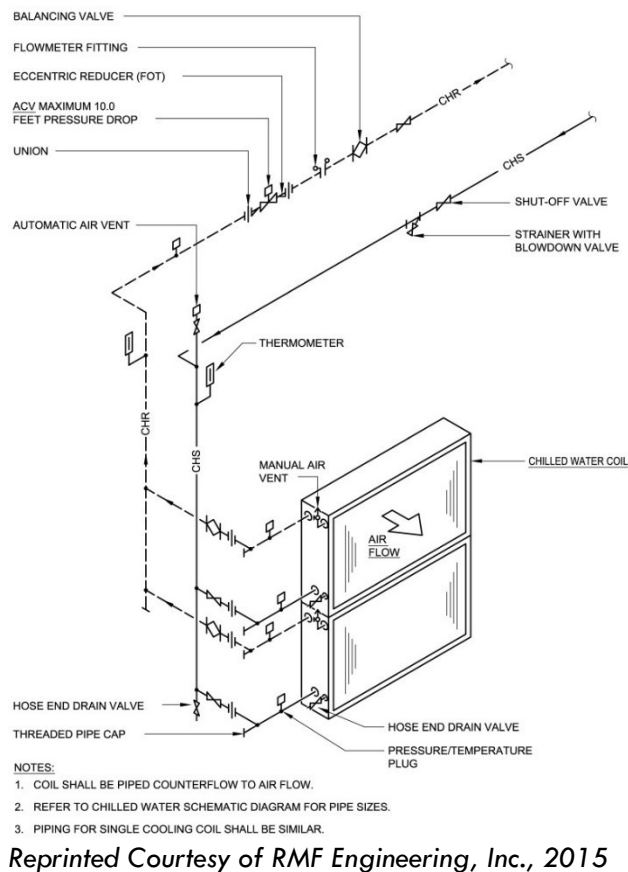
Isometric drawings are a pictorial drawing of systems of the building shown in 3D. Commonly they are drawn so that the plan view is turned 90° and the elevation 30° from the horizontal axis. Plumbing and fire protection systems commonly use this type of drawing to show pipe layout. Figure 4-18 shows the piping configuration of a cooling coil in an isometric view.

Details

Details are a type of view used to show special conditions of a component of a building. Typically, they are at a larger scale to show more detail. The location of the detail in relation to the building should always be provided to the reader either on the floor plan, elevation, sections, or other details. Door head/jamb details are provided on sheet

A601 in the sample set of drawings provided at the end of this chapter.

Figure 4-18 Example of an Isometric View



Schedules

A schedule is used to provide detailed information about specific building components or pieces of equipment. Schedules are commonly used to describe structural footings and provide information such as length, depth, and width as well as rebar size, location, and direction. Schedules are also used to describe the size, capacity, connections, and electrical requirements of equipment. An example of two HVAC schedules can be found on sheet M600 in the sample set of drawings provided at the end of this chapter.

Symbols

A set of drawings contains an enormous amount of information needed to construct a building. To save space on the paper and keep the drawings organized and readable, symbols are used to represent more-elaborate systems. Symbols can be letters, numbers, or thumbnail images. For example, the letter A may be used to describe a 2-hr fire-rated drywall partition. Symbols generally

represent typical components used often in a building. When symbols are used, a legend must be provided to explain their meaning. The symbol legend is often the first or last sheet of each of the disciplines in the set of drawings.

Notes

Sets of drawings will contain notes on many of the pages. Notes provide supplemental information needed to understand the pictorial plans. Notes can either be identified with symbols, which indicate to the reader that more information is available elsewhere in a note schedule, or they can be provided on plans without symbols because they are relevant to all the drawings. Civil plans often have extensive notes for storm water, clearing, and erosion requirements. These supplemental instructions come from the authority having jurisdiction and as such are often placed on the plans instead of in the specifications. All notes should be read on a page carefully because they can dramatically change how the drawings are interpreted. Notes can be found on sheet A101 in the sample set of drawings provided at the end of this chapter.

Grade Line

An important aspect of the building is its elevation. With civil drawings, it is common to indicate the existing and future elevations of the site in feet above sea level. However, for architectural and structural drawings, the elevation above sea level isn't important for construction. A fixed point, commonly the first-floor slab, is given an arbitrary elevation of 0 ft or 100 ft for easy calculation of other elevation points. The top of a footing may be shown at 98 ft; however, this doesn't mean it is 98 ft above sea level. Rather, it means that it is 2 ft below the arbitrarily determined elevation of 100 ft of the first-floor slab. Civil drawings will often contain a site plan with existing and future grade lines. Light colored dashed lines are used to show the existing elevation of grade and darker solid lines used to show the grade the contractor is to build to.

Line Types

Lines are used to show objects (visible and hidden), dimensions, and locations within a set of drawings. Figure 4-19 shows some of the most common types of lines and their typical uses.

Figure 4-19 Common Line Types

Light solid line: used to show dimensions, leaders, and extension lines	
Bold solid line: used to show objects	
Dashed line: used to show hidden objects or objects below/above the cutting plane	
Dash then dote line: used for centerlines	
Dash, dot, dot line: used for cutting planes	

Drawing Index

The drawing index is the table of contents for the set of drawings and is very useful for finding information quickly. The drawing index is located in the front of the set, oftentimes on the cover. The drawing list includes all pages of the drawings and identifies them by drawing number and title. The drawing number is made up of one or two letters followed by numbers (e.g., A101, A1.1). The letters correspond to the type of drawings. Following are commonly used letters:

C	Civil
A	Architectural
S	Structural
M	Mechanical
P	Plumbing
FP	Fire Protection
E	Electrical

The disciplines can be organized differently, but generally civil is first followed by architectural, structural, and the MEPs.

Sample Plans

A portion of a set of construction drawings has been provided on the following pages. Various important aspects of the drawings are highlighted. To not clutter the drawings, additional information about the plans is provided in Figure 4-20.

Special thanks to Lord Aeck Sargent, Inc., from Atlanta, Georgia, and RMF Engineering, Inc., from Charleston, South Carolina, for allowing the use of these drawings for the purpose of this study guide.

CONSTRUCTION DRAWINGS

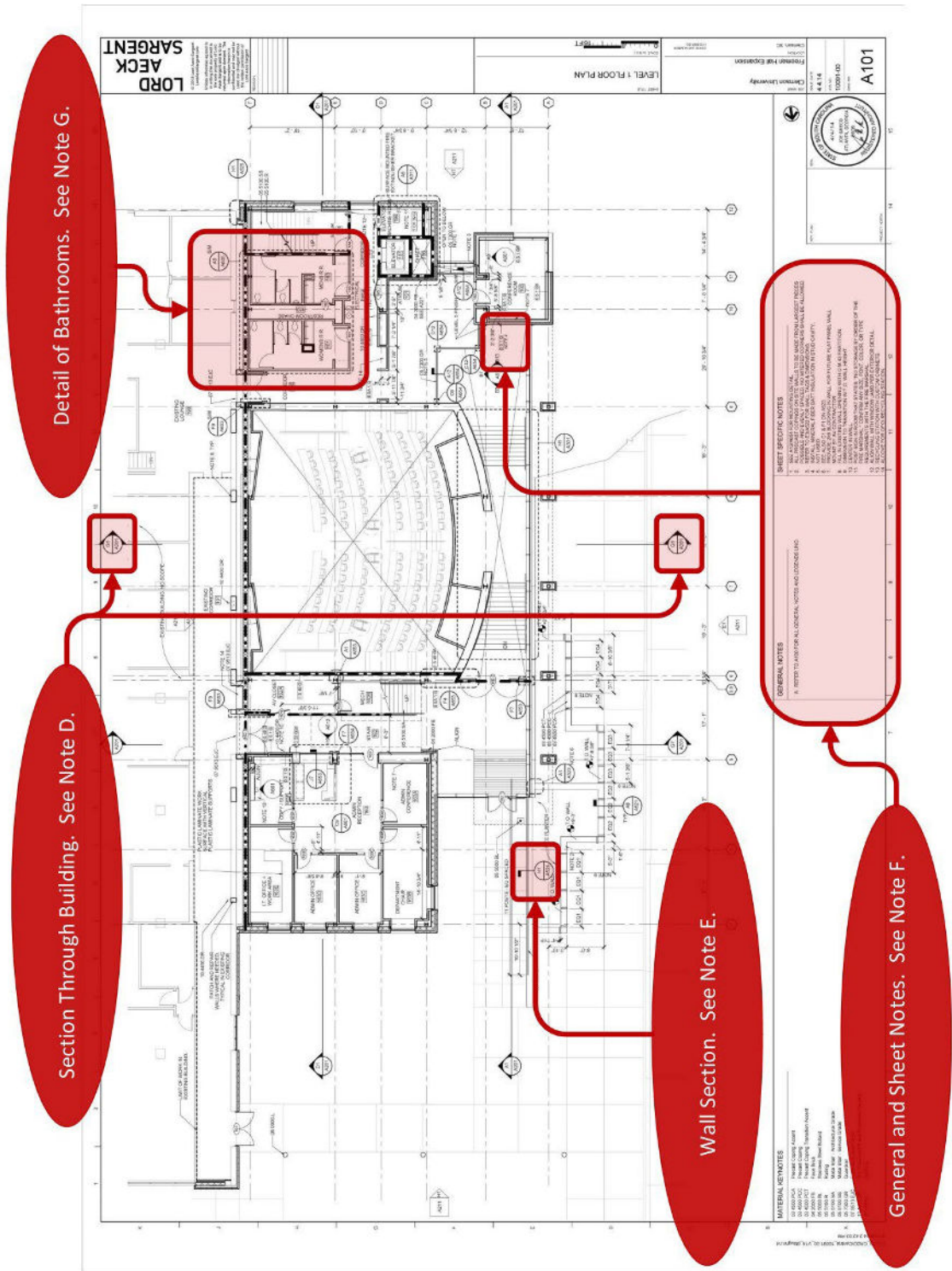
STUDY QUESTIONS

- Which of the following views is used in plumbing drawings to show a 3D view of pipe runs?
 - plan
 - elevation
 - section
 - isometric
- Where is the best location to look to determine the electrical requirements for a project's chillers?
 - contract
 - details
 - schedule
 - specifications
- Which of the following types of lines are used to show hidden objects or objects above or below the cutting plane?
 - light solid line
 - bold solid line
 - dot then dashed line
 - dashed line
- Using the sample drawings provided in this chapter, what is the fire rating for door 062.3?
 - not rated
 - 30 minutes
 - 60 minutes
 - 90 minutes
- Using the sample drawings provided in this chapter, what is the horse power of the fan servicing AHU-1?
 - 1 hp
 - 10 hp
 - 25 hp
 - 35 hp

Figure 4-20 Plan Notes

- A.** All sets of drawings will begin with the cover page, which at a minimum will include the project name. Here, the project name, date of the drawings, how complete the drawings are, and project numbers are identified.
- B.** In this particular set of drawings the drawing list is provided on the cover. This is a common practice; however, it is also very common to have the drawing list on a separate page. The drawing list is an excellent place to start when looking for information. The title of the page will help the reader identify where to first start looking for the desired information.
- C.** The far right side of the page is typically reserved for the title block. The title block will contain general information about the project and the designer who drafted it. The designer's seal is also placed here, certifying that the design is safe and constructible. The drawing number and title from the drawing list can be found here. It is also very important to look for the original drafted date and any dates of revisions to make sure you have the latest sheet.
- D.** There are two types of sections shown on this page: through building section and a wall section. What is highlighted here is a through building section. Notice the circles with arrows at the top and bottom of the page. These show the cutting plane of the section. In the circles with arrows you can see a G1 on top and an A201 on the bottom. These designations indicate that you can find the section on section G1 on sheet A201. The direction the arrow is pointing is the direction of the view.
- E.** A wall section is being highlighted in this note. A wall section cut is limited to the length of the line from the circle to the termination bar. In this case, a section is being cut through only the site planter wall. The section can be found on detail H1 on sheet A521. Section H1/A521 was used in Figure 4-17.
- F.** Many sheets contain additional information in the notes section. Here, they are called *general notes* and *sheet specific notes*; however, the title may differ slightly based on the set of drawings. Great care should be taken to read these notes in detail because they often contain additional scope or exceptions to what is shown in the drawing. For example, in this case Sheet Specific Note #4 indicates that batt insulation is to be installed in certain stud cavities. Without reading this note the contractor would not know that the walls of Conference Room 150 should be insulated.
- G.** Blow-up details are often provided for areas of the plans where a great deal of specific information is needed. The bathrooms are being highlighted here. Notice the dotted line around the restrooms with an A9/A605 tag. Bathrooms often have specific dimensions to be compliant with ADA requirements. A blow-up detail is provided on detail A9 on sheet A605 to show those dimensions but not clutter up the larger floor plan.
- H.** Because there are a wide range of doors, frames, and hardware on most projects, door schedules are critical in understanding what is to be installed. A door schedule will include all doors on the project and identify them individually with a door number. Often, door elevations, frame elevations, and details are provided on the same page. Much of the information in the schedule is identified with tags or abbreviations that refer the reader to other elevations or details. For example, Door 062.1 has a C:2 door. The C:2 is a tag that refers the reader to the door elevation type. The fire rating also is often provided in the schedule. In this case, door 062.1 is a 90-minute door. As always, care should be taken with plan notes. In this case there is a remarks column that refers the reader to the Door Remarks list of notes on the right side of the page.
- I.** Sheet M600 provides schedules for two pieces of equipment. Equipment schedules provide basic specifications for the equipment to be installed.
- J.** All major pieces of equipment are provided a designation tag. The tag serves as an abbreviation for the equipment shown on other drawings.
- K.** Schedules will provide the equipment manufacturers. The manufacturers listed are usually what the design was based around; however, equivalent equipment by other manufacturers is also commonly acceptable. The other acceptable manufacturers are most often provided in the specifications.
- L.** Equipment schedules typically provide the basic electrical requirements of the equipment. Most often the voltage, phase, and frequency are provided. Line voltage of most equipment ranges from 110 V–480 V. Equipment will either be single or three phase, and in the United States the frequency will always be 60 Hz. Notice that the pump and fan schedules display the electrical requirements differently but all the equipment shown requires 208 V, 3-phase, 60 Hz power.

[illegible]



[illegible]

DESIG

DESIG	SERVICE	TYPE	FLUID TEMP. (°F)	CAPACITY (GPM)	HEAD (FEET H ₂ O)	SUCTION X DISCHARGE	VOLTS	PHASE	HERTZ	PUMP BHP	MOTOR HP	RPM	PUMP EFFICIENCY (%)	BASIS OF DESIGN	REMARKS
CHWP-1	CHILLED WATER	TYPE A - END SUCTION	45	110	65	2.5" x 2"	208	3	60	2.8	5	1750	65.1	BELL AND GOSSETT SERIES 1510	1/2/3
CHWP-2	CHILLED WATER	TYPE A - END SUCTION	45	110	65	2.5" x 2"	208	3	60	2.8	5	1750	65.1	BELL AND GOSSETT SERIES 1510	1/2/3
SCHWP-1	CHILLED BEAM	TYPE A - END SUCTION	57	30	65	1.5" x 1.25"	208	3	60	1.2	2	1750	42.9	BELL AND GOSSETT SERIES 1510	1/2/3
SCHWP-2	CHILLED BEAM	TYPE A - END SUCTION	57	30	65	1.5" x 1.25"	208	3	60	1.2	2	1750	42.9	BELL AND GOSSETT SERIES 1510	1/2/3
HWP-1	HEATING WATER	TYPE A - END SUCTION	160	45	65	1.5" x 1.25"	208	3	60	1.5	2	1750	51.4	BELL AND GOSSETT SERIES 1510	1/2/3
HWP-2	HEATING WATER	TYPE A - END SUCTION	160	45	65	1.5" x 1.25"	208	3	60	1.5	2	1750	51.4	BELL AND GOSSETT SERIES 1510	1/2/3

PUMP SCHEDULE

1. PUMP MOTOR SHALL BE NON-OVERLOADING, THROUGH THE ENTIRE PUMP CURVE WITHOUT ENTERING MOTOR SERVICE FACTOR.

2. PUMPS WITH IMPROVED EFFICIENCIES, THEREBY REDUCING REQUIRED HORSEPOWER, MAY BE SUBMITTED FOR REVIEW DURING SUBMITTAL PROCESS.

3. PROVIDE WITH INVERTER DUTY MOTOR AND VARIABLE FREQUENCY DRIVE

DESIG

DESIG	SERVICE	TYPE	CFM	TSP (INCH WG)	ESP (INCH WG)	APPROXIMATE FAN RPM	BHP	MOTOR HP	WHEEL DIAMETER (IN)	DRIVE	AMCA CONSTRUCTION CLASS	ELECTRICAL (V/Ø/Hz)	BASIS OF DESIGN	REMARKS
SF-1	AHU-1	A	10,000	8.0	2.0	2,814	21.71	25	-	DIRECT	III	208/3/60	TWIN CITY EPON	1/2
RF-1	AHU-1	A	7,000	3.25	1.0	2,502	6.44	7.5	-	DIRECT	II	208/3/60	TWIN CITY EPON	1/2
TEF-1	TOILET EXHAUST	B	1,925	1.5	-	1,550	0.65	1.0	-	DIRECT	-	208/3/60	COOK ACURD	

FAN SCHEDULE

1. MOTORS SHALL BE INVERTER DUTY.

2. SP INCLUDES ADDITIONAL LOADED FILTER ALLOWANCE OF 0.05" W.C. FOR MERV 8 PREFILTER AND 0.75" W.C. FOR MERV 13 INTERMEDIATE FILTER.

CONSTRUCTION EQUIPMENT ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | C. | 2. | A. | 3. | C. |
| 4. | B. | 5. | C. | 6. | A. |
| 7. | B. | 8. | A. | 9. | B. |

SPECIFICATIONS ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | B. | 2. | A. | 3. | D. |
|----|----|----|----|----|----|

CONSTRUCTION DRAWINGS ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | D. | 2. | C. | 3. | D. |
| 4. | A. | 5. | C. | | |

CAC EXAM: STUDY GUIDE



CHAPTER 5

BIDDING AND ESTIMATING

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PROCUREMENT AND BIDDING PROCESS

BID DOCUMENTS

In many cases, albeit not all, the first step in the procurement and bidding process is the *prequalification* of the bidder. Prequalifying contractors is a way of verifying that they have the experience and financial strength to complete the project successfully. A company's financial statements, proof of insurance, bonding capacity, EMR, and litigation history are typically requested for the evaluation. Once a company has been prequalified it can be sent bid documents and continue the procurement and bidding process. Bid documents contain bidding instructions and information about a particular project. They generally consist of bidding information, technical specifications, and bid drawings. Often found in the initial sections of the project manual, bidding information includes the following:

- *Invitation to bid*, also known as *advertisement for bids*, is the invitation to bidders to bid on a particular project. Invitations to bid provide general information about the project including, type, size, and location of the project; the bid date; anticipated start and completion dates; bond requirements; location and cost of bid documents; and any other general or legal requirements. On public projects, invitations to bid must be publicly advertised. They are often posted in public places and advertised in the newspaper, on the Internet, in trade journals or magazines, and at local builder exchange offices.
- *Instructions to bidders*, also known as *information for bidders*, are instructions to bidders, stating the bidding procedures for a particular project. They often include much of the same general information as the invitation to bid and provide detailed information about the bid due date, location to deliver the bid, type of bid opening (public or private), instructions for filling out the bid form, how and when contracts will be awarded or rejected, responsibilities of the bidders, and other important details regarding the bid.
- *Bid form*, also known as a *proposal form*, is the document used by the bidders to submit their bids. They commonly include the contractor's name, amount of the bid (both written and numerical), price breakdowns, list of alternates, acknowledgment of addenda, fees for extra

work, unit prices, proposed time frame to complete the project, key subcontractors, disadvantaged business participation, and the signature of the bidder.

- *The Contract agreement* is the contract between the parties that will be used on the project and is often included in the bid documents for review by the bidders.
- *General conditions* are used to outline the rights, responsibilities, obligations, and authority of the project participants.
- *Supplementary conditions* are used to outline any project-specific conditions, such as wage scales, geotechnical reports, insurance and bond requirements, job-site office, temporary facilities, parking, signage, and cleaning requirements.
- *Alternates* are used when a project owner request separate pricing for changes to the base bid scope of work. The scope of this work is detailed in the bidding information, and separate line items are included in the bid form for each alternate. Alternates may be listed as added to or deducted from the base bid.
- *Addendas* are used to document and distribute any changes, corrections, or clarifications made to the contract documents during the bidding period.

For more information see Dagostino & Peterson in the list of references.

TYPES OF SPECIFICATIONS

The technical specifications, or simply specifications, are a written description of the work. They complement the drawings and provide information on how the work is to be put in place; however, during preconstruction it is particularly important to review the approved manufacturers and standards for workmanship. Specifications can be categorized as either prescriptive or performance.

Prescriptive Specifications

A prescriptive specification provides a complete design to the contractor. Specific equipment, materials, and to a degree the means and methods of installation are provided. Acceptable quality standards are also included. *Proprietary specification* is a type of prescriptive specification that names the specific manufacturer or system desired by the designer. A closed proprietary specification allows for only one manufacturer or

system to be selected from. A common use for this is when trying to match or integrate into existing conditions. An open proprietary specification provides a basis for design but allows for several preselected manufacturers or systems to be used. This allows for a degree of competition, which keeps the costs in line with the market.

Performance Specifications

A performance specification provides a performance criterion that the contractor must then meet. The designer provides information on the final function of the system and some general requirements but not the specific design. Oftentimes, this involves the contractor hiring an engineer to complete the design. This type of specification is most commonly used with complicated systems that are often customized to specific building applications, such as a curtain wall or security or audio/visual electrical systems.

For more information see Muller, Fausett, & Grau in the list of references.

LAWS, REGULATIONS, AND CODES

All projects must be constructed in compliance with local; state; and federal laws, regulations, and building codes. A building code presents the minimum requirements for design and construction established by the local governing body. In the United States, the most widely accepted building code is the International Building Code (IBC). The IBC is a family of codes that include the International Building Code, International Residential Code, International Energy Conservation Code, International Plumbing Code, and many more. Revisions to the IBC are published on a three-year cycle; however, local municipalities must adopt the revisions before they are enforced in that area. The energy code is notoriously slow to be adopted because more-efficient buildings generally have higher initial costs, which can be a highly political issue.

The terms *specifications*, *laws*, *codes*, *regulations*, and *standards* are commonly used interchangeably; however, there are important differences between the terms.

- *Specifications* are created by the designers to complement the construction drawings. They generally contain standards to supplement the design intent and set the benchmark for quality. The specifications are the part of the contract documents that must be in compliance with local

codes before a building can receive a permit for construction.

- *Laws* are rules created by the community authority, which is often the legislature, and enforced by judicial decision.
- *Codes*, if adopted, become statutory requirements of the municipality having jurisdiction and, if violated, can have civil or criminal penalties.
- *Regulations* have a similar effect as codes in terms of their statutory authority but are generally included or created in laws.
- *Standards* are created by standard organizations, such as ASTM, ANSI, or SMACNA and provide performance criteria for materials and systems. They are not legally binding unless specifically referenced with the code. Many standards are included in technical specifications, but few are included in the code.

For more information see Woods, Andres, & Smith in the list of references.

INSURANCE AND BONDS

Insurance and bonds are used to protect owners and/or contractors against risks. Insurance differs from bonds in who is responsible for payment in the case of a claim. With insurance policies, the insurance company is responsible for the cost of the claim. In a bond, the bonding company fulfills the contractor's obligation for payment but holds the contractor responsible for payments made on the contractor's behalf. Another important difference is who is being protected. With insurance, the party purchasing the policy is being protected, whereas, with a bond, the purchaser (contractor) is paying to protect another party (owner).

Insurance

There are various types, forms, and coverages of insurance used in construction. Insurances may be required by law and/or by the project documents. Following are some of the most common types of insurance found in construction:

- *Workers' compensation* is a type of insurance that compensates a worker for a portion of his or her lost wages (commonly 67%) and medical expenses for injuries that occurred at work. In exchange for this benefit, employees forgo their right to sue their employer for tort negligence. Workers' compensation is regulated by the state. The rate employers pay can be adjusted by an employer's Experience

Modification Rate (EMR). The EMR is a multiplier that adjusts the premium based on the employer's past work record. The standard multiplier is 1; however, if a company has shown a track record of safe operation, it may earn a lower EMR, such as 0.8, which would lower the company's premiums by 20% and make it more competitive. However, if a company has a history of accidents and is a higher risk for claims, then its EMR may increase to above 1, such as 1.2, which would increase its premiums by 20%.

- *Builder's risk* is an insurance that builders purchase to protect them from building damage that occurs while the building is under construction. It also typically includes the temporary structures, such as trailers and storage containers, that are located on the project site. The specific damage the insurance indemnifies against includes fire, storm, theft, and vandalism. Typically, it does not cover flooding or earthquakes unless a rider policy is purchased.
- *General liability* protects the contractor from claims by a third party of bodily injury, injury to person, and property damage as a result of ongoing operations. For example, this insurance would protect the contractor if a steel beam fell and crushed the building official's car.
- *Errors and omissions* protects designers from incomplete, incorrect, and faulty design documents. Contractors generally do not have this insurance unless they are providing design services, such as with a design-build contract, or have performance specifications requiring them to design a portion of the work.

Traditionally, the contractor and subcontractors are responsible for providing insurance for their own scope of work. However, OCIPs (owner-controlled insurance programs) and CCIPs (contractor-controlled insurance programs) are becoming more common. With OCIPs and CCIPs, the owner or contractor purchases a single wrap-up policy for all of the trades. OCIPs and CCIPs can have reduced premiums as a result of purchasing economies of scale, and they have greater control of the insurance held by the trades. Disadvantages of the programs include increased administration burden by the owner or contractor and potential for non-project-related fraudulent claims. It can also be difficult to get the full credit from the trades for insurance they traditionally purchase for themselves

to offset the cost of the policy purchased by the owner or contractor.

For more information see Halpin & Senior and Kibert in the list of references.

Bonds

Bonds are used to protect the owner in cases where the contractor fails to perform in accordance with the contract. Bonds are three-party agreements between an obligee (owner), a principal (contractor), and the surety (bonding company). General contractors often require their subcontractors to obtain a bond as well. In the event that the principal is in default, the surety is responsible for upholding the principal's obligations to the obligee. This could be to financially support the contractor through completion or to take over the project with another contractor. There are three main types of bonds commonly found in construction:

- *Bid bond* is used to ensure that the principal will honor his or her bid and enter into a contract with the obligee for the bid amount after the bid opening. The bid bond usually covers the difference between the low bid and the second-lowest bid, typically up to 10% of the bid price.
- *Performance bond* is a guarantee ensuring the obligee that the principal will perform all work in accordance with the terms of the agreement.
- *Payment bond*, also known as *labor and material bond*, guarantees the obligee that the principal will pay his or her bills for labor and materials provided on the project.

An alternative to bonding is subcontractor default insurance (SDI), commonly referred to by Zurich Insurance Group's trade name Subguard. SDI is an insurance policy, purchased by prime contractors, to protect themselves from subcontractor default. Unlike with a bond, which is a three-party agreement, SDI is a two-party agreement between the prime contractor and the insurance company. Under the SDI policy, the subcontractors are required to be prequalified, effectively lowering the risk of default. In general, SDI is lower cost and more flexible, and claims are processed faster when compared to a surety bond. Advantages to bonds over SDI policies include more case law and legal precedent and no deductibles (often >\$100,000 with SDI policies), and SDI may not cover third- or fourth-tier sub-subcontractors.

VALUE ENGINEERING AND LIFE CYCLE COSTING

Value engineering (VE) and life cycle costing (LCC) are two services commonly provided during preconstruction, but it's important to understand what exactly these terms mean and their differences. VE is a function analysis that seeks lower-cost alternatives for the services provided by the building. A value-engineered building will provide the owner the same function without sacrificing any quality or building services. An example of VE is to replace the structure of the building from block to tilt-up concrete panels because of the cost savings from an accelerated schedule. Block and tilt-up concrete panels serve the same function, so no building services are lost; however, there are cost savings resulting from a shorter schedule. Scope reduction, however, is not value engineering. An example of scope reduction would be if a project was over budget and motorized overhead doors were substituted for manually opened doors. This substitution, although perfectly legitimate, provides fewer building services to the owner. Contractors are often incentivized to provide VE suggestions by the owner sharing with the contractor a portion of the reduced costs.

Life cycle costing (LCC) is a financial analysis that evaluates the cost of a building component or system over its useful life and not just its initial costs. The use of LCC has grown significantly with the increase in high-performance sustainable buildings. High-performance HVAC equipment may increase the initial cost of the project; however, the savings in energy costs may pay for the upgrade in a relatively short period of time.

For more information see Halpin & Senior and Kibert in the list of references.

PROCUREMENT AND BIDDING PROCESS STUDY QUESTIONS

- Which of the following bid documents would the contractor place his or her price on?
 - instructions to bidders
 - bid form
 - contract agreement
 - general conditions

- Which of the following bid documents contains additional or supplemental information to the design documents?
 - instructions to bidders
 - addendum
 - alternate
 - general conditions
- Which type of specification provides the criteria that the contractor must build to but does not include a specific design?
 - performance specification
 - project specification
 - preliminary specification
 - prescriptive specification
- The criteria set by a trade organization for acceptable quality and installation procedures, such as the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) benchmarks for ductwork quality, are best described as a _____.
 - code
 - specification
 - regulation
 - standard
- If a project trailer is vandalized, which of the following type of insurance would cover the claim?
 - errors and omissions
 - builder's risk
 - general liability
 - property insurance
- What is the term used to describe the financial evaluation of the cost of a building component or system over its useful life?
 - cost ratio
 - value engineering
 - life cycle costing
 - initial cost analysis

ESTIMATES

TYPES OF ESTIMATES

There are several types of estimates that are used in the construction industry. They vary primarily in how complete the design is and their level of accuracy. As the design progresses, fewer

assumptions are made, and the closer the estimate gets to the actual cost of construction.

Detailed

A detailed estimate is used when 90% to 100% of the construction documents (CDs) are completed. With this estimate the estimator breaks the work down by the work breakdown structure (explained more in Chapter 6) and completes detailed quantity takeoffs (QTOs). QTOs are used to price material and to estimate the labor and equipment costs. Detailed estimates will include all of the direct costs, bonds, insurance, taxes, overhead, and profit. This type of estimate is the most labor intensive to create but has the lowest margin of error, which will range from $\pm 2\%$ to $\pm 4\%$.

Semidetailed

Semidetailed estimates, also known as *preliminary estimates*, are used when the construction documents are 30% to 90% complete. At this stage of the design some major systems, such as foundations and structures, are fairly well completed; however, other systems, such as HVAC and electrical systems, are only roughly outlined. Detailed estimates are created for components that are completed, but conceptual estimating techniques are used to fill in the gaps of the incomplete portions of the design. The expected margin of error for a semidetailed estimate will range from $\pm 5\%$ to $\pm 10\%$. Semidetailed estimates are often used as budget updates throughout the design process to make sure the design is aligned with the owner's budget.

Conceptual Estimate

Conceptual estimates, also known as *rough order of magnitude estimates*, are used early in the development process. Conceptual estimates are completed by owners, even before the designer is hired, to test the feasibility of the project. This type of estimate typically has a margin of error of $\pm 20\%$ or more but is relatively easy and inexpensive to create. Several techniques are used to develop conceptual estimates, which are shown below:

- *Square-foot estimate* is a rough-order-of-magnitude estimate that uses a total square-

foot cost of other similar buildings and multiplies it by the estimated size of the project. See Figure 5-1 for an example of a square-foot cost database.

Figure 5-1 Example of a Square-Foot Cost Database

Building Type	Costs/sq ft
Community center	\$106.09
College dormitory	\$139.81
Courthouse	\$146.50
Post office	\$95.02
Retail store	\$87.25
Supermarket	\$74.55
Town hall	\$92.55

Example: Based on past experience, a company's internal database indicates that community centers cost approximately \$106.09 to build per square foot. How much will a 3,000 sq ft community center cost?

$$\$106.09 \times 3,000 \text{ sq ft} = \$318,270$$

- *Assemblies cost estimate* is similar to square-foot estimates but breaks out major assemblies, such as foundations, finishes, and mechanical systems. The assemblies are commonly estimated by square-foot cost; however, other units of measure, such as cubic feet or linear feet, are often used. See Figure 5-2 for an example of an assembly cost estimate.

Figure 5-2 Example of an Assemblies Cost Estimate

Description	Quantity	Unit of Measure	Unit Price	Total Cost
Substructure Pad Footings	50,000	sq ft	8.23	\$411,500
Structure Structural Steel	100,000	sq ft	6.21	\$621,000
Enclosure Brick Veneer (80%)	20,000	sq ft	4.46	\$89,250
Windows (20%)	5,000	sq ft	71.4	\$357,000
Roofing Modified Bitumen	50,000	sq ft	6.11	\$305,500
Interiors Finishes	50,000	sq ft	23.54	\$1,177,000
Plumbing Standard Package	50,000	sq ft	6.68	\$334,000
HVAC Chilled Water	50,000	sq ft	9.78	\$489,000
Fire Protection Wet Pipe	50,000	sq ft	3.77	\$188,500
Electrical Standard 120/208	50,000	sq ft	14.44	\$722,000
Sitework Grading	6	acre	6,000	\$36,000
Paving	6	acre	6,000	\$36,000
Utilities	6	acre	2,000	\$12,000
Total				\$4,778,750

- *Cost indices estimate* is a type of estimating that uses known costs of previously constructed projects and adjusts the costs to current prices in a specific location. Figure 5-3 provides a historic cost index of four cities over a period of time. When adjusting cost the following formula is used:

Cost Index Estimate =

$$\frac{(\text{Known Cost})(\text{Cost Index for Estimated Cost})}{\text{Cost Index for Known Cost}}$$

Figure 5-3 Example of Historic Cost Indices

Year	Auburn	Purdue	Clemson	Provo
2016	48.1	46.2	36.7	51.8
2015	47.0	44.0	36.3	47.8
2014	46.0	41.9	35.9	44.0
2013	45.0	39.9	35.5	40.6
2012	44.0	38.0	35.1	37.4
2011	43.0	36.2	34.7	34.5
2010	42.0	34.5	34.3	31.8

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Example: A church was built in Auburn, Alabama, for \$1,500,000 in 2010. How much would that same church cost if built in Purdue, Indiana, in 2015?

Cost Index Estimate =

$$\frac{(\$1,500,000)(44.0)}{42.0}$$

Cost Index Estimate = \$1,571,429

- Parametric estimates are similar to square-foot cost estimates but use statistical relationships between building parameters to develop the costs. The equations in parametric estimates are very complicated, using log functions, ratios of parameters, and multiplication of parameters instead of just simply multiplying a square foot cost by the size. This estimate technique is used only early in the project and for high level conceptual estimates.

For more information see Holm, Schauffelberger, Griffin, & Cole and Dagostino & Peterson in the list of references.

OVERHEAD, CONTINGENCIES, AND PROFIT

Overhead is a grouping of costs for items needed to construct a project that aren't directly associated with the building itself. Job overhead, which is sometimes referred to as general conditions, direct overhead, or indirect field costs, are costs that are specific to a particular project. They range from 10% to 40% of the total project costs and include the costs associated with the superintendent, job trailer, temporary toilets, and job utilities. Notice that these costs are specific to the job and the company would not incur them if the project wasn't ongoing. This is different than home office overhead costs. Home office overhead, which is also called indirect overhead or general overhead, are costs incurred by the company independent of any particular job. These costs include home office rent, marketing, and executive salaries. These are all costs that are shared by all projects and typically added to the budget as a percentage of the work. The home office costs percentage is calculated using the following formula:

Home Office Overhead =

$$\frac{\text{Annual Home Office Overhead Costs}}{\text{Estimated Sales Volume}}$$

Example: A company has a total of \$700,000 in home office overhead expenses, such as accounting computers, marketing events, office rent, and project managers not assigned to a project. The company expects to put into place \$10,000,000 of construction work. What should the home office markup percentage be for projects that bid that year?

Home Office Overhead =

$$\frac{\$700,000}{\$10,000,000}$$

Home Office Overhead = 7%

On nearly every project, some cost items will be left out of the estimate, or some unexpected scope item will be discovered after the estimate is completed. To account for these unexpected costs, contingency is included with most estimates. Contingency is a pool of money that is not associated with a specific scope of work. For bid jobs, contingency helps reduce the risk to the hard bid contractor. However, the higher the contingency included, the higher the bid price and the less competitive the contractor is. With construction management work, the contingency is often a shared pool used jointly by the owner, architect, and CM.

For more information see Holm, Schauffelberger, Griffin, & Cole and Dagostino & Peterson in the list of references.

PRODUCTIVITY

When looking up published productivity rates, such as those in R.S. Means or other reference guides, the rates are typically provided by an individual tradesperson, such as a carpenter or painter, or by a composite crew.

The crew work hours per day is the total number of hours the crew expends in an 8-hr day. For a single individual such as a single carpenter, the work hours per day would be 8 hr. However, for crews with multiple workers, the total number of workers is multiplied by 8 to determine the work hours.

$$\begin{aligned}\text{Crew Work Hours Expended per Day} \\ &= \text{Crew Members} \times 8 \text{ hr/day}\end{aligned}$$

Example: A handrail crew has a foreman and three laborers. What is their crew work hours per day?

$$\begin{aligned}\text{Crew Work Hours Expended per Day} \\ &= 4 \text{ crew members } 8 \text{ hr/day}\end{aligned}$$

$$\text{Crew Work Hours Expended per Day} = 32 \text{ hr/day}$$

The productivity rates are expressed in work hours per unit or units per work hours. The productivity rates expressed in work hours per unit are calculated by taking the number of crew work hours expended per day and dividing it by their production rate (daily output).

$$\text{Work Hours per Unit} = \frac{\text{Crew Work Hours Expended}}{\text{Daily Output}}$$

Example: What is the productivity of the handrail crew if their daily output is 190 lnft/day?

$$\text{Work Hours per Unit} = \frac{32 \text{ hr/day}}{190 \text{ lnft/day}}$$

$$\text{Work Hours per Unit} = 0.1682 \text{ Whr/lnft}$$

The .1682 Whr/lnft represents how long it takes one worker to install 1 linear foot of the handrail.

The productive rate units per work hour is calculated by taking the daily output and dividing by the crew work hours expended.

$$\text{Units per Work Hour} = \frac{\text{Daily Output}}{\text{Crew Work Hours Expended}}$$

Example: How many feet of the handrail can be completed in 1 work hour given a daily output of 190 lnft/day?

$$\text{Units per Work Hour} = \frac{190 \text{ lnft/day}}{32 \text{ Whr/day}}$$

$$\text{Units per Work Hour} = 5.94 \text{ lnft}$$

The 5.94 lnft represents the length of handrail that one worker will complete per hour. This is another method for expressing productivity.

The total work hours needed to complete a construction activity is calculated by multiplying the work hours per unit by the quantity.

$$\text{Total Work Hours} = (\text{Work Hours per Unit}) \times (\text{Planned Quantities})$$

Example: How many work hours would it take to complete 1,500 lnft of handrail?

$$\text{Total Work Hours} = \frac{0.1682 \text{ Whr}}{\text{lnft}} \times 1,500 \text{ lnft}$$

$$\text{Total Work Hours} = 252 \text{ Whr}$$

The total number of crew days required to complete a construction activity is calculated by taking the planned quantity to be installed and dividing by the daily output of the crew.

$$\text{Total Number of Crew Days} = \frac{\text{Planned Quantities}}{\text{Daily Output}}$$

Example: How long would it take to install 1,500 lnft of handrail?

$$\text{Total Number of Crew Days} = \frac{1,500 \text{ lnft}}{190 \text{ lnft/day}}$$

$$\text{Total Number of Crew Days} = 7.89 \text{ days}$$

Equipment Productivity

Site-work equipment is often the focus for productivity analysis because of the repetitive nature of the work and the high cost of the equipment. The following section provides instructions through examples on how to calculate the productivity of a piece of site-work equipment.

Example: How many dump trucks are needed to maximize the productivity of a 3 cubic yard (cy) backhoe that loads at a rate of 150 cy/hr. Assume the dump trucks will haul 12 cy/load to the disposal site, which is 3 miles away. The trucks' average speed is 12 mph loaded and 22 mph empty. It takes 3 minutes to unload the truck.

Step 1: Determine the truck cycle time in hours.

Category (calculation)	Time (hr)
Load (12-cy truck/150-cy backhoe)	.08
Haul away (3 mile/12 mph loaded)	.25
Unload (3 minutes/60 minutes/hr)	.05
Return (3 mile/22 mph empty)	.14
Total	.52

Step 2: Determine the number of round trips per hour for one truck.

$$\text{Trips per hour for 1 truck} = \frac{1 \text{ trip}}{0.52 \text{ hr}}$$

$$\text{Trips per hour for 1 truck} = 1.92 \text{ trips/hr}$$

Step 3: Determine the number of dump trucks needed.

$$150 \text{ cy/hr} = 1.92 \text{ trips/hr} \times 12 \text{ cy/hr} \times \text{trucks}$$

$$\text{trucks} = 6.5 \text{ or round to 7 trucks}$$

ESTIMATES STUDY QUESTIONS

- Which type of estimate is most appropriate when the contract documents are 100% complete?
 - detailed estimate
 - cost indices estimate
 - parametric estimate
 - conceptual estimate
- Using the square foot costs from Figure 5-1, how much would a 6,500 sq ft post office cost?
 - \$484,575
 - \$617,630
 - \$660,055
 - \$689,585
- What would happen to the total cost of the building described in Figure 5-2 if the brick veneer made up 60% and the windows made up 40% of the building enclosure instead of 80% and 20%?
 - Cost would decrease \$780,900.
 - Cost would decrease \$334,650.
 - Cost would increase \$334,650.
 - Cost would increase \$780,900.
- Using Figure 5-3, how much would a bank that costs \$500,000 in Clemson, South Carolina, in 2012 cost if built in 2015 in Provo, Utah?
 - \$367,155
 - \$628,947
 - \$680,912
 - \$889,685
- How many crew days would it take to install 1,500 sq yd of carpet if the two-person crew can install 500 sq yd/day?
 - 1.25 days
 - 2.25 days
 - 3.00 days
 - 4.35 days

QUANTITY TAKEOFF

Quantity takeoffs are the process of determining the amount of material that will be used in a project. It is the most tedious and time-consuming part of the estimating process; however, it is essential because material quantities are used to determine labor and equipment costs as well as activity durations. The units of measure for common building materials are provided in Figure 5-4.

Figure 5-4 Units of Measure for Common Materials

Material	Unit of Measure
Concrete	Cubic yard
Formwork	Square feet of contact area
Rebar	Ton or linear feet
Brick/Block	Square feet
Structural Steel	Ton, linear feet, or each
Framing (wood)	Board feet
Framing (metal)	Linear feet
Roofing	Square (100 sq ft)
Doors/Windows	Each
Storefront/Curtain Wall	Square feet
Carpet	Square yard
Tile/VCT/Linoleum	Square feet
ACT	Square feet
Drywall	Square feet
Specialties	Each
Ductwork	Pound
Piping/Conduit	Linear feet

BASIC FORMULAS

Quantity takeoffs typically take off the length, area, perimeter, or volume of the building components. The QTO process is a practical extension of basic geometry. The formulas in Figure 5-5 are essential when completing QTOs.

EXCAVATION

A common QTO is earthwork excavation. This takeoff is slightly more complicated than others because the volume of earthwork changes depending on how compacted it is. Soil in its natural state is referred to as *bank*. The unit of measure for soil is cubic yards, so *bank cubic yards* (Bcy) is used. Soil that has been compacted is referred to as *compacted soil* (Ccy), and soil that was disturbed from bank, such as when it is excavated, is referred to as *loose* (Lcy). A *swell* or *shrinkage* factor is provided to determine how much the soil is compacted or how loose it is. Follow the steps below to determine the volume of soil removed and dumped.

Step 1: Determine the bank volume (Bcy) of the excavation. Typically, the trapezoid formula will be

used because the sides of the excavation will be sloped.

Step 2: Determine the loose volume (Lcy) by multiplying the bank volume by the swell factor. The loose volume would be used when calculating how many dump trucks are needed because they carry the disturbed loose soil (not bank or compacted soil).

Figure 5-5 Basic Formulas

Perimeter	
Square	$4 \times \text{sides}$
Rectangle	$2 \times (\text{length} + \text{width})$
Circle	$2 \times \pi \times \text{radius}$
Area	
Square	sides^2
Rectangle	$\text{length} \times \text{width}$
Triangle	$\text{base} \times \text{height} / 2$
Trapezoid	$\text{height} \times (\text{base}_1 + \text{base}_2) / 2$
Circle	$\pi \times \text{radius}^2$
Ellipse	$\pi \times \text{radius}_1 \times \text{radius}_2$
Cylinder (sides)	$2 \times \pi \times \text{radius} \times \text{height}$
Volume	
Cube	side^3
Cylinder	$\pi \times \text{radius}^2 \times \text{height}$
Trapezoid	$\text{height} \times (\text{width}_1 + \text{width}_2) / 2 \times (\text{base}_1 + \text{base}_2) / 2$
Other	
Sides of a right triangle	
$\text{side } a^2 + \text{side } b^2 = \text{hypotenuse } c^2$	

CHAPTER 5 ► BIDDING AND ESTIMATING

Example: What is the volume of loose soil if the bank volume is 2,000 Bcy and the swell factor is 30%?

$$2,000 \text{ Bcy} \times 1.30 = 2,600 \text{ Lcy}$$

Notice that a 1 was added to the swell factor so that it was volume in addition to the bank.

Step 3: Determine the compacted soil (Ccy) by dividing the bank volume by the shrinkage factor.

Example: How much bank soil is needed if you need to raise the building pad with 3,000 Ccy? Assume the compaction factor is 90%.

$$3,000 \text{ Ccy} / .90 = 3,333 \text{ Bcy}$$

Example: How much soil must be trucked away from the excavation shown in Figure 5-6, assuming the same soil can be used to backfill outside of the foundation walls. Assume a swell factor of 25% and a compaction factor of 85%.

- 1) Solve for the volume of the excavation by taking the width of the excavation at mid-height and multiplying it by the length of the excavation at mid-height and then multiplying it by the depth.

$$\text{Excavation} = \frac{(40 \text{ ft} + 50 \text{ ft})}{2} \times \frac{(40 \text{ ft} + 50 \text{ ft})}{2} \times 10 \text{ ft}$$

$$20,250 \text{ cft or } 750 \text{ cy}$$

- 2) Solve for the volume needed to backfill outside of the foundation walls by taking the total excavation and subtracting the foundation space not being backfilled.

$$\text{Backfill} = 20,250 \text{ cft} - (29.5 \text{ ft} \times 29.5 \text{ ft} \times 10 \text{ ft})$$

(Length was determined by centerline of 28 ft + width of wall)

$$11,547 \text{ Bcft or } 428 \text{ Bcy}$$

- 3) Determine how much compacted soil is needed by dividing the bank volume by the compaction factor.

$$428 \text{ cy} / 0.85 = 504 \text{ Bcy}$$

- 4) Determine how much soil must be hauled away by subtracting the bank cubic yards that were compacted from the total volume of the excavation and multiplying it by the swell factor.

$$(750 \text{ Bcy} - 504 \text{ Bcy}) \times 1.25 = 308 \text{ Lcy}$$

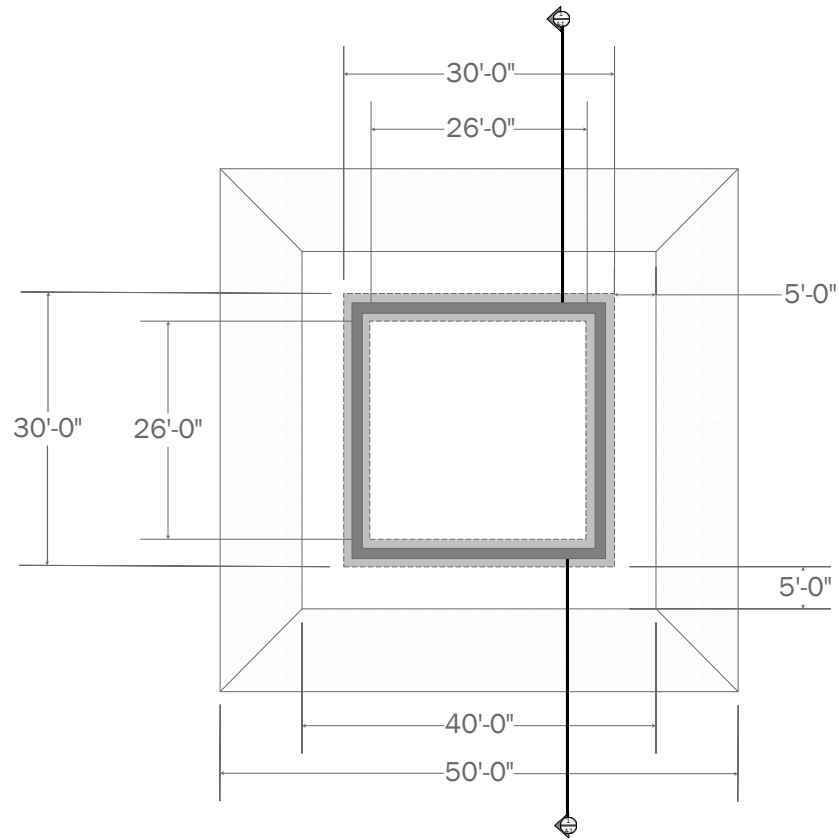
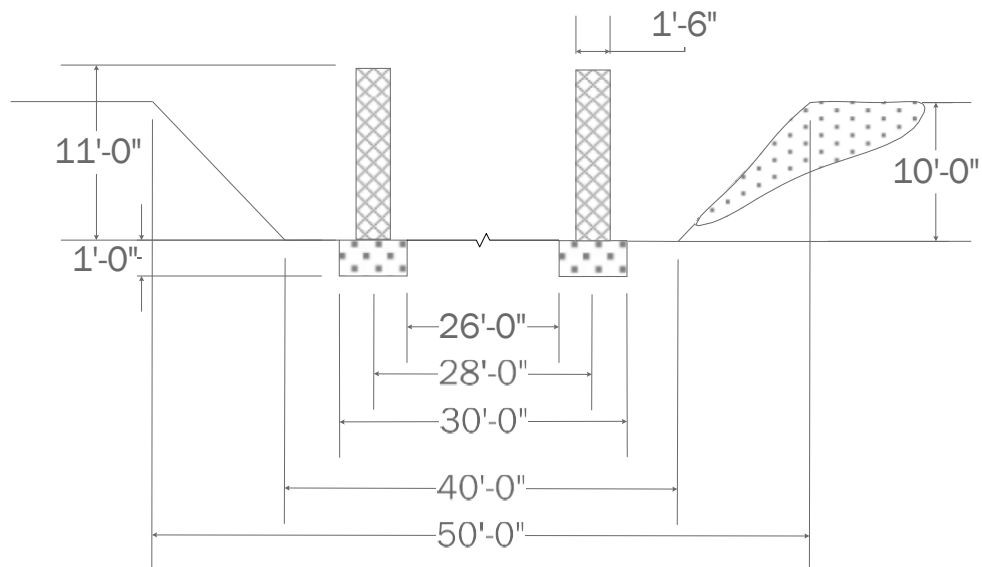
For more information see Dagostino & Peterson in the list of references.

FORMWORKS

Unless the concrete is earth formed, some type of formwork will be needed to place the concrete. There are many types of formwork available, but most are taken off by square foot of contact area. Contact is in reference to being in contact with the concrete. It is important to note that formwork is often on multiple sides of the concrete. Tie beams for example will require formwork on both sides of the wall but not the bottom. A suspended beam, however, will require formwork on all sides, the ends, and the bottom. Understanding the concrete placement is critical in taking off formwork.

Example: How many square feet of formwork are required for the foundation walls shown in Figure 5-6?

- 1) Determine the length of the foundation wall. Notice that the length of the inside formwork will be less than the outside formwork. There are several ways of determining the formwork length. One option is to treat each side separately. Each of the four inside walls is 26 ft 6 in., so you could just add them. You could then add that sum to the four outside walls, which are each 29 ft 6 in., for a total of 224 ft. Another way is to do the takeoff from the center of the formwork. In this example, the centerline of one wall of formwork is 28 ft, which is then multiplied by 4 for each wall and then 2 for both sides of the wall. With either way, the value is 224 ft of formwork.

Figure 5-6 Example of a Foundation Plan**Foundation Plan****Section***Illustration by author*

CHAPTER 5 ► BIDDING AND ESTIMATING

$$\begin{aligned} \text{Length} &= (26.5 \text{ ft} + 26.5 \text{ ft} + 26.5 \text{ ft} + 26.5 \text{ ft}) + (29.5 \text{ ft} + 29.5 \text{ ft} + 29.5 \text{ ft} + 29.5 \text{ ft}) = \\ &224 \text{ ft} \end{aligned}$$

or

$$\text{Length} = ((29.5 \text{ ft} + 26.5 \text{ ft})/2) \times 4 \times 2 = 224 \text{ ft}$$

- 2) Determine the square feet of contact area by multiplying the length of the formwork by the height.

$$224 \text{ ft} \times 11 \text{ ft} = 2,464 \text{ sq ft of contact area}$$

For more information see Dagostino & Peterson in the list of references.

CONCRETE

Concrete is taken off very similarly to soil because the process is basically a geometry exercise to determine the volume of the items taken off in cubic yards. Concrete takeoffs are a degree simpler because concrete doesn't compact or swell so compaction and shrinkage factors are not applicable. There are, however, many types of concrete, and the takeoffs for each type should be kept separate. For example, strip footings, pad footings, tie beams, sidewalks, stamped concrete, slab-on-grade, and elevated decks are all made of concrete and taken off by the cubic yard, but each has a very different installation unit cost. In addition, concrete comes in a wide range of strengths with different mix designs specific to particular components of the building. Each of these should be taken off separately and noted individually on the QTO summary sheet.

Example: How many cubic yards of concrete are needed for the foundation walls above the footings shown in Figure 5-6?

- 1) Determine the volume of concrete in cubic feet by first determining the length of the continuous foundation wall. When taking off a continuous concrete member the takeoff should always be taken from the center of the member. Taking it from the inside face will underestimate the concrete needed, and the outside face will overestimate it. Because the foundation wall in Figure 5-6 is a simple square with equal sides, we need to determine the center length of only one side and then multiply it by 4. In this example, the length of one of the walls is 28 ft.

$$\begin{aligned} \text{Length} &= 28 \text{ ft} \times 4 \\ &112 \text{ ft} \end{aligned}$$

- 2) Determine the volume of concrete in cubic yards by multiplying the length by height by width and then by dividing by 27 to convert from cubic feet to cubic yards.

$$\begin{aligned} \text{Concrete needed} &= 112 \text{ ft} \times 11 \text{ ft} \times \\ &1.5 \text{ ft} \times \frac{(1 \text{ cft})}{27 \text{ cy}} \end{aligned}$$

$$68.4 \text{ cy}$$

For more information see Dagostino & Peterson in the list of references.

REBAR

In almost every case, structural concrete contains reinforcing bars, or *rebar*. Rebar provides tensile and sheer strength, which concrete does not provide. Rebar is taken off by the weight (100-pounds or ton) or length (feet or 100-feet). Rebar can be ordered in specific sizes cut to the dimension of individual footings, walls, or slabs or can be cut from long lengths on-site. The length of a single rod of rebar is typically no longer than 20 ft because transportation becomes difficult for longer pieces. Because concrete members are often longer than 20 ft, rebar must be spliced or lapped to ensure continuity. The required length of the lap is an engineered function and typically provided by the design team in bar diameters (BDs). A bar diameter is the diameter of a piece of rebar. Rebar is sized in eighths of an inch increments. A #1 bar is 1/8 in. in diameter and a #5 bar is 5/8 in. Rebar in 24 BD and 30 BD is very commonly required. Another important concept about rebar is that it requires a certain amount of concrete coverage to protect it from the elements. Typically, concrete coverage is 2 in. to 3 in., which protects the concrete from moisture and salts that can cause the rebar to rust and the concrete to spall.

Example: How much rebar is needed in the foundation wall assuming that the available rebar comes in 20-ft lengths? Use the information found in Figures 5-6 and 5-7. Assume #4 rebar weighs 0.668 lb/lnft and #5 rebar 1.043 lb/lnft.

Figure 5-7 Concrete Schedule

Footing Type	Width	Depth	Length	Rebar Lap	Reinforcement
Foundation Wall	1'-6	11'0"	cont'	48 BDs	#5 bar @ 12" horizontal and #4 bar @ 16" vertical, 3" coverage
Continuous Footing	4'0"	1'0"	cont'	30 BDs	4 #5 bars continuous, 3" coverage

- 1) First, determine the effective length of one length of rebar. The effective length is the bar length minus the lap requirement. In this example the lap requirement is 48 BD for #5 rebar.

$$\text{Lap} = 48 \times \frac{5 \text{ ft}}{8} \times \frac{1 \text{ ft}}{12 \text{ in.}} = 2.5 \text{ ft}$$

$$\text{Effective Length} = 20 \text{ ft} - 2.5 \text{ ft} = 17.5 \text{ ft}$$

- 2) Determine the length of horizontal reinforcing required. This is done by determining the number of horizontal runs and multiplying it by the length of the wall.

$$\text{Horizontal Runs} = \frac{11 \text{ ft height}}{1 \text{ ft spacing}} + 1 = 12 \times 112 \text{ ft} = 1,344 \text{ lft}$$

- 3) Determine how many bars are needed. This is done by taking the length of the horizontal reinforcing required and dividing it by the effective length.

$$\text{Bars required} = \frac{1,344 \text{ ft}}{17.5 \text{ ft}} = 77 \text{ bars}$$

- 4) Determine the length of horizontal bars to order by multiplying the number of bars required by their bar length.

$$\text{Length to order} = 77 \text{ bars} \times 17.5 \text{ ft} = 1,344 \text{ lft}$$

- 5) Determine the weight of the horizontal bars to order by multiplying the length of the rebar by the weight per linear foot.

$$\text{Weight to order} = 1,344 \text{ ft} \times 1.043 \text{ lb/lft} = 1,401 \text{ lb}$$

- 6) Determine the length of vertical reinforcing required. This is done by determining the length of one bar and then multiplying it by the number of bars required. Because the height of the wall is less than 20 ft no splices are required.

$$\text{Length to order} = \left(\frac{11 \text{ ft} - 0.25 \text{ ft coverage at top}}{12 \text{ ft length}} \right) \times \left(\frac{12 \text{ ft}}{1.3 \text{ ft spacing}} + 1 \right)$$

$$\text{Length to order} = (10.75 \text{ ft}) \times (\text{round up to } 88) = 946 \text{ lft}$$

- 7) Determine the weight of the vertical bars to order by multiplying the length of the rebar by the weight per linear foot.

$$\text{Weight to order} = 946 \text{ ft} \times 0.668 \text{ lb/lft} = 632 \text{ lb}$$

- 8) Determine the total weight of rebar to order by adding the horizontal and vertical rebar together.

$$\text{Total weight to order} = 1,401 \text{ lb} + 632 \text{ lb} = 2,033 \text{ lb}$$

For more information see Dagostino & Peterson in the list of references.

ROUGH CARPENTRY

Rough carpentry includes wooden framing, trusses, joists, and flooring. There are a great many types of framing members that range in size, length, species of wood, and connection types. Often, steel

straps, connections, and ties are used in addition to nails to connect structural wood members. Carpentry can be taken off by the linear feet of individual members or often by the board foot. A board foot is a volume of wood that is equal to a piece of lumber 12 in. wide × 1 in. deep × 1 ft long.

$$\text{Board Feet} = \frac{\text{Nominal Width (in.)} \times \text{Nominal Depth (in.)}}{12 \text{ in.}} \times \text{length (ft)}$$

Example: Assume you have a wood-framed wall that is 20 ft long with 9 ft studs spaced 16 in. on center. Determine how many board feet of lumber should be ordered assuming the studs are 2 in. × 4 in. nominally.

- 1) First determine the number of overall length of stud material that must be ordered. This is done by determining the number of studs needed multiplied by the length of the stud. In this example the number of studs needed is a whole number but when there is a fraction you should round up to the next whole number.

$$\text{Length of Studs} = \frac{20 \text{ ft length}}{1.333 \text{ ft spacing}} + 1 \times 9$$

$$\text{Length of Studs} = (16) \times 9 \text{ ft} = 144 \text{ ft}$$

- 2) Determine the number of board feet required. This is done by multiplying the length by the width and depth of the member. It is important to use nominal, not actual, dimension in the calculation and be consistent with the units.

$$\text{Board Feet} = \frac{2 \text{ in.} \times 4 \text{ in.}}{12 \text{ in.}} \times 144 \text{ ft} = 96$$

For more information see Dagostino & Peterson in the list of references.

QUANTITY TAKEOFF STUDY QUESTIONS

1. Carpet is typically taken off by which unit of measure?
 - A. square foot
 - B. square yard
 - C. square
 - D. cubic yard
2. How many 7-cy dump truck loads are needed to remove 350 Bcy of soil assuming the swell factor is 15%?
 - A. 53
 - B. 58
 - C. 59
 - D. 412
3. How many bank cubic yards of soil would be needed to fill an excavation requiring 45 Ccy of fill assuming an 88% compaction factor?
 - A. 39.6
 - B. 40.5
 - C. 50.4
 - D. 51.1
4. Assuming the footings shown in Figure 5-6 were formed along the sides (not the bottom). How much formwork would be required?
 - A. 9 sq ft
 - B. 112 sq ft
 - C. 224 sq ft
 - D. 448 sq ft
5. How much concrete is needed for the footing shown in Figure 5-6?
 - A. 0.3 cy
 - B. 4.2 cy
 - C. 8.3 cy
 - D. 16.6 cy
6. How much rebar should be ordered for the footing shown in Figures 5-6 and 5-7? Assume rebar comes in 20-ft lengths.
 - A. 125 lft
 - B. 224 lft
 - C. 500 lft
 - D. 548 lft

PROCUREMENT AND BIDDING PROCESS ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | B. | 2. | B. | 3. | A. |
| 4. | D. | 5. | B. | 6. | C. |

ESTIMATES ANSWERS:

1. A.
2. B. $6,500 \times 95.02 = \$617,630$
3. C. $(25,000 \times 0.6 \times 4.46) + (25,000 \times 0.4 \times 71.4) - (89,250 + 357,000) = \$334,650$
4. C. $(500,000 \times 47.8)/35.1 = \$680,912$
5. C. $1,500/500 = 3.00$ days

QUANTITY TAKEOFF ANSWERS:

1. B.
2. B. $350 \times 1.15/7 = 57.5$
3. D. $45/.88 = 51.1$ Ccy
4. C. $(30 \times 4) + (4 \times 26) = 224$ sq ft
5. D. $(28 \times 4) \times 1 \times 4/27 = 16.6$ cy
6. C. Effective length = $20 - ((5/8) \times 30)/12 = 18.44$ ft
 Total length of runs = 28 ft centerline $\times$ 4 sides $\times$ 4 bars = 448 ft
 $448 \text{ ft}/18.44 = 25$ sticks of rebar
 $25 \text{ sticks} \times 20 \text{ ft} = 500$ lft
7. C. $2 \times 6 \times 200/12 = 200$
8. C. $(15 \text{ ft} + 2.5 \text{ ft}) \times 1.08 = 18.9$
9. D. Main = $73 \text{ ft}/1.3 = 55 + 1 = 56$
 $56 \times 2 \text{ sides} = 112$
 Extension = $20 \text{ ft}/1.3 = 16 + 1 = 17$
 $17 \times 2 \text{ sides} = 34$
 $112 + 34 = 146$

7. How many board feet is 200 lft of 2 in. $\times$ 6 in wood studs.
 A. 12 bft
 B. 138 bft
 C. 200 bft
 D. 2,400 bft
8. A structure is an intersecting hip roof with the main hip roof outside dimensions being 73 ft long and the width being 30 ft wide. The intersection portion extends 20 ft beyond the 30-ft side, and the intersecting portion is 20 ft wide. The overhang is 2 ft 6 in. and the slope is 5:12. The rafters are 16 in. on center. Based on the information provided, what is the total length of the common rafters in linear feet?
 A. 13.00
 B. 17.50
 C. 18.90
 D. 35.00
9. Using the information provided in the previous question, what is the total number of common rafters required for the roof?
 A. 55
 B. 72
 C. 112
 D. 146

CAC EXAM: STUDY GUIDE



CHAPTER 6

BUDGETING, COSTS, AND COST CONTROL

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BUDGETING

FROM ESTIMATE TO BUDGET

During the estimating phase the intention is to develop the final cost of the project. The estimate provides the maximum amount of cost that a project can incur before it starts to erode the contractor's profit. In the development of the estimate, lump sum subcontractor costs, square foot estimates, and allowances are used. The estimate developed during preconstruction is typically recast into a budget by the project management team. Lump sum cost items, square foot estimates, and allowances are broken down into labor, material, equipment, and subcontractor costs and assigned a cost code. Each cost code is a small, manageable portion of the overall budget.

For more information see Pierce and Halpin & Senior in the list of references.

Cost Codes

Most large construction projects will have hundreds if not thousands of cost codes. Companies may have a unique structure for their cost codes but typically align closely with the CSI divisions. A sample cost code structure can be found below:

```

031.000 Concrete formwork
  031.1200 Slabs on grade
    031.1210 Sidewalks
    031.1220 Stairs on grade
    031.1230 Exterior curb/gutter
    031.1240 Concrete paving
    031.1250 Special finishes
  
```

Most company cost code structures will also break down the labor, material, equipment, and subcontractor costs. Labor is especially important to manage because it is often a significant cost and can overrun a budget quickly. An example of this breakdown is shown below:

```

031.1210 Sidewalks
  031.1210.1000 Sidewalk Labor
  031.1210.2000 Sidewalk Material
  031.1210.3000 Sidewalk Equipment
  031.1210.4000 Sidewalk Subcontractor
  
```

In this example, 1000, 2000, 3000, and 4000 represent labor, material, equipment, and subcontractor cost codes, respectively. Labor,

material, equipment, and subcontractor costs from the estimate can be imported directly into the budget with the appropriate cost codes. This process is commonly referred to as “the dump” because the estimate is dumped into the project's budget. However, many costs included in the estimates are not broken down. For example, the estimator may have priced self-performing the sidewalk with a simple \$5.00/square foot value multiplied by the takeoff. In this example, the project manager will need to break that down into labor, material, and equipment and allocate money into all three cost codes to effectively manage the work.

For more information see Pierce in the list of references.

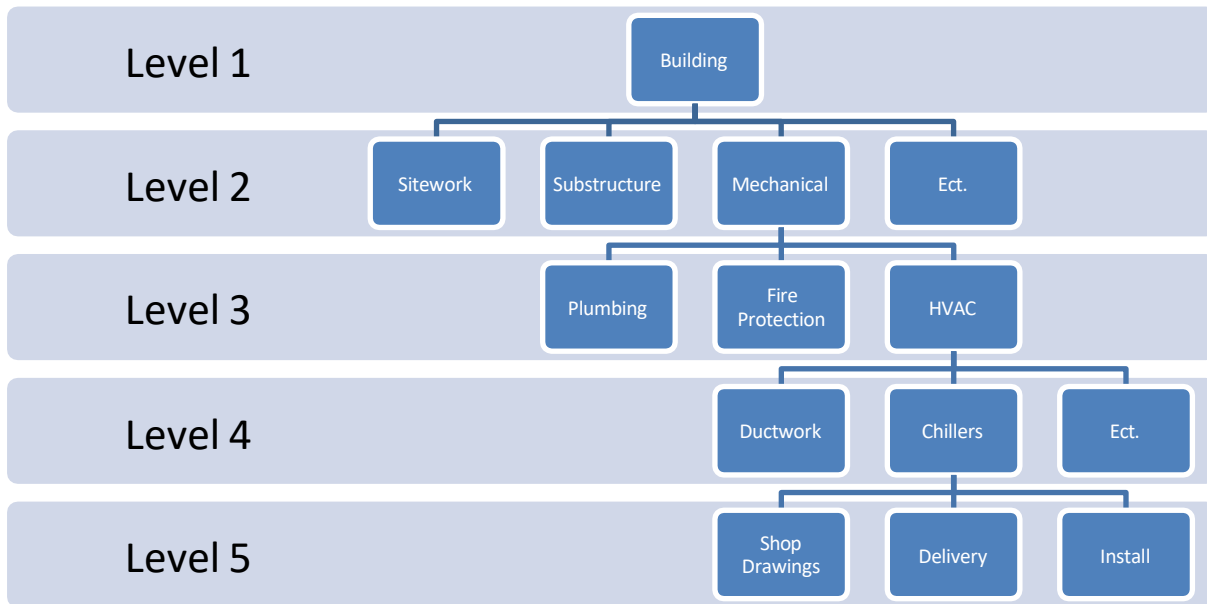
WORK BREAKDOWN STRUCTURE (WBS)

A work breakdown structure (WBS) is a hierarchy of tasks needed to complete the project. A WBS doesn't sequence the work but divides the project into manageable work packages. Work packages are the fundamental elements needed to complete the work under contract. Four guiding principles should be used when developing the WBS:

- There shouldn't be any overlap of scope between work packages.
- Each work package should have a definitive start and end date.
- There shouldn't be any overlap of cost between work packages.
- Final breakdown work packages should be at the level where progress can be measured precisely.

Figure 6-1 provides an example of a portion of a WBS. Notice how the activities get more and more specific. It's also important to notice that the activities are not in order of completion. The WBS is not a schedule. In the example shown in Figure 6-1, all of the work packages on level 5 (shop drawings, delivery, and install) would be included in the chiller work package shown in level 4. When the WBS is created, an assigned budgeted cost for work scheduled is assigned to each work package.

For additional information see Halpin & Senior in the list of references.

Figure 6-1 Work Breakdown Structure

BUDGETING STUDY QUESTIONS

- Which of the following statements is true about a company's cost code structure?
 - is most typically organized alphabetically by item description
 - is most typically organized by sequence of installation
 - often organized by CSI division with adaptations by individual companies
 - completely unique to each company
- Which of the following statements is true about the work breakdown structure?
 - divides the work into manageable packages
 - is created by the project manager to organize the activities of the operational team
 - is created at the end of the project to finalize and categorize costs
 - is organized by sequence of installation

- A work breakdown structure typically includes which of the following for each work package?
 - budgeted cost of work scheduled
 - actual cost of work performed
 - budgeted cost of work performed
 - earned value

COST CONTROL

THE LABOR COST REPORT

The labor cost report is used to compare the actual labor costs to the budgeted labor costs and project the final cost for each activity. The budgeted labor costs are obtained from the estimate created during preconstruction. The actual labor costs are obtained from labor reports and the detailed project cost ledger. Although in this example labor is reported, this type of report could also be used to track equipment and material costs as well.

A sample Labor Cost Report is provided in Figure 6-2. The following list explains the columns shown in the sample report.

Cost Code

Cost codes are small manageable portions of the work typically categorized by CSI division. In this example, cost code 035300.1000 is used for concrete wall forms.

Description

A simple, short description of the cost code.

Quantities

- *Budgeted Quantities:* This column indicates the estimated number of units needed to complete the activity. In this example, 1,120 sq ft of wall forms are needed.
- *Week:* This is the number of units completed during the current week.
- *To Date:* This is the total units in place to date. It is calculated by adding the current week amount to the previous week's to date quantities.

$$60 \text{ sq ft} + 64 \text{ sq ft (previous week not shown)} = 124 \text{ sq ft}$$

Unit

The unit is the unit of measure for the cost code. In this example, it is square feet of contact area of formwork.

Expended Costs

- *Week:* This is the costs incurred from payroll and fringe and all other costs associated with

labor for this cost code during the current week. This information is obtained from labor distribution reports, most often from the accounting department or project management software. In this example, the accounting department has reported that \$74 has been expended this week.

- *To Date:* This is all labor costs incurred for this cost code since the beginning of the project. It is calculated by adding the current week's expended cost to the previous week's to date expended costs. Most often it is included with accounting reports. In this example, the accounting department has reported that \$179 has been expended to date.

Budget Total

This is the total budgeted costs for the cost code and is obtained from the estimate ledger. In this example, during preconstruction it was estimated that the wall forms would cost \$3,595.

Unit Cost

- *Budget:* The budgeted unit cost is how much one unit of work was budgeted to cost. It is calculated by dividing the budget total by the budget quantities.

$$\$3,595 / 1,120 \text{ sq ft} = \$3.21 / \text{sq ft}$$

Figure 6-2 Example of a Labor Cost Report

LABOR COST REPORT EXAMPLE

PROJECT NAME: Big Office Building
PROJECT NUMBER: 2015-012

CODE	DESCRIPTION	QUANTITIES			UNIT	EXPENDED COST		BUDGET TOTAL	UNIT COST			PROJECTED	
		BUDGET	WEEK	TO DATE		WEEK	TO DATE		BUDGET	WEEK	TO DATE	COMPLETION	GAIN/LOSS
035300.1000	Wall Forms	1,120	60	124	Sqft	\$74	\$179	\$3,595	\$3.21/sqft	\$1.23/sqft	\$1.44/sqft	\$1,613	\$1,982

- **Week:** The weekly unit cost is how much one unit of work that was completed during the current week cost. It is calculated by dividing the weekly expended cost by the weekly quantities placed.

$$\$74/60 \text{ sq ft} = \$1.23/\text{sq ft}$$

- **To Date:** The to date unit cost is how much all units of work completed so far cost per unit. It is calculated by dividing the to date expended cost by the to date quantities placed.

$$\$179/124 \text{ sq ft} = \$1.44/\text{sq ft}$$

Projected

- **Completion:** The projected at completion labor cost is a forecast of what the total labor cost is expected to be when the estimated quantities are 100% in place. Using the straight line projection method, the projected labor cost at completion is calculated by multiplying the to date unit costs by the budget quantities.

$$1,120 \text{ sq ft} \times \$1.44/\text{sq ft} = \$1,613$$

- **Gain/Loss:** This column shows whether the contractor is expected to complete the activity over or under budget. The gain or loss is calculated by subtracting the projected completion from budget total. In this example, the budget total of \$3,595 is subtracted from the projected completion cost of \$1,613 for a gain (under budget) of \$1,982.

$$\$3,595 - \$1,613 = \$1,982$$

THE PROJECT COST SUMMARY REPORT

The Project Cost Summary Report can be the most valuable report because it sums up all actual and projected costs for the project by cost code and compares them to the budget. The projected cost compared to the budgeted cost shows the latest prediction of a profit or loss for the overall project. This report highlights to management specific work items that must be scrutinized closely to minimize losses. If used properly, the project cost summary can be used to implement corrective actions before the costs spiral out of control. Commonly, this report is reviewed by the project manager and his or her supervisor at least once a month.

A sample Project Cost Summary Report is provided in Figure 6-3. The following list explains the columns shown in the sample report.

Original Budget

The original budget column reflects the costs developed during preconstruction for the total cost of the project. Each cost code divides the original budget into manageable cost items.

Scope Changes

The scope change column reflects changes in the budget through change orders.

Figure 6-3 Example of a Project Cost Summary

PROJECT COST SUMMARY EXAMPLE

PROJECT NAME: Big Office Building
PROJECT NUMBER: 2015-012

CODE	Description	ORIGINAL BUDGET	SCOPE CHANGES	REVISED BUDGET	EXPENDED		COMMITTED COST	EXPENDED TOTAL COST	CURRENT PROJECTED COST	PROJECTED GAIN/LOSS
					PERIOD	TO DATE				
035300.1000	Labor	\$2,310	\$1,285	\$3,595	\$179	\$179		\$179	\$1,613	\$1,982
035300.2000	Material	\$400	\$504	\$904	\$800	\$800	\$341	\$1,141	\$1,141	(\$237)
035300.3000	Equipment	-0-	\$300	\$300	\$421	\$421		\$421	\$421	(\$121)
035300.4000	Subcontracts	-0-	\$207	\$207	\$0	\$100	\$120	\$220	\$220	(\$13)
Sub Total Costs		\$2,710	\$2,296	\$5,006	\$1,400	\$1,500	\$461	\$1,961	\$3,395	\$1,611

Revised Budget

The revised budget is the current budget inclusive of all change orders. It is calculated by adding the original budget to the scope changes column.

$$\$2,710 + \$2,296 = \$5,006$$

Expended

- *Period:* This column reflects the cost for the specific cost code during the current period, which is most often one month.
- *To Date:* This is all costs for the specific cost code since the project began.

Committed Cost

The committed cost includes cost items that the contractor has not paid yet but has either a contract or purchase order committing them to pay at some point in the future. Accounting software and reports vary, but in theory, as subcontracts and purchase orders are paid, the committed cost decreases and the expended cost increases.

Expended Total Costs

The expended total costs are the to date expended costs and the committed costs. This column basically tells the project manager what he or she has either spent or committed to spend through contract to date.

$$\$1,500 + \$461 = \$1,961$$

Current Projected Cost

The current projected cost is perhaps the most difficult to calculate but most important part of the report. This column indicates what the project manager expects to spend in each cost code at the end of the project. Three common ways for calculating the projected costs follow:

- *Using the straight line projection method where the to date unit cost is multiplied by the budgeted quantities:* This is commonly used with self-performed work where labor production rates and quantities are available.
- *Using the expended total cost column as the current projected costs:* This is commonly used with subcontract cost codes where they are contracted for all the scope and risk associated with that cost code.
- *Using the revised budget column as the current projected cost:* Most often used early in the project when little productivity or progress has been made to indicate a change from what has been budgeted.

Projected Gain/Loss

This is how much over or under budget each cost code is expected to be. It is the difference between the revised budget and the current projected costs.

$$\$5,006 - \$3,395 = \$1,611$$

See Figures 6-4 and 6-5 for additional clarification and calculation description.

Figure 6-4 Example of a Labor Cost Report with Illustration

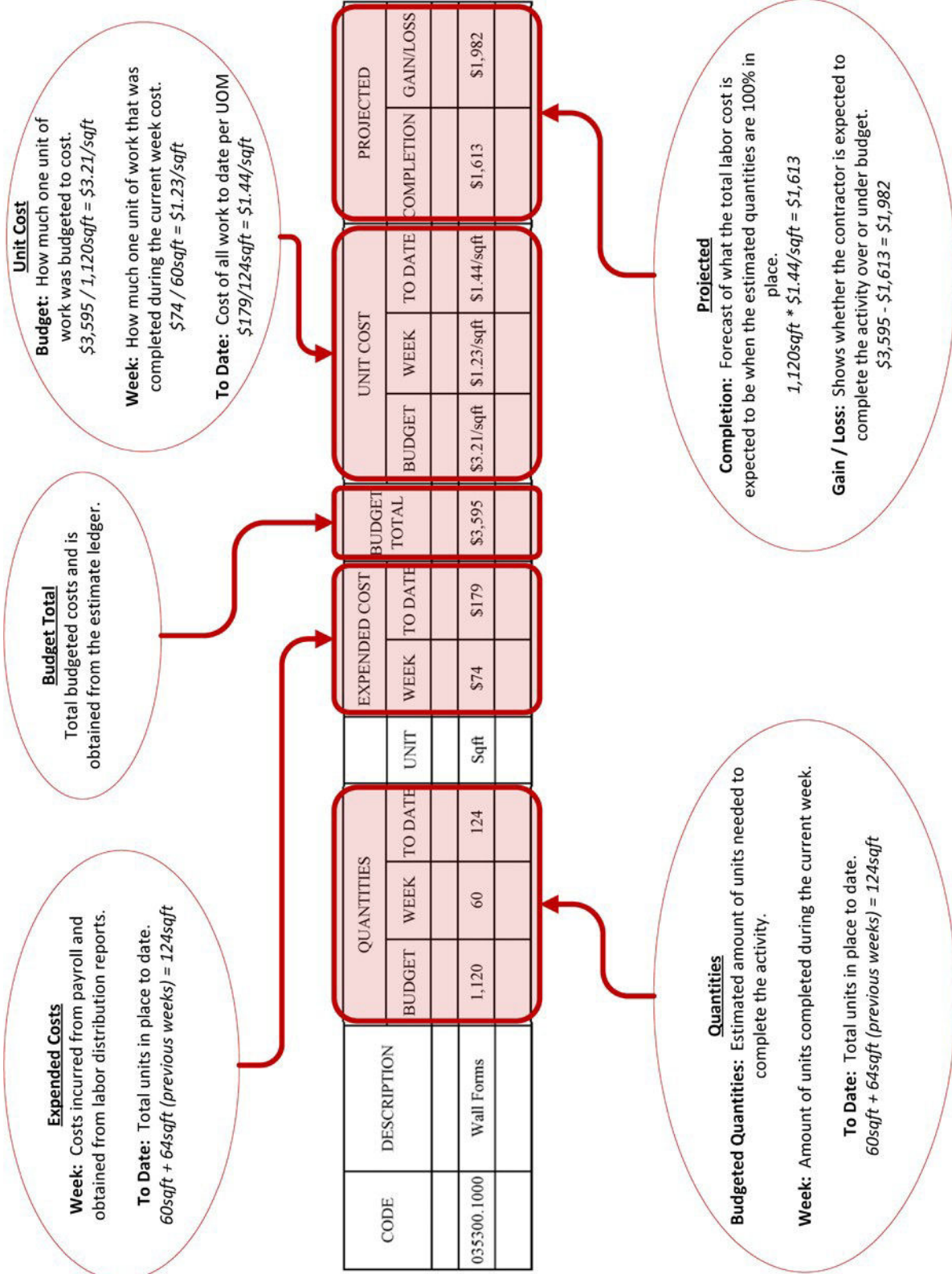
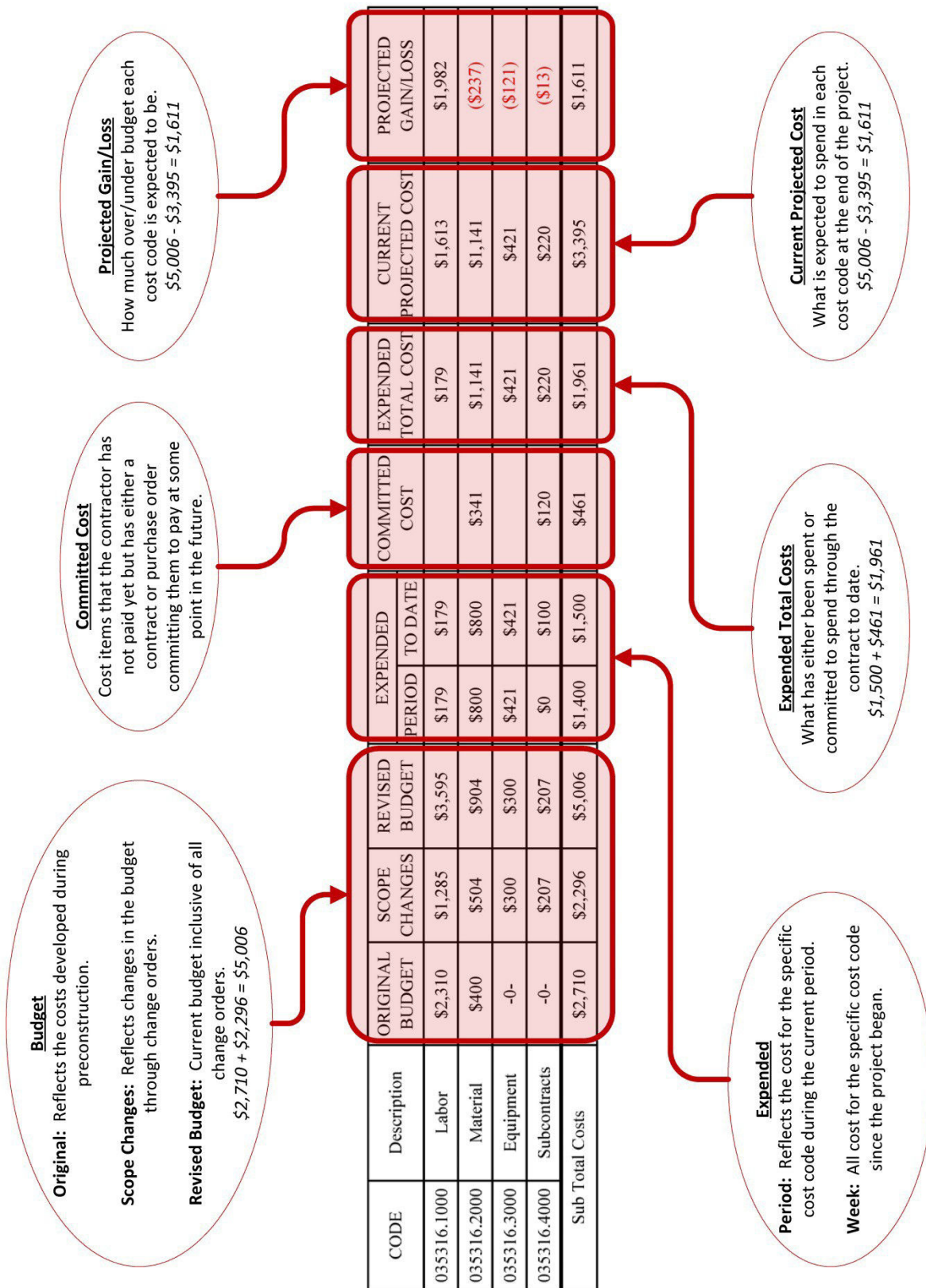


Figure 6-5 Example of a Project Cost Summary Report with Illustration



COST CONTROL STUDY QUESTIONS

- Using Figure 6-2, what are the projected completion costs if the to date quantities changed from 124 to 150 and the to date expended costs changed from \$179 to \$225?
 - \$1,680
 - \$2,199
 - \$2,224
 - \$3,222
- Using Figure 6-3, what would be the expected projected gain/loss for cost code 035300.4000-Subcontracts assuming that a \$100 change order was approved by the owner and that 100% of the change order was subcontractor costs?
 - (\$113) Loss
 - (\$13) Loss
 - \$0
 - \$113 Gain

FINALIZING COSTS

PROGRESS PAYMENTS

Contractors and construction managers are reimbursed for their services as the work is competed on a pre-agreed-upon payment schedule. For commercial construction, it is most common for the contractors to be paid monthly, and in residential construction a biweekly payment schedule is common. At the beginning of the project a schedule of values (SOV) is developed by the contractor and then approved by the owner and/or designer. The SOV includes the major components of the building and an assigned value for each item. The contractor often uses the WBS to develop the schedule of values.

At the end of each pay period, the contractor submits a request for payment based on the SOV and the estimated amount of work completed. Typically, the architect and owner are required to review and approve the application for payment prior to the payment being released. If they agree with the quantity of work being billed for, they approve the pay application, and it is forwarded to the owner's accounting department.

However, oftentimes, there are disputes on the amount of work claimed to be completed. It is

often a good practice to review a pencil copy of the application in person and agree on the work completed before the application is formally submitted. It is also a good practice to have the SOV broken down in sufficient detail so that all parties can feel comfortable that they are authorizing payment only for work that has been completed. An example of a potential conflict is when contractors request payment for shop drawings, mobilization costs, or off-site stored materials. Designers and owners may be reluctant to pay for these items because they are out of sight. However, if discussed early, arrangements can be made so that the owner is comfortable paying for these items if certain conditions are met, such as documentation, bills of sale, or insured storage. The efforts taken to fully discuss and appropriately break down the SOV will be rewarded throughout the project.

For more information see Halpin & Senior in the list of references.

Cost Loaded Schedule

Cost loaded schedules are schedules that have the cost of the work broken down and linked to the activities on the project schedule. The costs associated with the scheduled activities typically include the cost of the work plus the contractor's general conditions, overhead, and profit. Cost loaded schedules are often used for progress payments. Cost loaded schedules can also be used by the contractor to show cash flow when the baseline schedule is compared to the most current schedule reflecting actual work in place.

Retainage

A common practice is to withhold a percentage of the progress payment from the contractor as incentive for the contractor to complete the project. The percentage withheld from the billings is called *retainage*. The retainage is typically released once the contract is substantially complete. Retainage offers two benefits to the owner. First, holding retainage incentivizes the contractor to finish the project and complete all of the final activities that may not have a high dollar value but are essential to allow the owner to use the building. Second, retainage also creates a pool of money that the owner can use in the event the contractor fails to meet his or her contractual obligations and another contractor is used to complete the work. Typically, 10% retainage is withheld; however, the percentage is often reduced as the project is completed. For example, once the project is 50%

complete, the owner may reduce the retainage to 5% to correspond to the reduced risk.

Front End Loading

Most of the costs contractors incur such as salaries, equipment, and materials must be paid before they receive payment from the owner. As such, the contractors collectively are financing the project between billing cycles. In addition to this, retainage is withheld, which further decreases the contractor's cash flow. A technique used to increase the cash flow of contractors is called *front end loading*. This practice overvalues items that occur earlier in the project on the schedule of values. This essentially overbills the owner in the initial stages of the project to help improve the contractor's cash flow. This practice, while common, raises serious ethical issues and should be avoided.

Pass Through Clauses

Most construction projects will have a prime general contractor with subcontractors under them. Most subcontracts between general contractors and subcontractors will include *pass through clauses*, which essentially pass the obligations and restrictions of the general on to the subcontractor. This is commonly used with pay applications when an owner may cut the general contractor's pay application, which then allows the general to cut the subcontractor's payment. These types of clauses also link when the general gets paid from the owner to when the general is required to pay the subs. This specific clause is often referred to as a *pay when paid* clause.

FINAL CONTRACT AMOUNT

Very rarely is the initial price of the project the same as the final contract amount. In most projects, no matter the delivery method, there are change orders that adjust the contract price. Some change orders are from discrepancies or scope gaps from the contract documents but others come from owner-requested changes, sales tax savings through owner direct purchasing, shared savings through value engineering, or punitive change orders, such as back charges or liquidated damages.

Back Charges

Back charges are deductive change orders caused as a result of one contractor causing additional costs to be incurred by another. An example of a back charge is a deductive change order to an electrician for the costs to repair the drywall because an electrical outlet was missed.

When this type of situation arises, it is best to notify the contractor immediately and give them the opportunity to fix the issue themselves. Sometimes this isn't practical. In the example above, the electrician likely would not do the drywall work themselves or the general contractor may not feel they are qualified. However, other situations, such as back charging because a contractor didn't clean up after themselves, could lead to contractual complications. Questions such as could the contractor have done it themselves more cheaply or was the issue entirely one contractor's fault can complicate the situation.

Liquidated Damages

All standard construction projects have a time frame for completion. The contracts will provide a number of days or a specific date to complete. In either case, the contract dictates a specific point in time where the owner can take ownership of the building and use it for its intended purpose. If the contractor does not deliver the building to the owner by the agreed upon date, the owner may have a loss of expected revenue, costs that they couldn't capitalize on, or be damaged in other ways. At the end of the project, the owner could sue the contractor for damages, but to avoid this expensive process liquidate damage clauses are often included in the contract. Liquidated damages clauses set a fixed amount of damages the contractor must reimburse the owner for each day they are late. Liquidated damage amounts should not be arbitrary but based on the actual damages expected to be incurred.

For more information see Halpin & Senior in the list of references.

FINALIZING COSTS STUDY QUESTIONS

1. When are commercial contractors typically paid by the owner?
 - A. as the costs are received
 - B. weekly
 - C. monthly
 - D. a lump sum at the end of the project

2. Which statement is true about front end loading a schedule of values?
- A. common practice that is accepted by owners
 - B. increases the value of activities at the end of the project in the schedule of values to ensure the contractor completes them
 - C. increases the value of activities at the beginning of a project in the schedule of values to improve the contractor's cash flow
 - D. is typically denoted on a schedule of values, making it easy to identify which line items are front end loaded
3. Which of the following statements is true about liquidated damages?
- A. determined at the end of the job based on actual loss of revenue
 - B. determined at the time of contract signing based on estimated owner losses
 - C. a lump sum value deducted from the contract if the contractor is late
 - D. calculated by number of days late divided by total duration of contract and expressed as a percentage of total job cost

BUDGETING ANSWERS:

1. C. 2. A. 3. A.

COST CONTROL ANSWERS:

1. A. $225/120 = \$1.50/\text{sq ft}$; $1.5 \times 1,120 = 1,680$
2. B. $(207 + 100) - (120 + 100) = (\$13)$; no change

FINALIZING COSTS ANSWERS:

1. C. 2. C. 3. B.

CAC EXAM: STUDY GUIDE



CHAPTER 7

PLANNING, SCHEDULING, AND SCHEDULE CONTROL

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SCHEDULING CALCULATIONS	105
SCHEDULE ANALYSIS	110

PROCESS AND PLANNING

TYPES OF SCHEDULES

The terms *planning* and *scheduling* are often used interchangeably; however, there are important differences. Planning is the all-encompassing approach to completing a project. It addresses the specifics of who, what, where, when, and how a project will be constructed. Scheduling is a subset of planning and specifically addresses the when aspect of planning. There are several tools available to help the construction manager schedule a project, and they will be discussed in this chapter.

Activity and Milestones

There are several types of schedules that will be discussed in this chapter but all contain activities. An *activity* is simply a task to complete. The scope or complexity of the activity is subjective to and dependent on the project and how the schedule will be used. An activity can be as detailed as “paint base coat on west wall of room 101” or as general as “building skin.” Milestones are zero-day duration activities that mark important events in the project schedule. The *notice to proceed* or *substantial completion* are common milestones. Activities are often categorized as being design, procurement, or construction activities. More will be discussed on those later in the chapter.

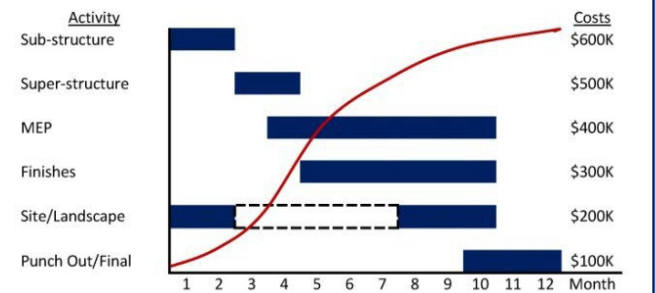
Gantt Chart

The Gantt chart is the simplest of the scheduling tools used in construction. It is a bar chart where each of the bars represents a task or activity. The tasks may be very detailed and short in duration or represent very lengthy activities or phases of construction. The activities that the bars represent may include periods of inactivity. For example, procuring doors may be an activity shown as a solid bar; however, most of that time is simply waiting for the doors to arrive. Oftentimes, this period of inactivity is indicated by dashed lines. Figure 7-1 provides a basic example of a simple Gantt chart.

Gantt charts are often used to show other time-dependent information besides the progress of an activity. Examples of this may be the number of worker hours expended or the construction costs. This is commonly shown graphically as a *lazy S*, where the x-axis denotes time and the y-axis denotes the additional information. The greatest strength of this type of chart is its simplicity in creation and how it displays the information. The most significant disadvantage is the lack of logic or

relationships between the activities. This weakness limits the number of activities and the complexity of information shown.

Figure 7-1 Example of Gantt Chart

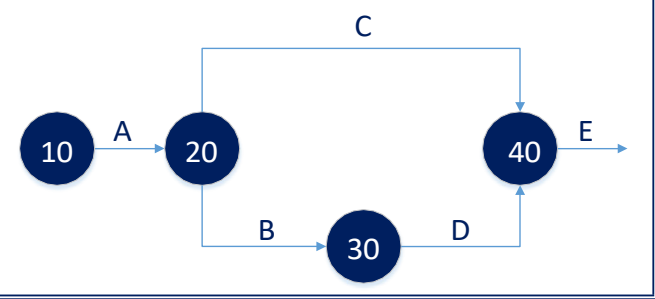


Network Diagrams

Network diagrams are an evolution from the Gantt chart and incorporate logic and relationships with the activities. One type of network diagram is an *activity on arrow network*, or simply arrow network. These types of diagrams use arrows to represent an activity and a node to represent a point in time.

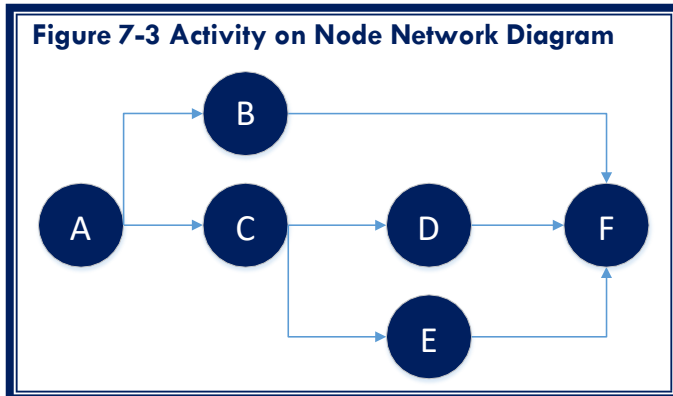
Figure 7-2 provides an example of an activity on the arrow network diagram. In this example, the nodes are represented by circles and are labeled by number. Each of the nodes represents a point in time in which an activity ends and another can begin. As the name suggests, the activities are represented by the arrows. In this example the activities are represented by letters A through E. The nodes provide logic to the diagram. Activities C and B cannot start until activity A is completed. Similarly, activity E cannot start until activity C and D are completed.

Figure 7-2 Activity on Arrow Network Diagram



Another type of network diagram is an *activity on node network*. Precedence diagrams are used commonly in construction and are an advanced form of this type of diagram. Activity on node diagrams

use arrows to represent the logic or relationships between the activities. Activities are represented by the nodes. Activities on node diagrams are much more commonly used in construction than arrow networks. Figure 7-3 provides an example of a simple activity on the node diagram. In this example, the activities are represented by letters A–F. The arrows represent the logic between the activities. The logic represented in Figure 7-3 restricts F so that it can be started only when activities B, D, and E are completed.



STEPS TO CREATE A PROJECT SCHEDULE

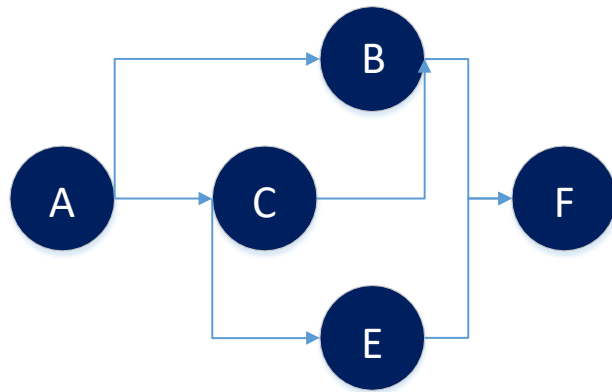
The first step to schedule a project is to break down the project into manageable activities. Although critical, there is no one correct method for determining how many activities or the level of detail that the project is broken down into. The breakdown is largely based on the scheduler's preference and experience; however, the number of activities and the detail should align with how the schedule will be used. The more activities included, the more detailed and precise the schedule will be. However, this will also increase the complexity of the schedule and the time needed to maintain it. A simpler, less detailed schedule will be easier to update but won't provide as much information. Generally speaking, factors that should be considered when creating activities are phases, location (floor, wing, building, etc.), who is responsible for completing the activity, major cost items, activity duration, lead times, and critical path. The work breakdown structure is a valuable tool used to develop the schedule.

The second step in the scheduling process is to determine the duration of each activity. Activities should be broken down so they have a consistent range of durations. These durations can come from published sources such as R.S. Means or from a company database. It is also a good practice to get

the feedback from the subcontractors performing the work and seasoned company personnel to ensure reasonable activity durations.

The third step is to determine the relationships and constraints between the activities. There are four types of relationships used with network diagrams, which are explained below. See Figure 7-4 for an example of how the relationships differ:

- *Finish to start*: the relationship where a successor activity can start only after the preceding activity has finished. This is the most common and simplest type of relationship used. An example would be the finishing of the foundations would allow a stem wall to start. An example in Figure 7-4 is the arrow between activities A and B.
- *Start to start*: the relationship where the start of one activity triggers the start of another activity. The two activities would be occurring concurrently; however, a lag (delay) is often imposed on one of the activities. An example would be that hanging of the drywall board can start when the metal studs start if a 2-day delay is imposed on drywall hanging. An example in Figure 7-4 is the arrow between activities C and E.
- *Finish to finish*: the relationship where the finish of an activity triggers the finish of another. This is used for concurrent activities. An example would be that the landscape cannot be finished until the irrigation is tested. An example in Figure 7-4 is the arrow between activities B and C.
- *Start to finish*: possible in theory but generally avoided in practice because it creates issues with resource leveling and logic issues when schedule is updated.

Figure 7-4 Example of Relationships

Finish to start: A to B, A to C, B to F, and E to F
 Start to start: C to E
 Finish to finish: C to B

For more information see Mubarak in the list of references.

PROCESS AND PLANNING STUDY QUESTIONS

1. A Gantt chart is which type of scheduling tool?
 - A. bar chart
 - B. activity on arrow network
 - C. activity on node network
 - D. precedent diagram
2. Which type of relationship is being shown in Figure 7-3 between activities C and E?
 - A. finish to start
 - B. start to start
 - C. finish to finish
 - D. start to finish
3. What type of relationship would best describe “installing the scratch coat of stucco” and then “installing the top coat of stucco”?
 - A. finish to start
 - B. start to start
 - C. finish to finish
 - D. start to finish

SCHEDULING CALCULATIONS

CRITICAL PATH METHOD

The critical path method (CPM) is a scheduling technique used to manage the project schedule and determine the overall duration. It is the most common method for scheduling construction projects, where each activity is assigned a duration and the critical path is calculated. The critical path is a series of activities, linked by logical relationships (finish to start, etc.), whose total duration is the minimum time needed to complete the project. In addition to the duration, activities used in the critical path method also include the following attributes:

- *Early start (ES)*: the earliest an activity can begin with the relationship links assigned to it.
- *Late start (LS)*: the latest an activity can start without extending the critical path's duration. The difference between the early start and the late start is the total float.
- *Early finish (EF)*: the earliest an activity can finish and is based on the earliest an activity can start and its duration.
- *Late finish (LF)*: the latest an activity can finish without delaying the critical path. The difference between the early finish and late finish is the total float.
- *Total float (TF)*: how much an activity can be delayed before the critical path is delayed. Critical path activities have zero float because any delay in them will increase the overall duration of the project. In other disciplines, total float, or simply float, is also referred to as slack.
- *Free float (FF)*: how much an activity can be delayed before it delays the subsequent activity. All critical path activities will have zero free float; however, not all activities with zero free float are critical.
- *Critical activities*: activities on the critical path. These activities have no float and if delayed will extend the overall duration of the project. Commonly these activities are highlighted in red to denote their importance.

FORWARD PASS

The critical path is calculated in a two-step process where the early start (ES) and early finish (EF) are calculated with the forward pass and the late finish (LF) and late start (LS) are calculated with the backward pass. This process will be explained in the following sections using Figure 7-5. The activity node format shown below will be used for this study guide; however, other formats are used in

the industry. Notice the location of the ES, EF, LS, LF, TF/FF, and duration in the node. The task name is the specific activity being performed.

Early Start	Duration	Early Finish
Task Name		
Late Start	Total Float Free Float	Late Finish

Forward Pass Calculation

The forward pass is used to determine the ES and EF of all activities in the schedule. The process moves from the first activity and progresses through the last activity. The first activity should have an ES of zero. It may seem intuitive to start with 1 because the first activity would start on the first day of the project; however, the forward and backward passes are calculations of time, so they start at zero, just like a stopwatch starts at zero. The early finish is the early start plus the duration.

$$\text{Early Start} + \text{Duration} = \text{Early Finish}$$



ES	Dur.	EF
Task Name		
LS	TF/FF	LF

An example of a CPM schedule is provided in Figure 7-5. In this example, Task A is the initial activity. The actual activity could be mobilizing, clear and grub, demolition, or any other activity we choose. However, for simplicity, a letter will be used to denote some activity. Here, Task A is the initial activity, so its ES will be zero. It has a duration of 1 day. Using the equation provided above, zero plus 1 provides an early finish on day 1.

Notice in Figure 7-5 that Task A is a prerequisite for Tasks B, C, and D. The lines provided extend from the end of Task A to the beginning of Tasks B, C, and D, denoting a finish to start relationship. What this means in practice is that activities B, C, and D cannot start until activity A is completed. Because the earliest Task A can be completed is day 1 (EF), that value is then carried forward to the ES of all succeeding activities. As such, Tasks B, C, and D all have an ES of 1. The early finish for Tasks B, C, and D is the same procedure as shown earlier, where the duration is added to the early start to calculate the early finish. See Figure 7-6.

$$\text{Task B: } 1 + 2 = \text{Day 3 early finish}$$

$$\text{Task C: } 1 + 3 = \text{Day 4 early finish}$$

$$\text{Task D: } 1 + 7 = \text{Day 8 early finish}$$

The earliest these activities could be completed is day 3, 4, and 8, respectively.

Figure 7-5 Example of a CPM Schedule

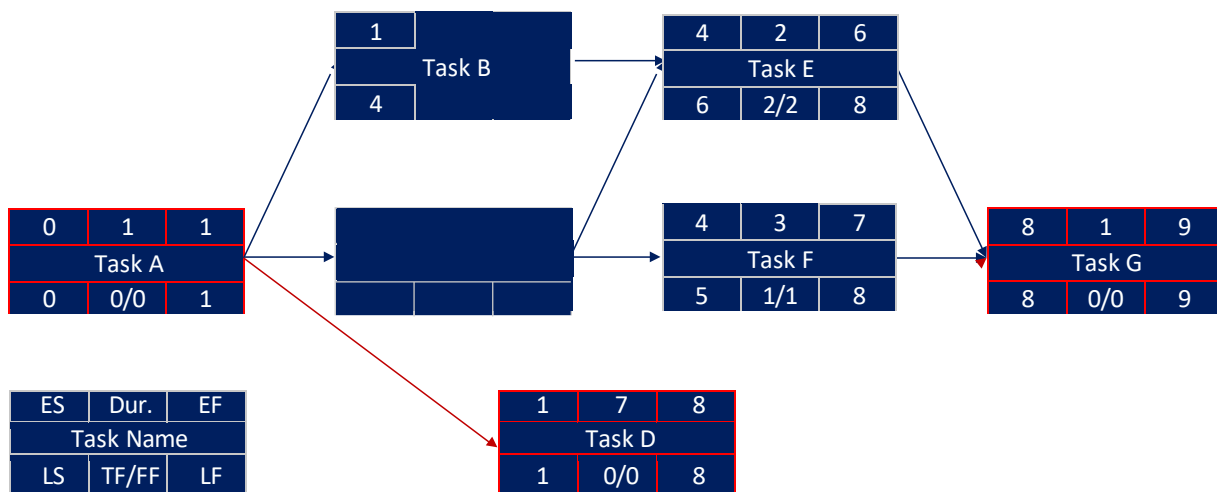
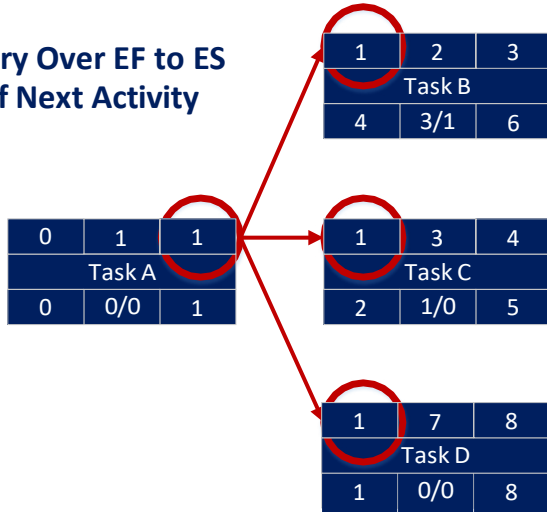


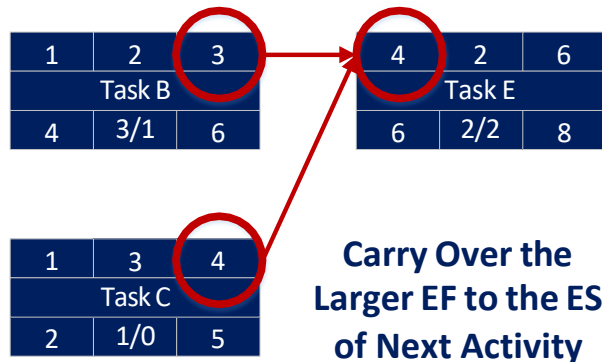
Figure 7-6 Early Start

Carry Over EF to ES of Next Activity



Oftentimes, activities have several preceding activities. An example of this is Task E in Figure 7-5. Tasks B and C both must be completed before Task E begins. Because Task C has a larger EF date than Task B (4 > 3), Task C is driving this sequence of activities. When there are multiple preceding activities, take the *larger* of the EF dates to carry over as the ES. In this example, because Task C's EF of 4 is larger than Task B's EF of 3, Task E's early start will be 4. See Figure 7-7.

Figure 7-7 Early Start with Two Predecessors



BACKWARD PASS

The backward pass is the second step in the CPM calculation, where the late start, late finish, and total float are calculated. Unlike the forward pass, the backward pass process starts at the last activity and moves backward through the schedule. Because the last activity is always critical, the late start and the early start, as well as the late finish and early finish, will be the same. To begin the

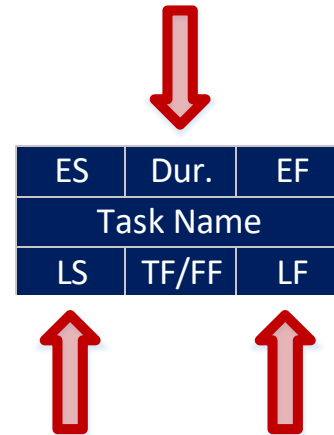
backward pass process, carry down the ES and EF to the LS and LF of the last activity. See Figure 7-8.

Figure 7-8 LS and LF on Last Activity



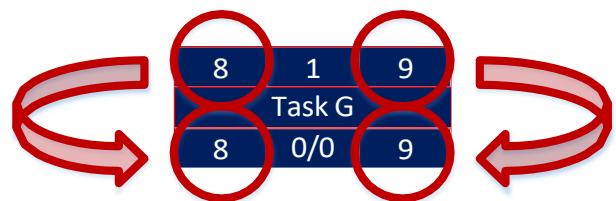
The late start is calculated by subtracting the duration from the late finish.

$$\text{Late Start} = \text{Late Finish} - \text{Duration}$$



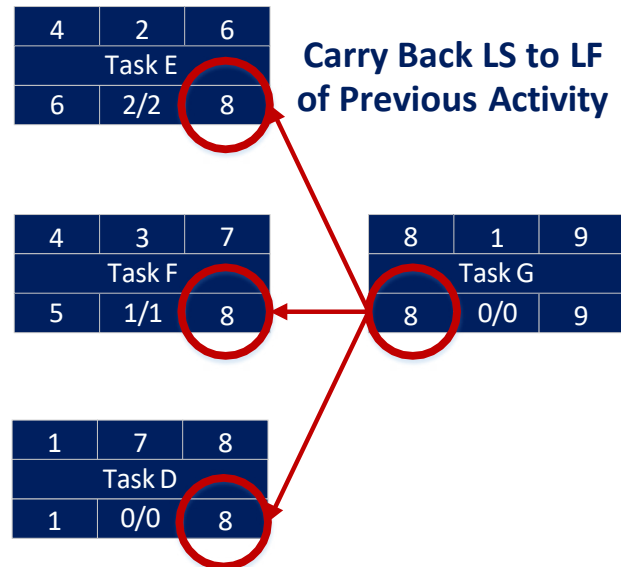
Using the sample CPM schedule provided in Figure 7-5, the backward pass can be calculated. The backward pass always starts with the last activity and carries the ES and EF down to the LS and LF. See Figure 7-9.

Figure 7-9 Example of LS and LF



Notice that Task G is the successor for Tasks D, E, and F. With the backward pass the LF is carried back from the LS of the succeeding activity. In this example, Task G has the LS on day 8, which is carried back to the LF of Tasks D, E, and F. See Figure 7-10.

Figure 7-10 LF from Backward Pass



The LS is calculated by subtracting the duration from the LF. In this example, Tasks D, E, and F all have an LF of 8 but different durations.

$$\text{Task E: } 8 - 2 = \text{Day 6 late start}$$

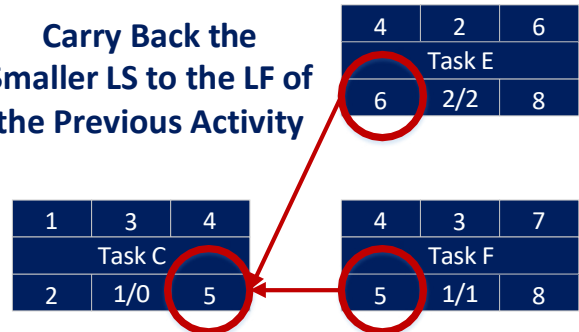
$$\text{Task F: } 8 - 3 = \text{Day 5 late start}$$

$$\text{Task D: } 8 - 7 = \text{Day 1 late start}$$

Oftentimes, activities have multiple successors. In these cases, because the activity with the smaller LS is driving the schedule, the smaller LS is carried back to the LF of the preceding activities. An example of this in Figure 7-5 is with Tasks C, E, and F. Here, Tasks E and F are both successors to Task C. Task E's EF is 6 and Task F's is 5. Because 5 is the smaller of the two LSs, it is carried back to the LF of C. See Figure 7-11.

Figure 7-11 Late Finish with Two Predecessors

Carry Back the Smaller LS to the LF of the Previous Activity



Float Calculation

There are two types of float often used in a construction schedule. Total float is how much an activity can be delayed before it impacts the critical path and extends the duration of the project. Total float is the difference between LS and ES and LF and EF.

$$\text{Total Float} = \text{Late Start} - \text{Early Start}$$

or

$$\text{Total Float} = \text{Late Finish} - \text{Early Finish}$$

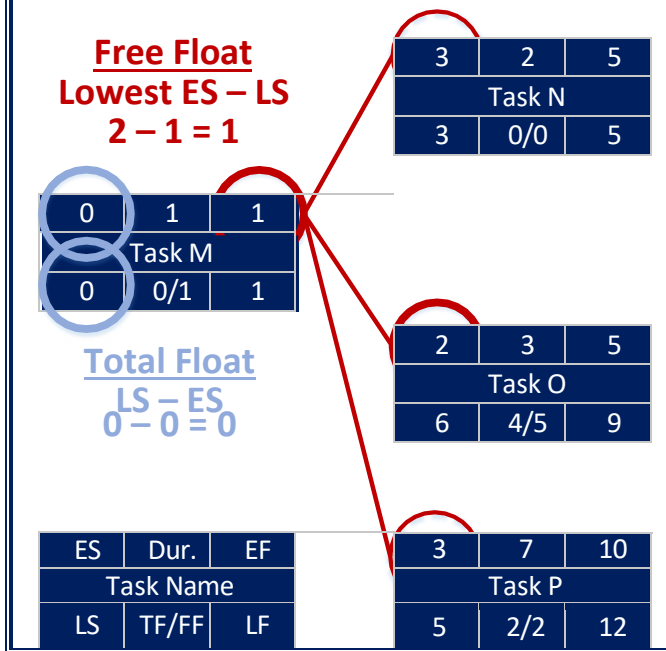
Figure 7-12 provides an example of total float. In Task M, the ES and LS are both zero, so the difference between them is also zero. Because Task M has zero float, this activity is critical. This is also true for Task N.

Free float is similar except that it indicates how much an activity can be delayed before it impacts the next activity. The formula for free float follows.

$$\text{Free Float} = \text{Early Start (next activity)} - \text{Early Finish}$$

In cases where there are multiple successors, the smaller of the ESs are used. In the example shown in Figure 7-12, Task N has the lowest LS, so that activity will drive the FF calculation.

Figure 7-12 Example of Total and Free Float



Critical Path

The critical path is a string of activities that drive the schedule. Any delay or acceleration of the critical path will directly delay or accelerate the overall duration of the project. The critical path is identified by all activities with no float in them. On simple schedules with a relatively few activities there may be several separate strings of activities, each with zero float, which are thus critical. However, for larger, more complicated schedules this rarely happens. Because of the number of activities, it is very rare to have two strings of independent activities with the exact same overall duration. Notice in Figure 7-5 that activities A, D, and G all have zero float and are highlighted in red.

SCHEDULING DEFINITIONS

Fast tracking: the overlapping accomplishment of design, procurement, and construction activities to complete a project faster.

Crashing: the shortening of the project schedule along the critical path. No activity can be crashed to a zero duration.

Resource leveling: the shifting of resources within the schedule from noncritical to critical activities. This shifting occurs as a result of a limited number of resources available, such as workers, equipment, material, or subcontractors.

Lead time: the amount of time to procure the materials.

Duration: the number of days it takes to complete an activity.

Predecessor: an activity that must be completed before the activity that is being evaluated begins.

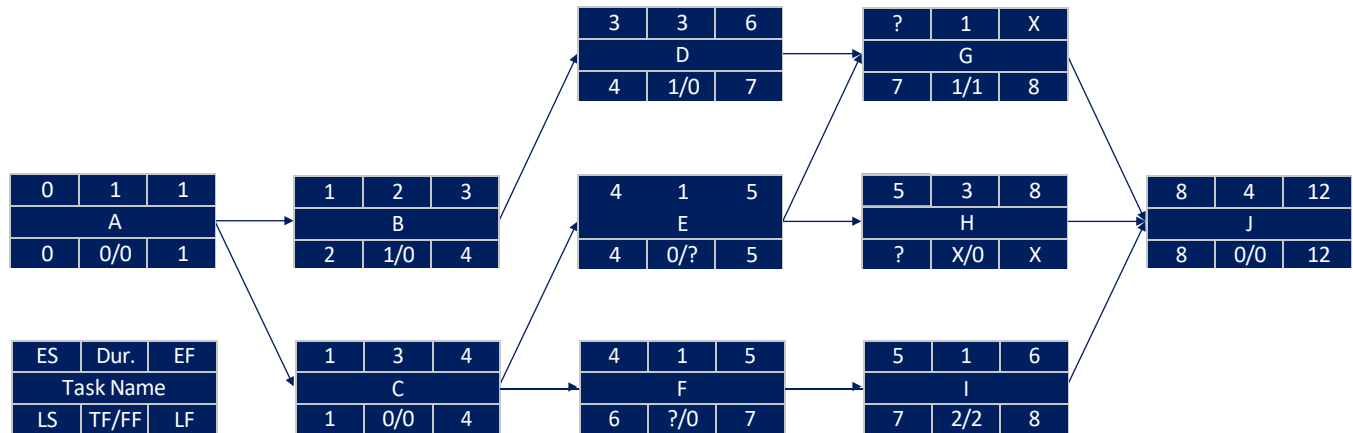
Successor: an activity that can start only after the activity that is being evaluated finishes.

For more information see Mubarak and Hinze in the list of references.

SCHEDULING CALCULATIONS STUDY QUESTIONS

- Using Figure 7-13, what is the early start for activity G?
 A. 5
 B. 6
 C. 8
 D. 9
- Using Figure 7-13, what is the late start for activity H?
 A. 4
 B. 5
 C. 8
 D. 12
- Using Figure 7-13, how much total float does activity F have?
 A. 0
 B. 1
 C. 2
 D. 3
- Using Figure 7-13, which activity is critical?
 A. B
 B. C
 C. D
 D. G
- Using Figure 7-13, how much free float does activity E have?
 A. 0
 B. 1
 C. 2
 D. 3

Figure 7-13 CPM Schedule for Scheduling Calculations Study Questions



SCHEDULE ANALYSIS

ACTIVITY SEQUENCE

Activities can be grouped generally into the main categories of design, procurement, and construction. Design activities include all activities to develop the program of the building and the contract documents needed to build it. Following are typical activities:

- architect and owner develop building program
- architect in discussion with owner develops schematic or process diagrams
- prepare the design development drawings packages
- formalize the final design and develop the contract documents
- client approves bid plans (final design)
- issue bid plans

Figure 7-14 provides a sample sequence of design activities.

The procurement sequence includes all activities that occur after the design but before the item or component is put into place at the job site. Following are typical activities:

- Prepare the bid package, request price quotations, and select and award the contract to the vendor.
- Vendor prepares and submits shop drawings, product data, or samples as outlined in the technical specifications.

- Contractor reviews and approves field measurements and field construction methods on the shop drawings.
- Architect or engineer reviews all design criteria prior to the fabrication or erection of the item.

Figure 7-14 Design Activities



- Vendor or subcontractor schedules the contract into their fabrication schedule and shop fabricates the items in accordance to the approved and revised drawings.
- Vendor arranges for shipment and delivers the material to the job site.

Figure 7-15 provides a sample sequence of procurement activities.

The construction sequence includes all activities that occur after procurement. They typically make up the majority of the construction schedule and end with turning over the project to the owner or the warranty period.

SCHEDULE ACCELERATION

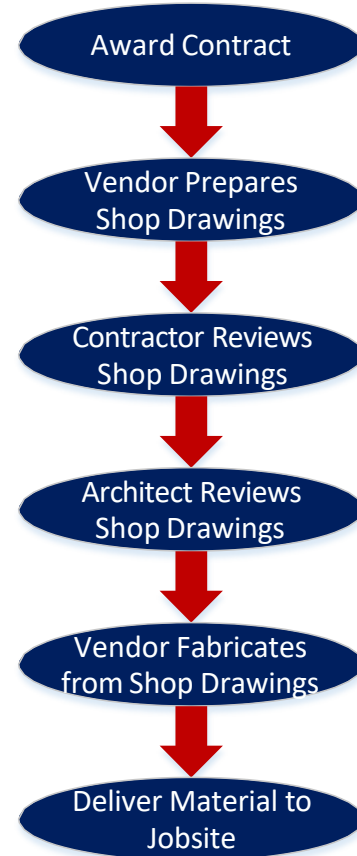
Project acceleration, sometimes called schedule compression or crashing, is the shortening of the normal duration of a schedule. There are generally four primary reasons why a schedule would be accelerated.

- After starting the project, a delay event occurs or the planned durations were underestimated, causing the normal finish date to extend past the contractual completion date.
- A contract has an acceleration clause that provides a monetary incentive for finishing early.
- By finishing early the contractor's team can start another project and earn fee on it.
- By shortening the duration the contractor can save general conditions and other expenses, increasing their profit on the project.

PROJECT ACCELERATION

There are a number of ways a project can be accelerated, but it's important to pick the means that maximize the acceleration while minimizing the additional costs. When accelerating the schedule, only critical path activities should be addressed. Accelerating noncritical path activities will only increase those activities' float and will do nothing for the overall schedule duration. The scheduler should also determine if moving existing resources from noncritical path activities to the critical path will decrease the overall duration of the schedule (resource leveling). This will reduce the float in some activities; however, it may decrease the duration of the critical path. Also, as a rule, critical path activities with the lowest acceleration costs, which occur earlier in the schedule, should be accelerated first.

Figure 7-15 Procurement Activities



Several common means of accelerating a schedule can be found below.

- Review the logic, relationships, and constraints in the schedule and determine if there are any errors or unnecessary restrictions on the activities.
- Fast-track the project by having the design and construction phase occurring concurrently. The decision to fast-track a project typically must be made before construction has started.
- Working overtime is a common means of accelerating the schedule. Care should be taken when choosing this approach because the overtime wages are increased from normal hours (time and half or more) but the productivity is most often significantly less. Essentially, you are paying a premium for the least efficient hours of a workweek.
- Offer incentives to the workers for improved production. Care should be taken with this approach so that quality doesn't suffer because workers are rushing to complete measurable units of work.

- Increase labor force by hiring more people. This can increase productivity; however, workers new to the job will not be as efficient as the seasoned workforce. In fact, the seasoned workforce may become less productive because they are training the new hires. In addition, having too many workers in a confined space, referred to as trade stacking, can decrease individual productivity.
- Improve communication, management, or site logistics of a site to improve productivity of the workforce.

For more information see Mubarak in the list of references.

PROCESS AND PLANNING ANSWERS:

1. A. 2. A. 3. A.

SCHEDULING CALCULATIONS ANSWERS:

1. B. 2. B. 3. C.
4. B. 5. A.

SCHEDULE ANALYSIS ANSWERS:

1. C. 2. B. 3. D.

SCHEDULE ANALYSIS STUDY QUESTIONS

1. What classification of activity would “shop drawing rejection” be?
 - A. acceleration
 - B. design
 - C. procurement
 - D. construction
2. What classification of activity would “building programming” be?
 - A. acceleration
 - B. design
 - C. procurement
 - D. construction
3. Which of the following defines the term *trade stacking*?
 - A. the loss of worker productivity from overtime work
 - B. the inefficiency from redoing work
 - C. the loss of productivity in the seasoned workforce from training new hires
 - D. the loss of productivity by placing too many workers in too small a space

CAC EXAM: STUDY GUIDE



CHAPTER 8

CONSTRUCTION SAFETY

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OSHA ADMINISTRATION

IMPORTANCE OF SAFETY

Construction safety is based on the fundamental principle that everyone on the job site should be able to go home in the same condition in which he or she arrived. It is often said that employees are a company's most important asset and that a safe workplace is a core value of a company. There are three main reasons why safety is given such high importance: morality and ethics, immediate financial cost of accidents, and long-term competitiveness of a company.

Moral and Ethical Reasons

Morality and ethics are often the first reasons given as to why a company should create and foster a positive safety culture. Employees and managers alike share common values, whereby nothing done at work, no matter how prestigious or impactful, is worth someone getting hurt. Traditional American values place a higher importance on the well-being of family members and coworkers than that placed on a project.

Immediate Financial Cost

Setting aside the moral and ethical aspect of a person getting hurt, accidents are expensive. The direct costs, such as damage to the project and medical compensation, can be significant, although often these costs are covered by insurance. However, the direct costs pale in comparison to the indirect costs. These costs, which are not covered by insurance, include construction downtime, liquidated damages for late work, additional administrative time, new hire training, and negative publicity. By some estimates, for every dollar covered by insurance, \$9 must be absorbed by the company.

Long-Term Competitiveness

The safety record of a company directly impacts its competitiveness and bottom line. For example, workers' compensation insurance is regulated by the state and is adjusted based on a company's safety record. In South Carolina for example, the premiums for workers' compensation can be reduced by 25% based on the quality of a company's internal safety program. Owners also often look at a company's safety record when selecting contractors for their project. Past injuries, poor public opinion in regard to safety, past legal actions, and a history of paying liquidated damages will all negatively impact a contractor's chance of winning a job.

For more information see De Vita & Clarke in the list of references.

OSHA

In 1970, Congress passed the Occupational Safety and Health Act (OSH Act) with the intention to "assure so far as possible every working man and woman in the nation safety and healthful working conditions and to preserve our human resources" (OSH Act of 1970). The OSH Act gave Congress the charter to create the Occupational Safety and Health Administration (OSHA) under the U.S. Department of Labor. The OSH Act covers almost all employers, with exceptions made for those who are self-employed, work on family farms, are coal miners, or work for some government agencies. The specific rules that OSHA enforces are referred to as OSHA standards and are included as one of many titles in the U.S. Code of Federal Regulation (CFR), published by the office of the Federal Register. Specifically, all OSHA standards are included in Title 29 of the CFR. Title 29, part 1926, addresses all safety and health regulations for construction. Within part 1926 are subparts A–Z, which are specific hazards related to the construction industry. Subparts A–Z are found in Figure 8-1. In addition to part 1926, parts that aren't specific to construction but are still applicable include 1903-OSHA Inspections, 1904-OSHA Record Keeping, and 1910-General Industry. OSHA references many third-party standards, such as ANSI, which effectively codifies them.

OSHA RECORD KEEPING

Employers with 10 or more full-time employees are required by OSHA to maintain specific safety logs and record accidents. OSHA forms 300, 300-A, and 301 are used for this purpose. Contractors are required to keep these logs for 5 years, and they must be made available to all employees at any time.

- *Log of Injuries and Illnesses (Form 300)*: a form to record all reportable injuries and illnesses that occur in the workplace. This log will specifically record where and when the accident occurred, the nature of the incident, job title of employees, and the number of days away from work or on modified assignment.
- *Summary of Work-Related Injuries and Illnesses (Form 300-A)*: a means of informing employees of the injuries and illnesses that occurred at their workplace in

the past year. This log is required to be compiled and certified by a company executive and posted in a conspicuous place for three months (Feb 1–April 30).

- *Injury and Illness Incident Report (Form 301)*: used to record the information on how and why a specific accident occurred. It includes the substances, objects, and people involved and what part of the body was affected.

What Is an Injury or illness?

OSHA defines an injury or illness as an abnormal condition or disorder. Injuries and illnesses include cases such as cuts, fractures, sprains, skin diseases, or respiratory conditions. For OSHA record-keeping purposes, an injury or illness can also consist of only subjective symptoms, such as aches or pain. However, these logs do not need to include minor first aid (no prescriptions). As a general rule, these logs should be maintained for work-related injuries and illnesses if they involved any of the following:

- death
- days away from work
- restricted work or transfer to another job
- medical treatment beyond first aid
- loss of consciousness
- any significant injury or illness diagnosed by a licensed health care professional

COMMUNICATION WITH EMPLOYEES

One of the principal objectives of the OSH Act is to make sure that employees are informed of their rights and their working conditions. To that end, OSHA requires several documents be posted in a location where company information is normally displayed. These documents include the following:

- *OSHA Job Safety and Health: It's the Law! poster*: The poster informs workers of their rights. It is available free to all employers and can be downloaded in English and Spanish from osha.gov. See Figure 8-2.
- *Summary of Work-Related Injuries and Illnesses (Form 300-A)*: This form was discussed in a previous section of the chapter.
- *Copies of all OSHA citations* must be posted for three days or until the hazard has been abated, whichever is longer.
- *Summaries of Variances of Regulations Requested*.

Figure 8-1 29 CFR, Part 1926

Subpart A	General
Subpart B	General interpretations
Subpart C	General safety and health provisions
Subpart D	Occupational health and environmental controls
Subpart E	Personal protective and lifesaving equipment
Subpart F	Fire protection and prevention
Subpart G	Signs, signals, and barricades
Subpart H	Materials handling, storage, use, and disposal
Subpart I	Tools: hand and power
Subpart J	Welding and cutting
Subpart K	Electrical
Subpart L	Scaffolding
Subpart M	Flooring and wall openings
Subpart N	Cranes, derricks, hoists, elevators, and conveyors
Subpart O	Motor vehicles, mechanized equipment, and marine operations
Subpart P	Excavations
Subpart Q	Concrete and masonry construction
Subpart R	Steel erection
Subpart S	Underground construction, caissons, and cofferdams
Subpart T	Demolition
Subpart U	Blasting and use of explosives
Subpart V	Power transmission and distribution
Subpart W	Rollover protective structures; overhead protection
Subpart X	Stairways and ladders
Subpart Y	Commercial diving operations
Subpart Z	Toxic and hazardous substances

Figure 8-2 Job-Site OSHA Poster


**Job Safety and Health
IT'S THE LAW!**

All workers have the right to:

- A safe workplace.
- Raise a safety or health concern with your employer or OSHA, or report a work-related injury or illness, without being retaliated against.
- Receive information and training on job hazards, including all hazardous substances in your workplace.
- Request an OSHA inspection of your workplace if you believe there are unsafe or unhealthy conditions. OSHA will keep your name confidential. You have the right to have a representative contact OSHA on your behalf.
- Participate (or have your representative participate) in an OSHA inspection and speak in private to the inspector.
- File a complaint with OSHA within 30 days (by phone, online or by mail) if you have been retaliated against for using your rights.
- See any OSHA citations issued to your employer.
- Request copies of your medical records, tests that measure hazards in the workplace, and the workplace injury and illness log.

Employers must:

- Provide employees a workplace free from recognized hazards. It is illegal to retaliate against an employee for using any of their rights under the law, including raising a health and safety concern with you or with OSHA, or reporting a work-related injury or illness.
- Comply with all applicable OSHA standards.
- Report to OSHA all work-related fatalities within 8 hours, and all inpatient hospitalizations, amputations and losses of an eye within 24 hours.
- Provide required training to all workers in a language and vocabulary they can understand.
- Prominently display this poster in the workplace.
- Post OSHA citations at or near the place of the alleged violations.

FREE ASSISTANCE to identify and correct hazards is available to small and medium-sized employers, without citation or penalty, through OSHA-supported consultation programs in every state.

This poster is available free from OSHA.

Contact OSHA. We can help.

1-800-321-OSHA (6742) • TTY 1-877-889-5627 • www.osha.gov

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HAZARD COMMUNICATION SAFETY DATA SHEETS

OSHA requires that all materials that contain potentially hazardous chemicals provide documentation on the hazard and how to handle it safely. This documentation is provided in Safety Data Sheets (SDS), which were formerly known as Material Safety Data Sheets, or MSDS. It is often the project superintendent's responsibility to keep a binder of all of the SDS on-site so that they can be referenced quickly in an emergency. As of June 1, 2015, all new SDS will be in a uniform 16-section heading format.

COMPETENT PERSON

OSHA standard 29 CFR 1926 requires that every job site have at least one competent person responsible for overseeing the health and safety of the project. A competent person must be able to

identify existing hazards and to anticipate future hazards in the workplace. This subject-matter knowledge must be demonstrated through formal education and/or practical experience. In addition to having the knowledge, OSHA also stipulates that the competent person must have the authority to stop the work and take prompt corrective measures to eliminate the hazard.

CITATIONS AND PENALTIES

OSHA has the authority to issue citations to employers for violations of the OSHA standards, with corresponding penalties. OSHA categorizes violations in the following four ways (OSHA.gov):

Willful

A willful violation is defined as a violation in which the employer either knowingly failed to comply with a legal requirement (purposeful disregard) or acted with plain indifference to employee safety. The penalty may be reduced depending on the company's size and its past safety record.

Serious

A serious violation exists when the workplace hazard could cause an accident or illness that would most likely result in death or serious physical harm, unless the employer did not know or could not have known of the violation.

Repeated

An agency may be cited for a repeated violation if the agency has been cited previously for the same or a substantially similar condition within the past five years. Citations that are being contested or appealed cannot be cited as being repeated.

Other-than-Serious

A violation that has a direct relationship to job safety and health, but is not serious in nature, is classified as other-than-serious. The penalty for this type of violation may be reduced by 95% depending on the company and its good-faith effort to remediate the hazard.

Employers have the option to formally appeal a citation, penalty, or the duration given to abate the hazard. However, informal meetings can be arranged between the employer and OSHA's area director, in which the area director has the authority to revise the citation before an official appeal is filed. If the informal meeting with the OSHA area director does not resolve the issue to the employer's

CHAPTER 8 ► CONSTRUCTION SAFETY

satisfaction, the employer can file either a petition for modification of abatement (PMA) or a notice of contest. A PMA is used when the employer intends to abate the hazard but needs more time than what the citation allows. The notice of contest (NOC) is filed if the employer contests the citation, penalty, or duration of abatement. The notice of contest must be filed within 15 days of the issuance of the citation.

For more information see U.S. Department of Labor OSHA Technical Manual; OSHA Standards (29 CFR) and Goetsch in the list of references.

OSHA ADMINISTRATION

1. When was the Occupational Safety and Health Act passed?
 - A. 1790
 - B. 1930
 - C. 1970
 - D. 1990
2. Which of the following parts of CFR Title 29 addresses safety and health regulations for construction?
 - A. 1904
 - B. 1926
 - C. 1980
 - D. 2111
3. How many employees must an employer have before OSHA record keeping is required?
 - A. 1 or more
 - B. 10 or more
 - C. 11 or more
 - D. 100 or more
4. Which of the following forms is used to record the information of a single specific incident?
 - A. Form 300
 - B. Form 300-A
 - C. Form 301
 - D. Form 409

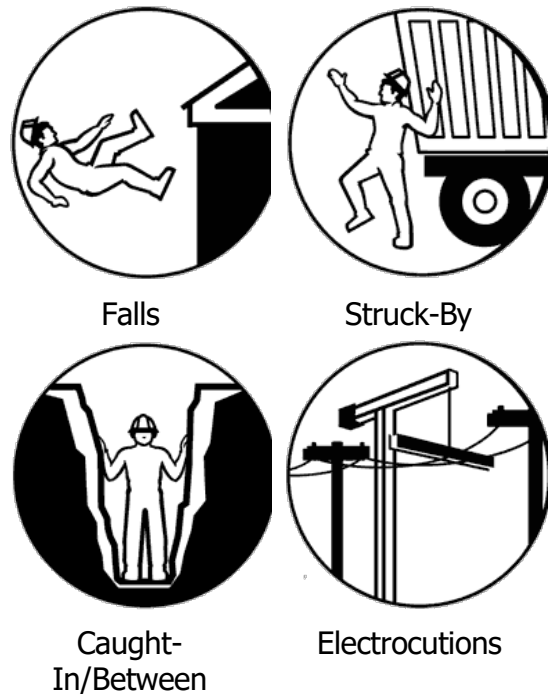
5. How long must the OSHA Form 300 be kept by the employer?
 - A. until the hazard has been abated
 - B. 3 months
 - C. 1 year
 - D. 5 years
6. Within how many days must a notice of contest be filed for an OSHA citation?
 - A. 1 day
 - B. 15 days
 - C. 30 days
 - D. no statute of limitation

SAFETY PROCEDURES AND INTERPRETATION

OSHA'S FOCUS FOUR

OSHA has reported that the construction industry makes up approximately 20% of all workplace fatalities. Of this 20%, over half of these fatalities can be classified as either falls, struck-bys, caught-in/between, or electrocutions, which OSHA refers to as the *focus four* (Figure 8-3). Of these four, falls make up the majority of the fatalities.

Figure 8-3 OSHA'S Focus Four



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PERSONAL PROTECTIVE EQUIPMENT (PPE)

Employers have the responsibility to protect employees from workplace hazards, such as falling objects, chemicals, excessive noise, and respiratory contaminants. As a first step, the employer must do everything feasible to reduce or eliminate these hazards. After that, the employer is required to provide personal protective equipment, or PPE, to minimize the impacts of a hazard when they exist. Construction employers are required to provide PPE to their employees at no charge, with a few minor exceptions, such as safety-toe footwear, prescription eyewear, and everyday or weather-specific clothing. A list of common hazards and appropriate PPE is provided in Figure 8-4.

Figure 8-4 PPE Schedule

Body	Hazard	Protection
Head	-Overhead falls	Hard hat
Eye	-Dust or flying particles	Safety glasses Goggles
	-Corrosive gases	Face shield
	-Liquid chemicals	Welding shield
	-Molten metal splash	
	-Intense light	
Ear	-85 decibels (dB) average	Earmuffs
		Earplugs
		Canal caps
Foot	-Crushing foot	Safety shoes
		Steel toe boots
	-Stepping on nails/spikes	
	-Molten metal splash	
	-Hot or wet surface	
	-Slippery surfaces	
Hand	-Burns	Gloves
	-Abrasions	Leather
	-Cuts	Coated fabric
		Nonconductive
	-Punctures	kevlar
	-Fractures	Chemical-resistant
	-Chemical exposures	rubber

PORTABLE FIRE EXTINGUISHER

Portable fire extinguishers are labeled based on the type of combustible material they can extinguish. The materials are labeled using letters and/or a pictograph.

- Type A: normal combustibles, such as wood, paper, trash, or clothes
- Type B: flammable liquids, such as fuel oil, gasoline, or paint
- Type C: electrical fires
- Type D: combustible metals, such as aluminum or magnesium
- Type K: cooking material, such as vegetable oil or animal fats

A way to remember this is A is for ash, which is left after normal combustion; B is for boiling, which is what liquids do; C is for circuit, which is what electricity passes through; D is for durable, which most metals are; and K is for kitchen, where cooking occurs.

A fire extinguisher, rated not less than 2A (type A and equivalent of 2.5 gal of water of extinguishing capacity), shall be provided for each 3,000 sq ft of protected building area, or major fraction thereof. Travel distance from any point of the protected area to the nearest fire extinguisher shall not exceed 100 ft. Portable fire extinguishers should be mounted 3.5 ft to 5 ft above the floor.

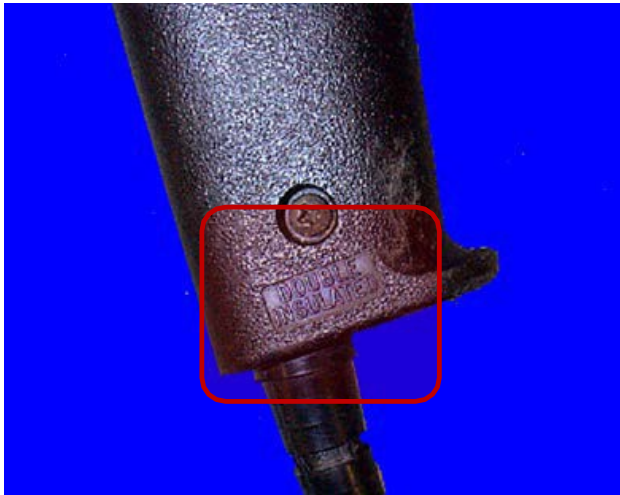
ELECTRICAL

Electricity is the flow of energy from one point to another. The movement of electricity, measured in amperes, is pushed by electrical pressure, measured by the volt, through an electrical path, called a circuit. Injuries related to electricity include direct electrocution, electrical burns, and falls. Some of the most common ways to prevent electrical injuries follow:

- Isolate electrified components through fully enclosed junction boxes, cabinets, and fittings. This includes filling all knockout holes in boxes.
- Keep a minimum of 10 ft away from all power lines. This can be facilitated with appropriate warning signs.

- Replace all damaged extension cords and tools. This specifically includes cords that have damaged insulation, have been stretched, are missing grounds, or are not marked for hard or extra-hard duty.
- Make sure that all 120 V, single-phase loads, such as power tools, are plugged into a GFCI outlet or have an assured equipment grounding conductor program.
- Power tools should have either a three-wire cord with ground, be double insulated, or be powered by a low-voltage isolation transformer. See Figure 8-5 for an example of a double-insulated appliance.
- Implement an appropriate lock-out/tag-out program, where all equipment is de-energized and remains de-energized while being worked on.
- Appropriate PPE, such as proper foot protection and nonconductive hard hats, must be used.

Figure 8-5 Double-Insulated Tool



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SCAFFOLDING

A scaffold is an elevated temporary work platform. OSHA divides scaffolding into three major categories: supported scaffolds, suspended scaffolds, and aerial lifts (Figure 8-6). The most common hazards associated with scaffolding are falls, being struck by falling debris, electrocutions from overhead utilities, and scaffold collapse by overloading and poor planking. Workers on a scaffold elevated 10 ft or more must be protected by guardrails, nets, and/or personal fall arrest

systems. All scaffolds should be inspected by the competent person after each shift and after any alterations.

Figure 8-6 Scaffold Types



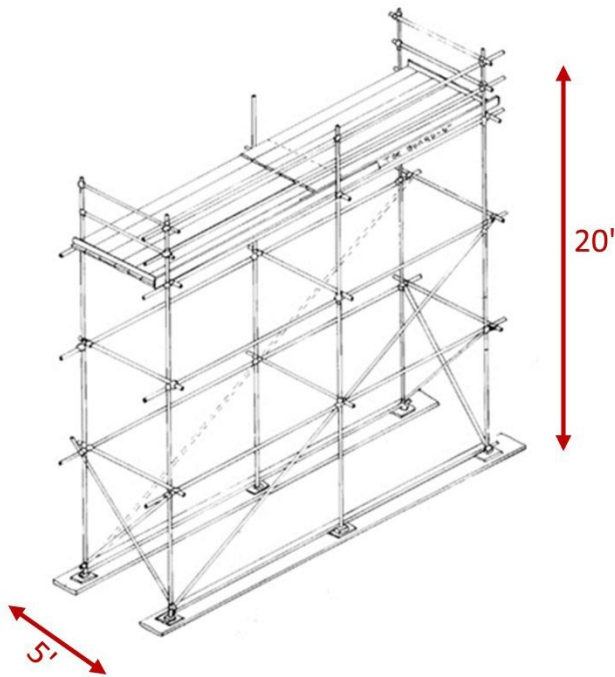
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Supported Scaffolds

A supported scaffold is a platform supported by ridged, load-bearing members, such as poles, legs, frames, and outriggers. The platforms must be fully planked or decked with no more than a 1-in. gap between adjacent planks. The platform must be able to support four times the maximum intended load and be at least 18 in. wide. Planked platforms must have the planks overlap no less than 12 in. and be located above support unless restrained to prevent movement. See Figure 8-7 for an example of where the planks are not properly overlapped or above the support. Unless restrained by hooks, cleats, or other means, the ends of the planks must extend past the end of the support by 6 in. but no more than 12 in. (18 in. for planks longer than 10 ft) to prevent an excessive cantilever. Unless braced or tied back to a structure, the scaffold height should not be more than four times the dimension of the base. See Figure 8-8.

Figure 8-7 Planks Not Properly Overlapped or Supported

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Figure 8-8 Scaffold Height

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Suspension Scaffolds

A suspended scaffold is a platform suspended by ropes or cables or other nonrigid overhead supports, such as a swing stage or bosun's chair. The support devices must be designed to support four times the maximum intended load. Counterweights

must be made of a nonflowable material, such as sand, gravel, or metal weights. All tiebacks must be secured to structurally sound anchor points, which are most typically the building's structure.

Aerial Lifts

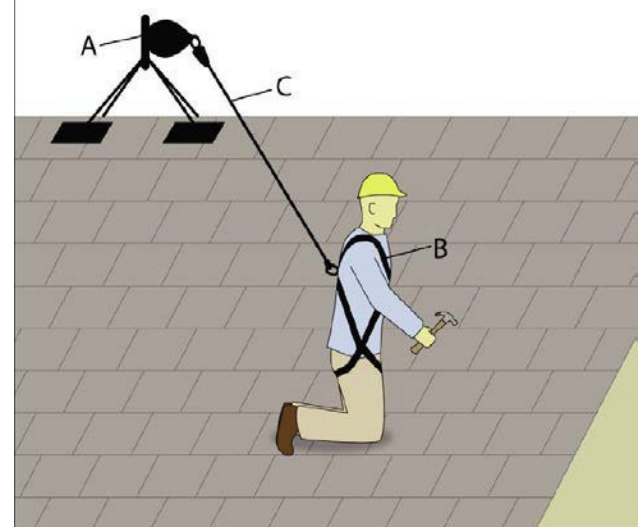
Aerial lifts are motorized scaffolding, such as a cherry picker or boom truck. Aerial lifts must have proper fall protection, which includes guardrails and personal fall arrest systems. Workers in the basket should be tied off to the boom or basket but never to an adjacent structure, pole, or other piece of equipment.

FALL PROTECTION

Falls are the leading cause of fatal accidents in the construction industry. OSHA mandates that protection means must be in place for any potential falls greater than 6 ft and are commonly used for ramps, wall openings, holes, excavations, and roofs. The protection generally comes in the form of personal fall arrest systems (PFASs), guardrails, and safety nets.

Personal Fall Arrest Systems (PFASs)

PFASs include an anchor point, lifeline, and body harness and are designed to minimize the impact of a fall if it occurs. See Figure 8-9. A single anchorage point may be used for multiple workers but must be designed to support 5,000 lb for each worker or twice the impact load, whichever is greater.

Figure 8-9 Example of a PFAS

A) Anchor points, B) Full body harness, C) Lifeline
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Guardrails

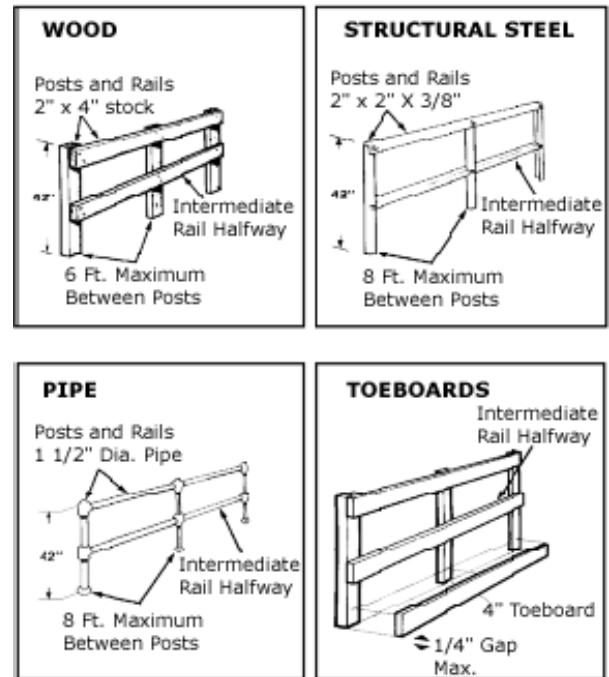
Guardrails can be used to protect against falls on leading edges of floors, stairs, and many other surfaces. Guardrails must include a top rail and midrail. A toe board may be required if the guardrail is used for falling-object protection. The top rails must be 42 in. $\pm$ 3 in. and the midrail 21 in. $\pm$ 3 in., and the toe board must be at least 3.5 in. in height. The guardrail must be able to resist a lateral load of 200 lb at the top rail (Figure 8-10), 150 lb at the midrail, and 50 lb at the toe board. See Figure 8-11 for proper installation of several guardrail types. Cables can be used for guardrails if they are flagged every 6 ft, there is a maximum sag of 3 in., and the same dimensions provided for traditional guardrails are maintained.

Figure 8-10 Guardrail Lateral Force



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Figure 8-11 Guardrails



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Safety Nets

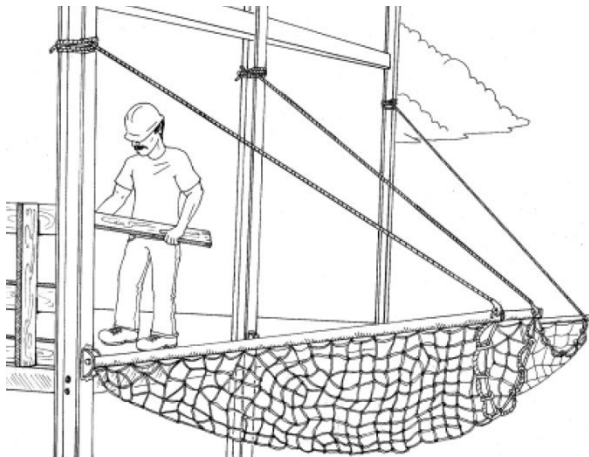
Safety nets are screens used to catch falling employees (Figure 8-12). They are most typically used around the perimeter of buildings. The safety nets should be placed as close as possible to where the employees are working but no more than 30 ft below the working surface. The net must extend horizontally 8 ft for falls up to 5 ft, 10 ft for falls up to 10 ft, and 13 ft for falls greater than 10 ft. Safety nets must be drop tested after initial installation, whenever relocated, after a major repair or after 6 months in one location. A drop test includes dropping a 400-lb bag of sand at the highest surface of the potential fall hazard but not less than 42 in. Safety nets should be inspected weekly, after fall events, and after major alternations or repair.

EXCAVATION

Excavation is one of the most hazardous activities in the construction industry. Cave-ins are the highest risk; however, there are other significant hazards, such as asphyxiation; inhalation of toxic materials, such as fuel fumes; fires; and electrocution by serving underground utility lines. Employees are required to be protected from cave-ins through sloping, shoring, and shielding for all trenches 5 ft in depth or more. Trenches over 20 ft must have the

protection systems designed by a professional engineer.

Figure 8-12 Safety Net



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Sloping

Sloping is a technique that requires a maximum angle on the sides of the trench. The angle of the side walls varies depending on the soil type and other job-site factors. The description of the OSHA soil types follows.

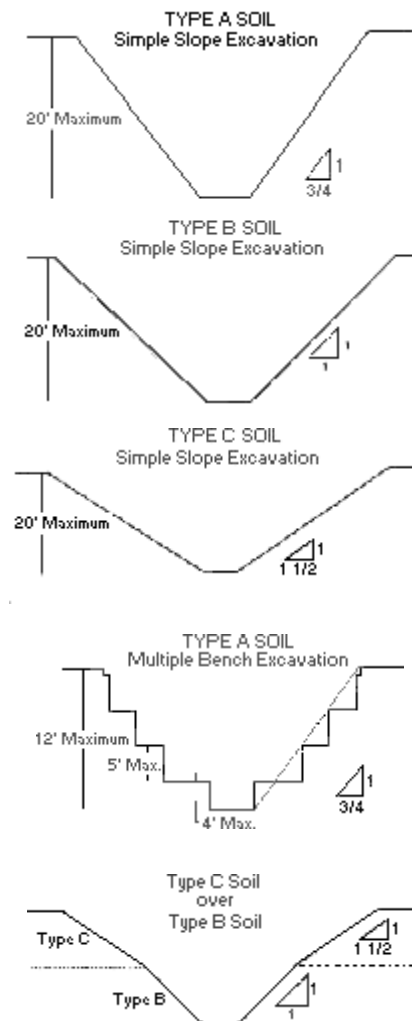
- **Type A:** This is the most stable of the three soil types, with an unconfined compressive strength of 1.5 tons per square foot. Examples of this soil type include clay, clay loam, and sandy clay. The maximum allowable slope for excavations less than 20 ft is 3/4:1.
- **Type B:** This type of soil is moderately stable and has a compressive strength between .5 and 1.5 tons per square foot. Examples of this soil type include sandy loam, silt loam, and angular gravel. The maximum allowable slope for excavations less than 20 ft is 1:1.
- **Type C:** This is the least stable soil type and has a maximum unconfined strength of .5 ton per square foot. Examples of this soil type include sand and gravel. The maximum allowable slope for excavations less than 20 ft is 1.5:1.

Benching is excavating the sides of a trench to form one of a series of horizontal levels or steps, usually with vertical or near-vertical surfaces between the levels. The maximum benching angle is the same as that for sloped soil and dependent on the soil type. See Figure 8-13. Depending on the soils, combinations of sloping and benching can be

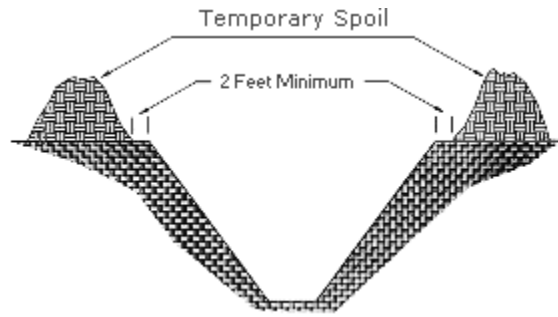
used. Type C soil cannot ever be benched. See Figure 8-13 for examples of allowable sloping and benching.

Temporary spoils are the soils removed from the trench; they must be placed no closer than 2 ft from the surface edge of the excavation. The measurement is taken to the edge of the base of the spoil to the edge of the excavation. See Figure 8-14 to illustrate.

Figure 8-13 Examples of Sloping and Benching



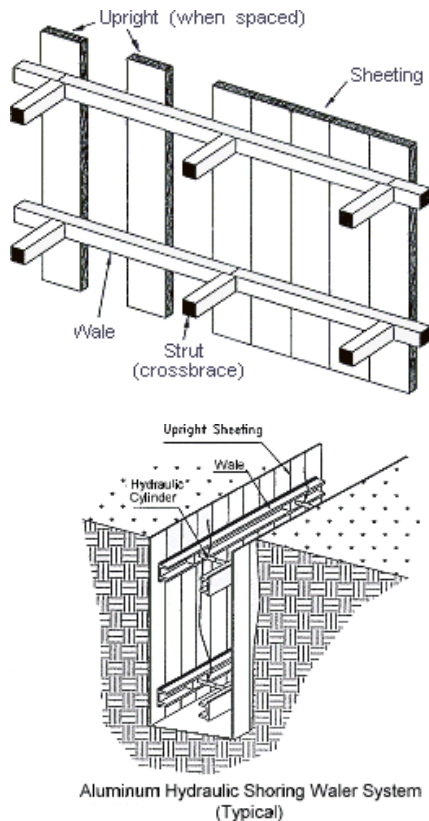
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Figure 8-14 Temporary Spoil Location

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Trench Shoring

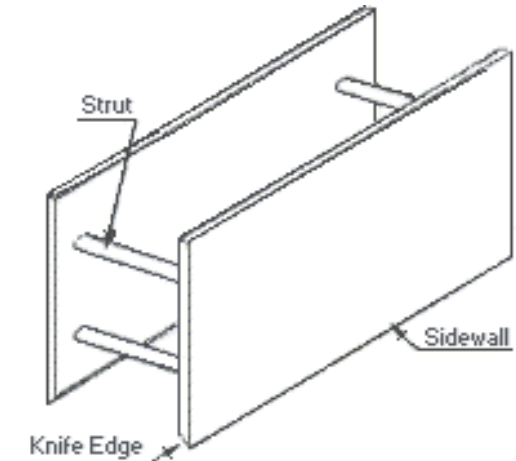
Trench shoring is a support system to protect trenches from cave-ins. Shoring is typically either timber construction or metal hydraulic. See Figure 8-15. Timber shoring is made of wood sheeting, wales, and struts. Hydraulic shoring is typically made of aluminum or steel and composed of prefabricated sheets, wales, and struts.

Figure 8-15 Trench Shoring

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Trench Shielding

A trench shield is similar to shoring in that both are types of cave-in protection that use two flat plates or sidewalls, which are supported by struts to prevent soil from collapsing in on the trench. See Figure 8-16. A trench shield is different from shoring in that it is typically a premanufactured box that acts as a shield to protect from cave-ins but doesn't necessarily support the trench wall itself.

Figure 8-16 Trench Shield

Reprinted Courtesy of OSHA.gov

Trench Ingress and Egress

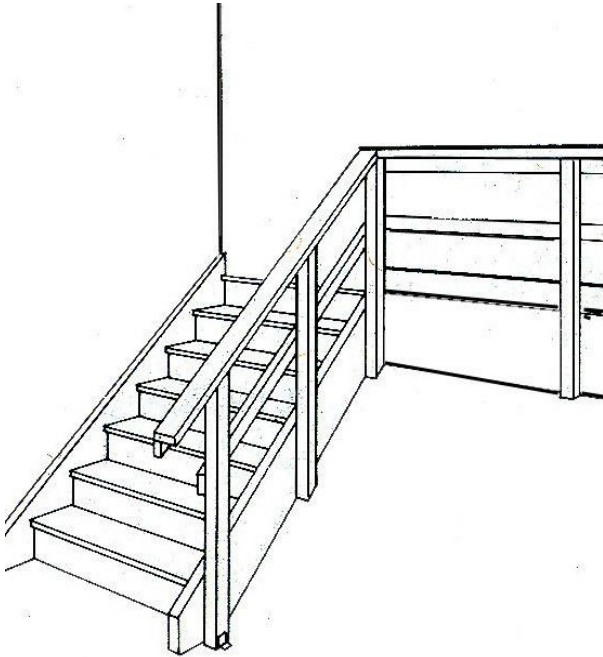
Trenches 4 ft or more in depth are required to have a fixed means of egress, which is most often a ladder. If a ladder is used, the top must extend 3 ft above the top of the trench. Additionally, the worker must not have to travel more than 25 ft to the nearest ladder or other means of egress (multiple ladders spaced no more than 50 ft apart).

LADDERS AND STAIRWAYS

Stairs or ladders must be provided when there is a break in elevation of 19 in. or more (Figure 8-17). Stairways with four or more risers or 30 in. in height must be equipped with at least one handrail. Handrails are also required on all unprotected sides or edges of stairways. Stairs should be installed between 30° and 50°, with a uniform height and depth of treads and risers.

For more information see U.S. Department of Labor OSHA Technical Manual; OSHA Standards (29 CFR) and Goetsch in the list of references.

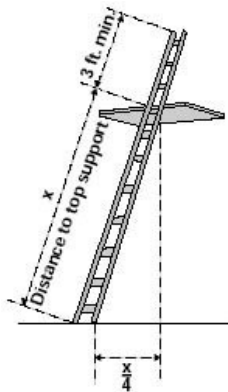
Figure 8-17 Handrail on Unprotected Edge



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Self-supporting portable ladders are required to support at least four times the maximum intended load; however, this can be reduced to 3.3 times for extra-heavy-duty, 1A ladders. Non-self-supporting ladders, such as ladders that lean against a wall, should be positioned at an angle where the horizontal distance from the top support to the foot of the ladder is one-quarter of the working length of the ladder. See Figure 8-18. When using portable ladders to access the upper landing surface, the side rails must extend at least 3 ft above the upper landing surface.

Figure 8-18 Ladder Angle and Extension



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SAFETY PROCEDURES AND INTERPRETATION STUDY QUESTIONS

- Which of the following accidents makes up the majority of fatalities in the construction industry?
 - falls
 - inhalation
 - explosion
 - cranes
- What size load must a personal fall arrest system be designed to?
 - minimum 200 lb per person
 - minimum 500 lb per person
 - minimum 1,000 lb per person
 - minimum 5,000 lb per person
- Which of the following heights would be acceptable for the top rail of a guardrail system?
 - 21 in.
 - 38 in.
 - 45 in.
 - 52 in.
- Which of the following ratios of vertical rise to horizontal run is acceptable for an extension ladder supported against a building?
 - 1:1
 - 2:1
 - 3:1
 - 4:1
- What is the maximum horizontal travel distance that a portable fire extinguisher can be located on a job site?
 - 50 ft
 - 75 ft
 - 100 ft
 - 3,000 ft

CHAPTER 8 ► CONSTRUCTION SAFETY

6. What is the farthest away that an egress ladder can be located from a worker in a trench excavation greater than 4 ft in depth?
 - A. 15 ft
 - B. 25 ft
 - C. 35 ft
 - D. 50 ft
7. Which of the following ratios of vertical rise to horizontal run is acceptable for a supported scaffold that is not braced or tied back to a structure?
 - A. 1:1
 - B. 2:1
 - C. 3:1
 - D. 4:1
8. What is the minimum load that a suspension scaffold must be designed to?
 - A. 5,000 lb
 - B. 10,000 lb
 - C. three times the intended load
 - D. four times the intended load
9. What is the average noise level for which hearing protection is required to be worn?
 - A. 85 dB
 - B. 90 dB
 - C. 95 dB
 - D. 100 dB

OSHA ADMINISTRATION ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | C. | 2. | B. | 3. | B. |
| 4. | C. | 5. | D. | 6. | B. |

SAFETY PROCEDURES AND INTERPRETATION ANSWERS:

- | | | | | | |
|----|----|----|----|----|----|
| 1. | A. | 2. | D. | 3. | C. |
| 4. | D. | 5. | C. | 6. | B. |
| 7. | D. | 8. | D. | 9. | A. |

Qualification of Content

This Study Guide was written for the sole purpose of preparing for the AIC Certified Associate Constructor exam. It does not provide a comprehensive exploration of the OSHA standards or regulations and should not be used in preparing or managing a job-site safety plan. Consult the OSHA standard and/or a qualified construction safety professional for additional information.

CAC EXAM: STUDY GUIDE



CHAPTER 9

CONSTRUCTION GEOMATICS

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SURVEY EQUIPMENT

GEOMATICS

Surveying, which has more recently been referred to as *geomatics*, is the practice of determining the positions of points on and beneath the earth. Geomatics is geometry in practice and is essential for all but the most basic construction projects.

UNITS OF MEASURE

Surveying commonly provides to the builder the length, area, volume, and angles of the building or site. The units used in the United States are most typically based on the English (Imperial) system of feet, yards, and acres. However, most of the rest of the world uses the International System of Units (SI), which uses meters, kilometers, and hectares. The chart shown in Figure 9-1 shows the most typical units used and their conversions.

Figure 9-1 Units of Measure

Unit of Measure	Conversion
1 centimeter (cm)	.39 in.
1 meter (m)	100 cm 39.37 in.
1 kilometer (km)	1,000 m .62 mile
1 square meter (sq m)	10.76 sq ft 1.20 sq yd
1 hectare	10,000 sq m 2.47 acres
1 mile	5,280 ft 1,609 m

EQUIPMENT

There is a wide range of equipment used in surveying. In fact, the tools available to the surveyor have dramatically increased in recent years with the development of GPS satellites and smart instruments. This section will provide an overview of some of the fundamental equipment used and their primary functions.

Stakes, Ribbons, and Nails

Locations of points are often identified by the surveyor with stakes, ribbons, and nails. Stakes, commonly 1.5 in. × 1.5 in. pine or metal, are driven into the ground so that the head of the stake is at

the desired elevation. Colored ribbon is used to make the stakes more visible. In addition, the ribbon color may denote a particular aspect of the survey. Different colors may mean a different part of the survey, such as building footprint, below-grade utility, or lot line. Nails are often driven into existing surfaces that will not move to denote a set, fixed point to reference from. For example, a nail may be driven into a large tree or asphalt parking lot and used to establish an elevation point that other elevations can be set from.

Plumb Bobs and String

Plumb bobs and string are used to show a line that is perfectly perpendicular to the horizontal plane of the earth. Plumb bobs have a heavy weight suspended by a string. As gravity pulls it straight down, the line created can be used as a reference plane for other vertical surfaces. An example of a plumb bob is provided in Figure 9-2.

Figure 9-2 Plumb Bob



Reprinted Courtesy of Tajima Tool Corp., 2015

Surveyor's Measuring Tape

Surveyor's measuring tapes are used to determine the distance between two points, most typically in the horizontal direction. Most measuring tapes come in 100-ft, 200-ft, and 300-ft lengths and are often made of fiberglass, PVC, or steel. Although steel is very durable, it may expand in the heat, providing an inaccurate reading. Correction factors to account for expansion at high temperatures may be included with the instrument. An example of a measuring tape is provided in Figure 9-3.

Figure 9-3 Long Measuring Tape

Reprinted Courtesy of Keson Industries, Inc., 2015

Levels and Rods

A dumpy level is a piece of equipment that is mounted to a tripod and can move 360° horizontally. The level is mounted so that it is plumb and level with the horizontal plane of the earth. (Some levels are automatic leveling, or self-leveling.) The surveyors can then look through the lens of the level and turn it 360°. The horizontal angle can be recorded with this instrument. A leveling rod, sometimes called a grade rod, is a long stick with dimensions that extend from the base to the top of the rod; it is used as a target for the level. There are several types of rods, such as Florida, California, and Detroit rods; however, the most common is the Philadelphia rod. The Philadelphia rod is a telescoping wooden rod made from two wooden lengths. The wooden lengths have dimensions provided in hundredths of a foot. The rod is then placed vertically, and the distance from the base of the rod is read with a level, transit, or other instrument. The level is then used in combination with the rod to determine the elevation of two points in relation to each other in a process called differential leveling. With differential leveling the elevation of a fixed/known point is used to calculate the elevation of a second unknown point. Differential leveling will be elaborated on more later in the chapter. See Figure 9-4 for an example of a common builder's level.

Figure 9-4 Builder's Level

Reprinted Courtesy of Johnson Level & Tool Mfg. Co., Inc., 2015

Transits and Theodolites

Transits and theodolites are similar to levels in that they all are used to measure horizontal angles; however, transits and theodolites are also used to measure vertical angles. Transits and theodolites serve the same basic function; however, theodolites are more modern and have a few more automatic features. A sample theodolite is provided in Figure 9-5.

Figure 9-5 Theodolite

Reprinted Courtesy of Johnson Level & Tool Mfg. Co., Inc., 2015

Total Station

A total station, or TST (total station theodolite), is a commonly used piece of modern survey equipment that provides the functions of a measuring tape, level, and theodolite. Lasers are used to determine the distance between two points,

and the instrument can determine the angle between them. Internal programming calculates other information based on the recorded distance and angles. Robotic total stations have servos, which allow the instrument to move on its own and be remotely controlled by the operator. This allows a single surveyor to operate the total station remotely, whereas in the past one surveyor was needed for the grade rod and another to operate the TST. An example of a robotic total station is provided in Figure 9-6.

For more information see Ghilani & Wolf and Roberts in the list of references.

Figure 9-6 Robotic Total Station



Reprinted Courtesy of Robert Bosch Tool Corporation, 2015

SURVEY EQUIPMENT STUDY QUESTIONS

- Which of the following pieces of equipment does not measure vertical angles?
 - builder's level
 - theodolite
 - transit
 - robotic total station
- What type of telescoping rod is often used with levels, transits, and total stations?
 - Alachua rod
 - Leon rod
 - Pinellas rod
 - Philadelphia rod

- How many feet are in 1 mile?
 - 12
 - 100
 - 5,280
 - 12,000

TOPOGRAPHIC SURVEY

TOPOGRAPHIC MAP

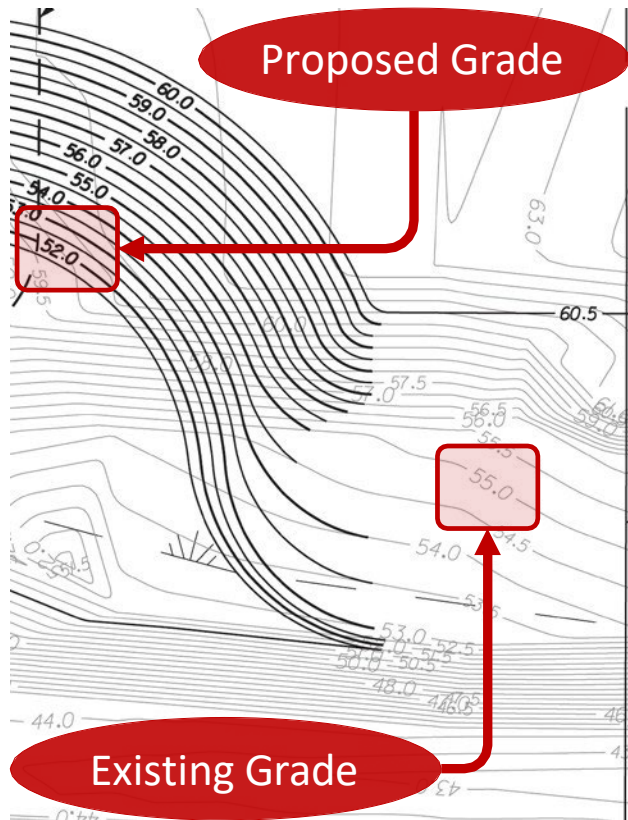
A topographic survey, or simply a topo survey, is a graphical representation of natural and man-made features in a fixed area. These maps typically show elevations of the earth, property lines, existing buildings, and any other relevant information for the builder. Typically, the civil engineer is responsible for obtaining an existing topo survey of the site if it exists or developing a new one for the builder. Before relying on the topo map, which is typically provided in the civil plans, the contractor should field verify the major features shown to make sure things have not changed since it was created and that nothing was omitted from the plan. In general, of all of the prints in the contract documents, the topo survey will likely be the least accurate.

Percentage Grade

The incline, or slope of grade, is often given as a percentage. The percentage is calculated simply by dividing the horizontal increase in height (rise) over the same horizontal length (run) and then multiplying it by 100. For example, a road that is 100 yd long and has an incline of 10 yd would have a grade of 10%. To put this into perspective, the world's steepest paved public road, located in Dunedin, New Zealand, has a grade of 35%. Generally, a maximum 6% grade is allowed for U.S. highways.

Contour Lines

Topographic surveys are most commonly used in construction to show the elevations of the existing grade and the proposed grade. This is shown on the topo survey with contour lines. In general, lightly shaded or dashed contour lines denote the existing elevation, and bolded or solid lines denote the proposed elevation. Elevations are typically shown on the contour lines. Lines close together denote a steep elevation change, and contour lines far apart show a more gradual slope. See Figure 9-7 for an example of existing and proposed contour lines.

Figure 9-7 Topographic Contour Lines

Reprinted Courtesy of H.W. Lochner, Inc., 2015

For more information see Ghilani & Wolf and Roberts in the list of references.

TOPOGRAPHIC SURVEY STUDY QUESTIONS

- If a 1,000-ft road has a vertical rise of 10 ft what percent incline does the road have?
 - 0.01%
 - 0.10%
 - 1%
 - 10%
- The contour lines showing the existing grade on a topographic survey are commonly _____.
 - bold solid lines
 - highlighted solid lines
 - colored dashed lines
 - lightly colored dashed lines

- What do contour lines that are spaced closely together indicate?
 - slight slope
 - steep slope
 - direction of erosion
 - direction of water runoff

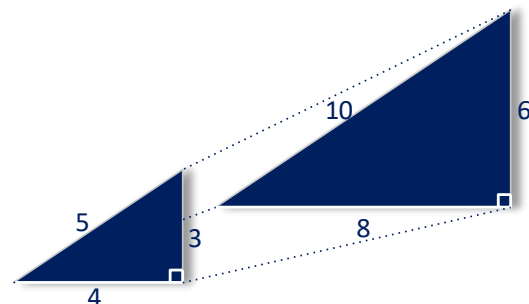
CALCULATIONS

TRIGONOMETRIC FUNCTIONS

As mentioned earlier, surveying is a practical application of geometry. Although this is true, it is also an application of trigonometry. The basis of many applications of surveying is the use of right triangles and using two knowns, such as length of a side or angle, to determine the remaining angles and lengths of sides. The first basic concept is the Pythagorean theorem. Using the formula below, the length of any two sides (a and b) can be used to determine the length of the third side (c).

$$a^2 + b^2 = c^2$$

The second basic concept is that of a 3-4-5 right triangle. This is a common ratio where the lengths of the three sides of the triangle are 3, 4, and 5 units. The unit of measure doesn't matter as long as all sides are expressed in the same unit. Because this is a ratio, multiples of 3, 4, and 5 can be used for other right triangles, such as 6 in.-8 in.-10 in. or 30 ft-40 ft-50 ft. See Figure 9-8 for an example.

Figure 9-8 3-4-5 Right Triangle

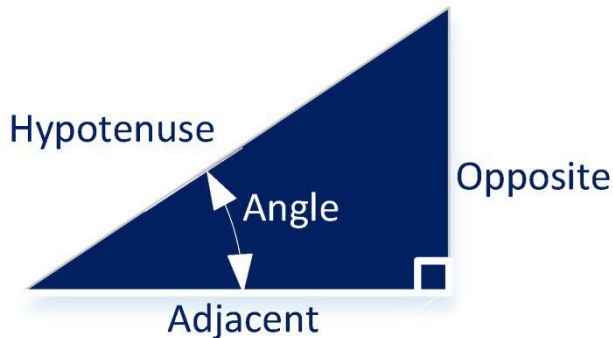
There are trigonometric functions that allow the surveyor to be able to determine a leg of a triangle given an angle and the length of another leg. A scientific calculator is needed for this calculation. The formulas are provided below and illustrated in Figure 9-9.

$$\text{Sin of Angle } \theta = \frac{\text{Opposite Side}}{\text{Hypotenuse}}$$

$$\text{Cos of Angle } \theta = \frac{\text{Adjacent Side}}{\text{Hypotenuse}}$$

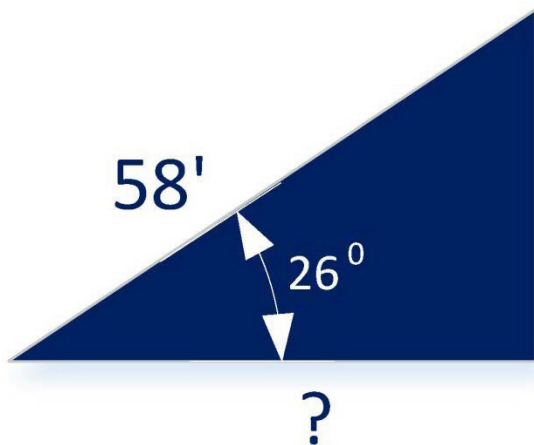
$$\text{Tan of Angle } \theta = \frac{\text{Opposite Side}}{\text{Adjacent side}}$$

Figure 9-9 Trigonometric Functions



Example 1: This example will demonstrate the steps for how to find the length of one side of a right triangle given the other side and one angle. Assume a sidewalk is 58 ft long. The 58-ft side (hypotenuse) of the sidewalk intersects with a street at an angle of 26°. What is the horizontal distance of the sidewalk (adjacent side)? See Figure 9-10 for a diagram of the variables.

Figure 9-10 Example of a Trigonometric Function



Select the most appropriate of the Sin, Cos, and Tan formulas. In this case, because the angle and hypotenuse are known and we want to solve for the

adjacent side, the Cos formula is most appropriate. To solve for the adjacent side, 58 is multiplied by the Cos of the angle. The value of the Cos 26° is 0.89879. Multiplying 58 ft by 0.89879 will result in the length of 52.13 ft of the adjacent side.

$$\text{Cos of Angle } \theta = \frac{\text{Adjacent Side}}{\text{Hypotenuse}}$$

$$\text{Cos of Angle } 26 = \frac{\text{Adjacent Side}}{58}$$

$$.8988 = \frac{\text{Adjacent Side}}{58}$$

$$\text{Hypotenuse} = 52.13 \text{ ft}$$

Example 2: Assume you are placing gravel on a temporary driveway that is 10 ft wide × 1 ft thick. The plans show the drive is 150 ft horizontally (adjacent). How much higher (opposite) is the top of the driveway from the bottom assuming an incline of 28°?

$$\text{Tan of Angle } \theta = \frac{\text{Opposite Side}}{\text{Adjacent Side}}$$

$$\text{Tan of Angle } 28 = \frac{\text{Opposite Side}}{150}$$

$$.5317 = \frac{\text{Opposite Side}}{150}$$

$$\text{Adjacent} = 79.8 \text{ ft}$$

DIFFERENTIAL LEVELING

The term *leveling* refers to the process whereby the elevations of points on a map or survey are determined. One of the most common ways of leveling in construction is the technique of *differential leveling*. This technique uses a telescope with magnification, such as a level or transit, to read dimensions on a grade rod in reference to a known benchmark elevation.

Datum Elevation

The datum elevation, or vertical datum, is a base plane from which all other points and elevations are referenced. All points shown on the

survey are either above or below the datum plane. The most common datum elevation used is mean sea level, or MSL, which is the elevation of oceans, gulfs, and major bodies of water averaged over several years.

Benchmarks

For most projects, a benchmark point is established and then used as a reference point throughout the project. The benchmark point is commonly a mark or nail placed on some object that will not be disturbed throughout the life of the project, such as a utility pole, concrete curb, or other fixed point. This point will be in reference to a major plane of the future building, such as the slab-on-grade of the first floor. The major plane will be given an arbitrary elevation, such as 0 ft 0 in. or 100.0 ft, for easier calculations by the contractors.

Leveling

Differential leveling is the process of using telescopes or other leveling instruments to transpose an elevation from a known benchmark elevation to other points whose elevations are not known. The instrument is level with the datum plane and can read the measurements of grade rods that are in its line of sight and its horizontal plan. The process is demonstrated in Figure 9-11. The instrument reads the *backsight* (BS) of the grade rod, which is located on top of the known benchmark point. The *height of instrument* (HI) is then calculated. The instrument is then turned to the grade rod above the point whose elevation is not known. The *foresight* (FS) is reading the dimension on the rod on the unknown elevation point. Differential leveling can be expressed in two formulas:

$$HI = \text{elevation} + BS$$

and

$$\text{Elevation} = HI - FS$$

In Figure 9-11, the benchmark elevation is set at 100 ft. When the backsight is read the horizontal plane of the level is 10.0 ft. In other words, the surveyor would read the 10.0-ft dimension on the grade rod. The height of the instrument is the addition of the benchmark elevation plus the backsight.

$$HI = \text{elevation} + BS$$

$$HI = 100 + 10$$

$$HI = 110$$

The elevation of the second point can be calculated similarly. Using the formula below, the foresight is subtracted from the height of the instrument.

$$\text{Elevation} = HI - FS$$

$$\text{Elevation} = 110 - 2$$

$$\text{Elevation} = 108$$

This process can be repeated if the elevation point desired is not in the benchmark point's line of sight. In this case, the point solved for would be the first *turning point* (TP). The instrument would be set up at another location closer to the final point and essentially use the TP as the next benchmark. This process would be repeated as many times as needed to collect all of the required elevations. The observations are recorded as field notes. A sample field note entry is provided in Figure 9-12. In this case there are three intermediate points (IPs), denoting that the process described earlier was repeated three times.

For more information see Ghilani & Wolf and Roberts in the list of references.

Figure 9-11 Example of Leveling

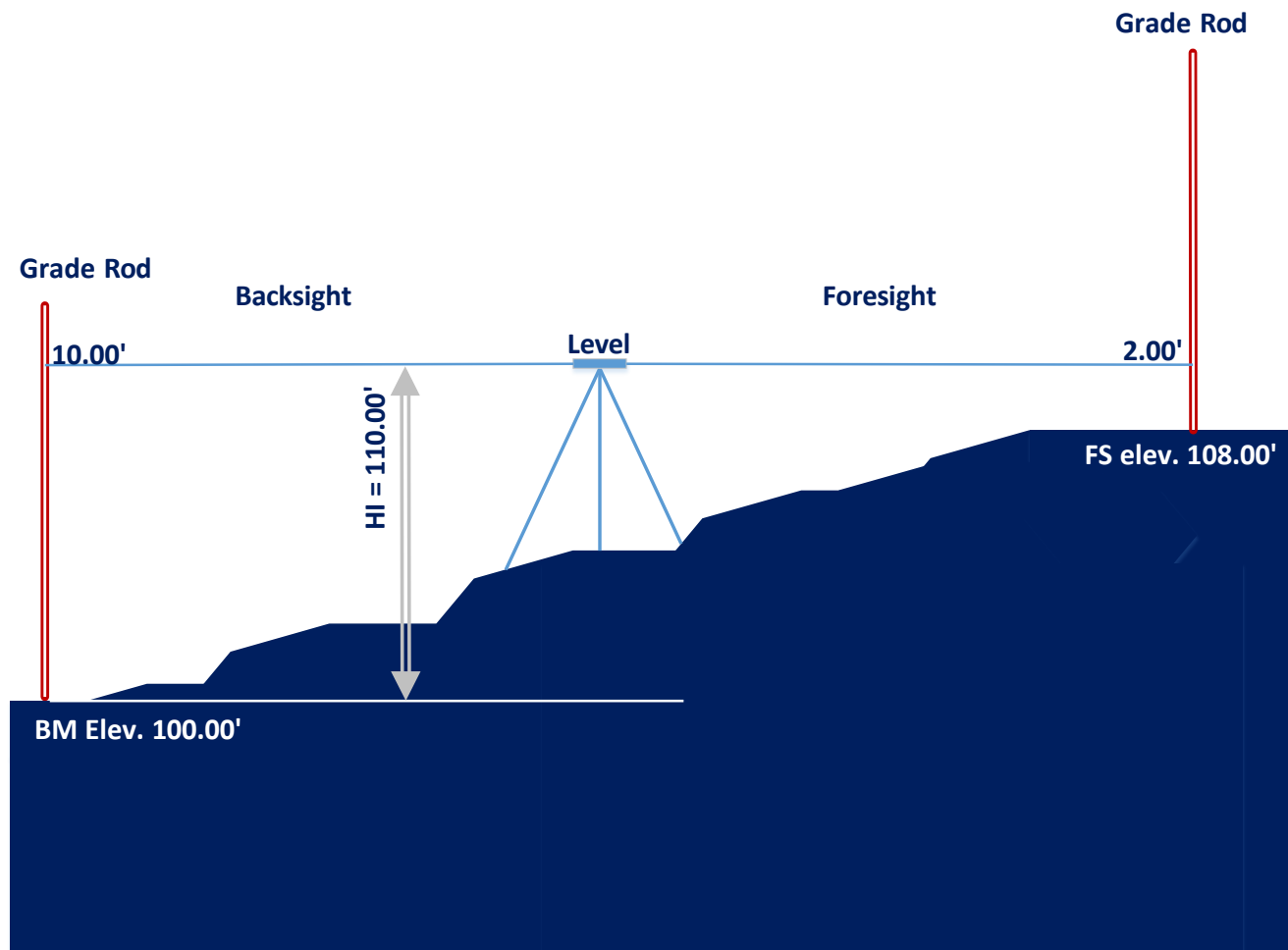


Illustration by author

Figure 9-12 Example of Field Notes

IP	BM Elev.	BS Rod Reading	HI	FS Rod Reading	TP Elev.
1	843.29	4.68	847.97	5.91	842.06
2	842.06	3.17	845.23	3.94	841.29
3	841.29	5.05	846.34	4.72	841.62
4	841.62				

CALCULATION STUDY QUESTIONS

1. A rectangular slab on grade is 60 ft 0 in. long $\times$ 45 ft 0 in. wide. What is the diagonal measurement in feet and inches?
 - A. 52 ft 6 in.
 - B. 75 ft 0 in.
 - C. 105 ft 8 in.
 - D. 115 ft 11 in.
2. Assume you have a right triangle with a hypotenuse of 310 ft. If one of the angles is 20° , what is the length of the side that is opposite this angle?
 - A. 106.03
 - B. 112.84
 - C. 291.09
 - D. 851.73
3. A rod reading of 4.72 ft is taken on a benchmark whose elevation is 813.30. The finish floor is 809.00. The top of the batter board is set 1 ft above the finish floor. What rod reading is required to set the line for the top of the batter board?
 - A. 4.30
 - B. 5.30
 - C. 8.02
 - D. 9.02
4. What does the surveying abbreviation TP mean?
 - A. tangent point
 - B. turning point
 - C. traverse point
 - D. terminal point
5. Using Figure 9-13, what is the benchmark elevation at IP #4?
 - A. 864.62
 - B. 889.90
 - C. 896.27
 - D. 902.64
6. You are required to establish grade to the bottom of a footing that is 1 ft thick. The elevation at the top of the footing is 102.33 ft. The backsight of the instrument on the benchmark of 100.00 ft is 6.78. What is the correct reading of the rod at the bottom of the footing?
 - A. 0.64
 - B. 3.81
 - C. 4.45
 - D. 5.45

Figure 9-13 Field Notes for Calculation Study Question #9

IP	BM Elev.	BS Rod Reading	HI	FS Rod Reading	TP Elev.
#1	877.26	7.45		3.1	
#2		7.12		1.1	
#3		4.44		2.17	
#4	???				

SURVEY EQUIPMENT ANSWERS:

1. A. 2. D. 3. C.

TOPOGRAPHIC ANSWERS:

1. C. 2. D. 3. B.

CALCULATION ANSWERS:

1. B. $60^2 + 45^2 = \text{diagonal}^2 = 75 \text{ ft}$
2. A.
3. C. $(813.3 + 4.72) - 810 = 8.02$
4. B.
5. B.
6. D. $(100 + 6.78) - (102.33 - 1) = 5.45$

CAC EXAM: STUDY GUIDE



CHAPTER 10

PROJECT ADMINISTRATION

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PROCUREMENT OF RESOURCES

PROCUREMENT

Gould and Joyce define procurement as “the overall process of finding and purchasing the materials . . . and hiring the best subcontractors to build the project.” The procurement phase of construction is often referred to as the *bidding and award* phase and is traditionally the time between the design and construction phases.

Subcontractor

For most commercial construction projects, a general contractor will oversee and supervise the construction, but will hire subcontractors to actually put most of the work in place. The general contractor writes contracts with the subcontractors that identify the exact scope of work they are responsible for. Generally, the subcontractors are required to provide all labor, equipment, and material needed to perform their scope of work. Often, subcontractors will sub-subcontract out portions of their contracted work. Just like the general contractor is ultimately responsible to the owner for their subcontractors’ work, so is the subcontractor responsible for their sub-subcontractors’ work.

Great care should be taken in which subcontractors are allowed to bid a job. General contractors often prequalify subcontractors prior to allowing them to bid their projects. Subcontractors are screened to make sure they have the financial stability, past experience, safety record, and overall competence needed to successfully carry out the work. General contractors should be cautious in awarding a subcontract if their prices are significantly lower than their competitors’, which indicates there may be an estimating mistake. Subcontractors who misestimated a job may be less cooperative, have an overly narrow interpretation of the contract, and generate excessive change order requests in an attempt to correct their preconstruction mistake.

Material and Equipment

The hiring of subcontractors by the general contractor is a time-consuming process. The scope must be bid out, the bids evaluated, and the terms of the contract negotiated. Because this is a lengthy process, it is important to prioritize which contracts get bought out first. The order of priority is generally driven by either which material is needed first or by how long it takes to procure the material.

For example, the building shell contractor is often one of the first packages bought out not because concrete takes a long time to procure but because the concrete footings are predecessors to most other activities. Conversely, the glazing contract may also be one of the first packages bought out because it is an early activity but because of the long lead time of glass. Still another example is the elevator contractor who is typically bought out early because of the need to coordinate that work with other trades.

In general, subcontractors are responsible for purchasing the material and equipment associated with their scope of work; however, there are exceptions. There are cases, such as with phased construction, when the owner or construction manager will order long-lead-time material or equipment while the rest of the scope is bid out. This has the advantage of accelerating the overall schedule as well as saving the subcontractor’s overhead and profit on the equipment. Furniture, fixtures, and equipment (FF&E) is often either owner furnished/owner installed (OFOI) or owner furnished/contractor installed (OFICI). In both cases, the contractor’s scope of work is limited; however, the contractor is still required to coordinate the material installation with the owner.

For more information see Gould & Joyce in the list of references.

Ethics

There is an expectation that general contractors keep the bids of the subcontractors confidential. The act of showing subcontractors their competitors’ prices in the hope that they will lower their bid is called *bid shopping* or *bid peddling* and is considered very unethical. Not only is it considered unethical; in some states it is illegal. In an attempt to limit bid shopping, some owners, especially on publicly funded projects, will require the general contractor to list their subcontractors on the bid form and require their use as a condition of the award.

For more information see Holm, Schaufelberger, Griffin, & Cole and Dagostino & Peterson in the list of references.

PROCUREMENT PROCESS

Although there are exceptions, the process of procuring labor, material, and equipment should proceed according to the following steps:

1. *Bid scope of work:* Once the design is complete, contract documents should be sent to several contractors (three or more is generally acceptable) to price a specific scope of work.
2. *Award:* The bids from the contractors are evaluated to ensure they have a complete scope of work and compliance with the bid documents. The successful contractor is notified that their bid was accepted with a *letter of intent* or *notice of award*. The receipt of this notification authorizes the contractor to start precontract administrative activities, such as generating submittals, acquiring insurance, and obtaining bonding.
3. *Contract:* After the bids are evaluated, a formal contract with the scope of work is negotiated and agreed to by the parties. Specific conditions, such as freight costs, taxes, bonding, accounting terms, warranty terms, and insurance costs, must be allocated to the appropriate party.
4. *Submittals:* The submittals, which include product/material data, shop drawings, and samples, are provided by the subcontractor and reviewed by the prime contractor and the design team. The contractor and designer check for general consistency to the contract document. Reviewed submittals do not supersede the contract documents, and if discrepancies exist, either before or after the review, the contract documents govern.
5. *Order material and equipment:* Only after the submittals have been reviewed can material be ordered. The document used with freight companies, which are commonly referred to as *common carriers*, is called a *bill of lading*. The shipping term *freight on board* (FOB) refers to when ownership of the material is transferred. *Freight on board job site* means that the vendor has ownership of the material until it arrives at the job site.
6. *Installation and invoicing:* Once the material is on-site it can be installed. Typically, the contractor can bill for the material even if it isn't installed in their next billing cycle.

Accounting Terms

Sometimes vendors require that payment be made in full at the time of delivery. This is commonly referred to as *COD*, or *collect on delivery*. Although this payment term exists, payment isn't typically due

for 30 days from the date the material is received. To improve their cash flow, vendors may provide an incentive to the contractor for early payment. Terms such as 1/10 Net 30 are provided, which means that if payment is provided within 10 days a 1% discount is given but regardless full payment is due in 30 days.

PROCUREMENT OF RESOURCES STUDY QUESTIONS

1. What is the process of screening subcontractors before they bid a project to ensure they are capable of completing the work called?
 - A. prescreening
 - B. prebidding
 - C. preresourcing
 - D. prequalifying
2. What is the act of showing subcontractors the price of their competitors in the hope that they will lower their bid called?
 - A. bid looking
 - B. bid shopping
 - C. bid happy
 - D. bid capping
3. Which of the following statements is true about the procurement process?
 - A. Specific contract terms, such as taxes, bonding, and accounting terms, are always included with the bid.
 - B. Submittals are typically included with the bid.
 - C. Submittals must be approved before a contract is signed.
 - D. Submittals do not supersede the contract documents even if they have been reviewed by the general contractor and designer.

DUTIES AND RESPONSIBILITIES

CONTRACTOR POSITION DESCRIPTIONS

A commercial job site is staffed with personnel in a supervisor-subordinate relationship with each other. Traditionally, the positional hierarchy is arranged so that the project manager is ultimately responsible for the entire site. The field responsibilities are delegated to the superintendent, and the office responsibilities are retained by the project manager with support by project engineers and assistant project managers. The common roles and responsibilities of each of the contractor's project team members are provided below.

Project Executives

The specific title of this position may change from company to company but titles such as vice president of operations, construction manager, and project executive have often been used. These people oversee multiple projects and have many project managers report to them. Their role is to make sure the project is going well from a high level. They look at overall profitability, scheduling trends, and the relationship with the owner. They are rarely involved in the day-to-day operations but may attend owner/architect/contractor update meetings occasionally. Their salaries are often part of office overhead and not part of the site-specific general conditions. In addition to their involvement with the specific projects, they are also involved with senior leadership to set strategic goals and the direction of the company.

Senior Project Managers

Senior project managers (SPMs) are responsible for the overall success of the project. SPMs may be responsible for several smaller projects or one large project. Their daily responsibilities include developing/managing the overall project plan, drafting subcontracts and purchase orders, processing progress payments, scheduling, change orders, negotiating claims, and managing relationships with the owner and designer. They are also responsible for job-site HR responsibilities, such as evaluations and disciplinary actions.

Project Managers

The responsibilities of project managers (PMs) are the same as those of SPMs for small to midsize projects. On large projects, there may be multiple PMs to support the SPM. On these projects, the PMs will be assigned specific aspects of the project to manage, such as core and shell or the MEPs.

Senior Superintendents

Senior superintendents report to the SPMs or PMs. Their core responsibility is to the field. They are responsible for planning and scheduling construction activities, coordinating with subcontractors, maintaining daily logs and records, coordinating changes in the field, managing inspections, quality control and assurance, safety inspections, and all activities related to putting work in place.

Superintendents

The responsibilities of the superintendents are the same as those of the senior superintendents on small to midsize projects. On large projects there may be multiple superintendents to support the senior superintendent. On these projects each superintendent will be assigned to a particular aspect of the job. This could be several trades, such as concrete and steel, or a particular area or phase of the project.

Crew Leaders

The position of crew leader is commonly called a *field superintendent*. Their responsibilities are to support the superintendent in the field. They conduct activities such as leading crews for a specific task, preparing daily time cards, conducting safety inspections, performing manual labor in support of crews, and training new personnel.

Project Engineers

The project engineer position is often called a field engineer or assistant project manager depending on the company. Their core responsibilities are to support the project manager and superintendent although their career track generally follows a path that leads to project management. Specific activities they will be responsible for are managing submittals, requests for information (RFIs), and meeting minutes. Other responsibilities include taking field dimensions, negotiating minor change orders, scheduling updates, coordinating BIM files, tracking and documenting LEED points, creating punch lists, closing out documents, and anything else that may be required by the PM or superintendent to complete the project.

Other Positions

Other positions in a commercial construction company that are self-explaining include project scheduler, estimator, project accountant, job secretary, and marketing.

Trade Workers

There are a variety of titles of workers that correspond to their individual skills and trade. Many of these, such as bricklayers, carpenters, and drywallers, are self-explanatory. However, several may not be familiar and are described below:

- *Tapers or jointers*: seal the joints in drywall board or other types of similar board
- *Glaziers*: cut and install glass, plastic material, and mirrors for windows, curtain walls, and storefronts
- *Rodbusters*: fabricate, tie, and install reinforcing bars for concrete structures
- *Boilermakers*: fabricate and assemble structural steel for steam assemblies, such as boilers, pressure vessels, and pipes
- *Millwrights*: assemble and align rotating machines and equipment, such as turbines and pumps
- *Pipefitters*: fabricate and assemble high-pressure piping often in industrial settings, such as refineries, power plants, and water treatment facilities
- *Sheet metal workers*: fabricate and install HVAC ductwork
- *Operators*: operate machinery and equipment, such as backhoes, cranes, or skid steers
- *Iron workers*: fabricate and erect structural steel

LABOR LEGISLATION

There is a great deal of legislation regarding labor, so it is critical for managers to be familiar with the laws and what rules must be followed. The following sections provide a high-level summary of some of the most important legislation that has been implemented.

Fair Labor Standards Act

The Fair Labor Standards Act (FLSA) was originally passed in 1938 and is often referred to as the minimum wage law. It establishes a minimum wage, overtime pay, record-keeping requirements, and youth employment standards.

Illegal Immigration Reform and Immigrant Responsibility Act (IIRAIRA)

The IIRAIRA is an act of Congress to bolster existing immigration laws and ensure an applicant's eligibility to work in the United States. The primary way in which the eligibility is verified is with an I-9 form, which must be filed within three business days

of the employee's first day of employment. Proof of eligibility may be asked for by the employer and may include documentation such as a passport, permanent resident card, or combinations of other documentation. The I-9 should not be confused with a W-4 (Employee Withholding Exemption Certificate), which deals with paycheck tax withholdings. E-Verify is a new Internet-based system created by the federal government that verifies the I-9 and supporting documentation with the records of the Department of Homeland Security, Social Security Administration, and other government agencies (see Figure 10-1). It is a much faster and more accurate way of verifying the employment status of all workers. E-Verify does not replace the I-9 but improves the way it is filed.

Figure 10-1 E-Verify



Reprinted Courtesy of U.S. Citizenship and Immigration Services

Civil Rights Acts

There are various civil rights acts that have been passed that prohibit discrimination in the workplace. The first of these is the Civil Rights Act of 1965, and it has been expanded with the Age Discrimination in Employment Act of 1967, Americans with Disabilities Act of 1990, and the Civil Rights Act of 1991. All of these acts of legislation protect employees from discrimination and harassment in the workplace on the basis of age, color, disability, gender, pregnancy, national origin, race, religion, sexual orientation, veteran status, and genetic information.

DUTIES AND RESPONSIBILITIES

STUDY QUESTIONS

- Which trade ties and places rebar?
 - rigger
 - rod buster
 - pile driver
 - iron worker
- Which job title traditionally has multiple project managers from the same project report to them?
 - project executive
 - senior project manager
 - senior superintendent
 - project engineer
- Which of the following documents is used to prove eligibility to work in the United States?
 - I-9
 - W4
 - IIRAIRA
 - 1099

JOB-SITE MOBILIZATION

FIELD OFFICE

Most commercial projects necessitate some kind of field office to manage the project. For projects on an existing campus, existing facilities near the site are often used. For projects on virgin land or if existing facilities are not available, temporary office trailers are used. These facilities are used for clerical work and paperwork storage, and they provide a safe place to store the permit documents and hold meetings. This is typically where the owner and designer will first arrive to inspect the job, and because of this, it should be kept clean and professional. Right or wrong, the condition of the temporary office is often seen as a litmus test for how well the project is being run. When equipping a temporary office, the following items should be considered:

- desks, chairs, conference tables, and other FF&E
- plan tables and plan racks
- filing cabinets
- temporary phone, fax, and data system
- toilet, lavatory, and kitchenette facilities
- heating and cooling
- janitorial services

- copy machine
- computers, server, and terminals (laptops/desktops)
- office supplies and stationary

For more information see Fisk & Reynolds in the list of references.

SUBMITTALS

One of the core responsibilities of the project engineer is the collection, review, coordination, distribution, and tracking of submittals. The term *submittal* is a general term that refers to product/material data, shop drawings, and samples required by the designer to be reviewed prior to installation. Which materials required to be submitted, the number of copies, and the specific information to be provided can be found in the technical specification section of the project manual. The purpose of the submittals is to verify that the contractor has understood the design intent and/or to complete the design to fulfill the designer's intent.

Submittal Process

In most cases, submittals are first assembled by the subcontractor. Product/material data, commonly called *cut sheets* are produced by the manufacturer of the material. Cut sheets provide the specific tests and standards that the material meets. It also may include the various options the material or equipment has and may be used by the subcontractor to order the material from the vendor. Shop drawings are different than product/material data sheets in that they are usually custom documents for the specific project. Shop drawings often resemble the designer's drawings except have a great deal more detail. The purpose of shop drawings is to show the designer the specific means and methods for meeting the design intent of the contract drawings. Approved shop drawings are then used to fabricate and install the material.

Once the subcontractor assembles the product data, shop drawings, and samples, the submittal package is formally submitted to the general contractor. There should be a transmittal that accompanies the submittal package that specifically indicates what is submitted, the number of copies included, and what the relevant specification sections are. The general contractor then reviews the package and verifies that what is submitted is consistent with the contract documents. In addition, it is the general contractor's responsibility to coordinate all of the trades' submittals to avoid conflicts. For example, the elevator submittals

should be coordinated with the structural steel shop drawings to make sure the shaft opening is the correct dimensions. The trade-specific information of the elevator shaft size won't be shown on the contract documents but is a critical means-and-methods responsibility of the contractor. After the review, the contractors put their stamps on the drawings indicating whether or not they accept the submittals. Most contractors' stamps will indicate whether the submittal 1) is accepted, 2) is accepted with comments, 3) needs to be revised and resubmitted, or 4) is rejected. Contractors will commonly use green ink for their review, architects will use red, and engineers blue.

If the general contractor accepts the submittal, they will transmit it to the architect for their review. If the submittal involves a trade or system for which the architect has hired an engineer to design, such as structural, civil, or MEP, then the architect will forward the submittal to them for their review. After the engineer reviews the submittal, they will transfer them to the architect, who then sends them back to the GC and ultimately back to the subcontractor. The architect and engineer will also stamp the submittal indicating whether they accept or reject the submittals as being in compliance with the contract documents. Under most contracts it's only after all parties have accepted the submittal that material can be ordered. This makes certain submittals critical and a very important early activity of the job.

Shop Drawing Approval

There is a great deal of misunderstanding as to what the acceptance or approval of the submittal means. In general, an approved submittal means that the parties have reviewed the submittal and it appears to be in compliance with the design concept. Submittal stamps will use very loose and noncommittal language. It is important to understand that submittals are not change orders and do not change the provisions or scope of the contract. If the wrong product was submitted but approved by the architect, it does not necessarily mean that it can be installed by the contractor. There is much case law surrounding misapproved submittals, which is beyond the scope of this study guide. However, as a general rule, any deviations between the submittal and contract documents should be clearly identified and brought to the attention of all parties, and if the proposed deviation is accepted, it should be formalized with

a change order or other contractual change document.

For more information see Fisk & Reynolds in the list of references.

DOCUMENTS USED IN CONSTRUCTION

There are many documents used in construction to authorize specific actions by the various parties. The following bullets summarize some of the most common.

- *Notice of award* and *letter of intent* are documents provided by the owner after the bid has been awarded but before a contract is issued. They are generally used to start the administrative process of going to contract while the final terms of the contract are negotiated. Typical activities these documents start are acquiring insurance, obtaining the bonds, and starting the submittals.
- *Notice to proceed* is a document that is issued by the owner after the contract is signed and is the formal start of the project. The date of the document is the formal start of the project and used to calculate when it is contractually required to be finished. The notice to proceed is also a certification from the owner that the site is clear of encumbrances and ready for the contractor to start their work unimpeded.
- *Stop work order* is a document typically issued by the owner ordering the contractor to stop all work on the project. The justification could range from owner financial issues, labor concerns, unsatisfied liens, or contractor's poor performance.
- *Schedule of values* is typically required at the beginning of the project and provides a breakdown of the cost of work. The schedule of values is most often used for progress payments.
- *Permits* are documents provided by the municipality having jurisdiction to approve the construction of a project based on the contract documents developed by the designer. The general contractor is typically responsible for acquiring the master permit; however, the specialty subcontractors may be required to obtain specialty permits, such as for the mechanical, electrical, and plumbing systems.

- *Certificate of substantial completion* is a document that indicates that the owner has accepted the building and that it can be used for its intended purpose. Typically, this starts the warranty period. Substantial completion does not mean that the project is finished because there is often a punch list and closeout documentation to complete.
- *Certificate of occupancy* is a document issued by the municipality having jurisdiction indicating that the building is safe to occupy, and it formally closes out the permit. This document does not mean the building is finished and is often a prerequisite for substantial completion. This document allows the owner to start installing their FF&E.
- *Request for information (RFI)* formally documents a question or request for clarification by the contractor to the designer. The response does not formally alter the scope, time, or price of the contract and should not be used as a substitute for a change order.
- *Record of as-built drawings* are documents maintained by the contractor that show all of the deviations and changes in installation of the work from how it was shown on the contract documents.
- *Change order* is the document that formally changes the cost, duration, or scope of the contract agreement. With AIA contracts, for a change order to be executed the architect, owner, and contractor must agree to the changes.
- *Construction change directive (CCD)* is a document issued by the owner/designer directing the contractor to proceed with changes to the work without necessarily agreeing to a price. The advantage of this document is that work can proceed without having to wait for the change order to be formally processed. However, if there are disputes on the price, the contractor has lost much of their negotiating leverage if the work has already been completed. With AIA contracts, construction change directives require agreement by the owner and architect to be valid.
- *Minor changes* is a term included with AIA contracts that allows architects, without necessarily having approval of the owner or contractor, to authorize small changes in the

work. Minor changes may affect cost and schedule, which would ultimately need to be reconciled with a change order.

- *Architect supplemental instruction (ASI)* is a document included with AIA contracts and used for minor changes in scope without any changes in schedule or costs.

CLAIMS AND DISPUTES

A construction claim is an unresolved request by the contractor for additional time or money as a result of a condition they believe is outside of the contract terms. Some of the most common causes for claims follow:

- slow change order, RFI, and submittal processing
- unresolved construction change pricing
- differing site conditions
- extreme or unusual weather conditions
- productivity loss from excessive change orders or miscoordination from owner/designer
- errors and omissions in contract documents

For more information see Fisk & Reynolds in the list of references.

Conflict between Plans and Specs

Rushed designs, compressed design budget/schedule, boilerplate specifications, and excessive design changes often lead to design documents that fail to adequately define the work to be performed by the contractor and can lead to claims and disputes. Often, systems and materials are described by both the plans and specifications. This arrangement creates a situation where discrepancies are easy to create. As a rule, when there is a discrepancy between the plans and the specifications, the specifications will govern.

Five Principles of Contract Administration

Fisk and Reynolds identify five principles of contract administration:

1. *The document must be read as a whole.* All provisions in the contract or contract document have meaning and may influence the interpretation of any single provision or clause of the contract.
2. *The documents will be construed against the drafter.* What this means is that when a reasonable dispute exists where both sides have valid claims, the documents will be interpreted against the party that drafted it.
3. *The documents supersede all previous discussion.* Oral commitments and all other understandings are superseded by the most current contract.
4. *Specific terms govern over general terms.* When conflicts occur, the courts have ruled that specific terms were crafted more intentionally to the specific situation and thus more aptly reflect the intention of the contract.
5. *Document must be read in the context of the trade.* Basically, the phrasing of the contract will be read and interpreted in the language (lingo) used by the parties to which it applies.

For more information see Fisk & Reynolds in the list of references.

CLAIM RESOLUTION

There are several techniques at the parties' disposal that are used to resolve claims. The four most common claim remedies are negotiation, mediation, arbitration, and litigation.

Negotiation

Negotiation is the best option when a dispute arrives. Negotiations involve all of the parties working out a solution among themselves without expensive outside involvement. Successful negotiations include compromises, and the negotiations should be entered into with the understanding that all parties are probably going to have to give up something. The expression "cooler heads prevail" is applicable with negotiations, and all proposed settlements should be weighed against the cost of counsel, court fees, and other legal expenses.

Mediation

Mediation is similar to negotiations but includes a neutral third-party mediator who assists with the negotiation. The mediation process is nonbinding, and any party can stop the process at any time. The mediator is often a skilled negotiator and looks for ways for both parties to reach an acceptable settlement. The cost for the mediator can range from a few hundred to a few thousand dollars a day, which is significantly less than arbitration and litigation.

Arbitration

Arbitration is a form of dispute resolution that is often included in the contract as a required alternative to litigation. The American Arbitration Association is the most well-recognized certifying body for arbitrators and is often referenced in contracts. Clauses in contracts, agreed to before the dispute occurred, often require arbitration as the means for formal dispute resolution and make their decisions legally binding. Arbitration is widely accepted as a faster and less costly alternative to litigation.

Litigation

The final option to claim disputes is formal litigation through the courts. This is generally considered the last resort because of the high cost of legal and court fees. The opinion of many contractors is that if a claim goes to litigation, it isn't a matter of winning but of who loses the least. Litigation is formally recorded and may be viewed by clients as a black eye and deter them from giving the contractor future work.

QUALITY CONTROL

It has been said that there are three legs to any construction project: cost, time, and quality. Quality is perhaps the least tangible but by no means least important. From the contractor's point of view, quality control is the act of ensuring that the building described in the contract document is built to the specified tests, standards, codes, tolerances, and design intent called for. However, quality doesn't just happen. Like everything else on a construction project, quality must be planned and managed. This is often referred to as a quality assurance/quality control (QAQC) plan. Each QAQC plan should be tailored to the specific job; however, there are several practices used to ensure the quality that the owner paid for.

Inspections and Testing

All buildings will need to be inspected as part of the building permit. However, the building code represents the minimum level of quality allowed. Additional inspections by the superintendent, project manager, special inspectors (waterproofing specialist for example), and subcontractors' executives/owners should be used to ensure the quality of work. It is often a good practice for the superintendent to inspect the work with the subcontractors' foremen to reinforce to the crews that quality is an important aspect of the project and will be monitored. Defective work should be redone without compromise. Exceptions bring only complications and headaches to the contractor later. It is also a good practice to invite the owner and designer to inspect work before it is concealed, such as before drywalling both sides of the wall or before installing the acoustical ceiling tiles.

Pre-Installation Meeting

Before subcontractors start on the job or before the start of a major portion of their work, a meeting with the project manager, superintendent, and subcontractor is recommended. At this meeting clear expectations of quality should be discussed along with how this quality is going to be achieved and assessed. Submittals and the specifications should be reviewed in addition to the plans. The manufacturers' recommendations and testing requirements, as indicated in the submittals, should be followed strictly.

Use of Qualified Contractors

Ideally, only contractors that have been prequalified should be allowed to bid. As part of the prequalification process, the subcontractors should demonstrate that they have the experience and qualifications needed to complete the scope of work to the specified standards. If the subcontractor is not prequalified, the burden is on the project manager to evaluate whether the subcontractor is capable of completing the job prior to awarding them the project.

Factory Inspections

Oftentimes, manufacturers will inspect the work for authorized contractors. The factory representatives have the most experience and expertise of their product. They will need to honor the warranty of the product so they are well motivated to honestly assess the installation.

Mock-Ups and Samples

A mock-up is a small sample of the work that will be installed on a large scale. Mock-ups are excellent tools used to give the owner and designer an accurate picture of the level of quality that can be expected with the finished product. The mock-up does not need to be without defects, although it should still be consistent with the requirements of the contract documents. If special attention is given to the mock-up and it exceeds the level of finish or quality that the owner purchased, the designer and owner may have false expectations, which can lead to disputes later in the project.

Stored Material

Care should be given to stored material to prevent it from being damaged. Depending on what type of material it is, it should be covered or protected in some other way. It should also be located away from high-traffic areas to minimize the chance of accidental damage. If possible, material on-site should be minimized to reduce the chance of damage or theft.

For more information see Fisk & Reynolds in the list of references.

JOB-SITE MOBILIZATION STUDY QUESTIONS

- Which of the following documents is considered a submittal?
 - RFI
 - specification
 - change order
 - shop drawing
- Contractors typically mark up their submittals in which color?
 - green
 - red
 - blue
 - orange
- Who is most commonly responsible for creating shop drawings?
 - architect
 - owner
 - general contractor
 - subcontractor

4. Which of the following statements is true if the contract documents required #6 rebar but #5 rebar was submitted and approved by the general contractor and the architect?
 - A. The approval of the submittal allows the contractor to use the #5 rebar.
 - B. The approval of the submittal allows the contractor to use the #5 rebar only if a credit is provided.
 - C. A new submittal must be issued for the #5 rebar highlighting the change, but the material can be ordered.
 - D. The approved submittal does not change the scope of the contract documents.
5. Which of the following documents starts the contractor's schedule to complete the project?
 - A. notice of award
 - B. letter of intent
 - C. notice to proceed
 - D. start work order
6. Which of the following alternative dispute methods is often required by contract to resolve a claim?
 - A. negotiation
 - B. mediation
 - C. arbitration
 - D. litigation

PROJECT CLOSEOUT

CLOSEOUT AND TURNOVER

The final phase of a construction project is the closeout and turnover phase. This is the period of time when the punch list is completed, the building is operated and used by the owner, and the contractor receives their final payment. The process may seem simple but is actually fairly involved. Contractors often lament that getting the last 5% of their money is the hardest.

Substantial Completion

The term *substantial completion* is used to denote a specific point in the project when the owner can use the building for its intended purpose. The conditions that must be met to reach substantial completion vary by contract but generally include certificate of occupancy by the building department, approval by the fire marshal, lien releases for all work in place, and completion of all of the work except for minor punch list items. Usually the date of substantial completion is used to start

the warranty period; however, other terms such as *beneficial occupancy* or *final completion* may be used. Care should be taken when those phrases are used because they mean very different things.

Substantial completion is also important to the contractor because it triggers the release of retainage. Often, the release of retainage can concern owners because this eliminates the financial leverage over the contractor. It is important to discuss the steps and requirements of final completion with the owner in advance so when the time comes there is a clear process and set of milestones that have been agreed to prior.

Punch List

When the contractor is nearing project completion and they have done their own internal quality checks, they will call for the owner and designer to walk the project and generate their punch list. The punch list is a list of minor incomplete items or items that are unacceptable to the owner or designer. Generally speaking, the owner and designer get only one opportunity to generate this list, so the building needs to be very nearly finished before they will agree to create the formal punch list.

Closeout Documentation

As part of the closeout package, the contractor is required to provide the owner all of the closeout documentation. This documentation often includes multiple three-ring binders packed with operational and maintenance data, subcontractor contact information, warranty information, and all other information needed for the owner to take control and maintain the building. Many contracts require the contractor to meet with the owner's facility maintenance staff and train them face-to-face on the operation of the building. A good practice, whether it is required or not, is to video record the training. Attic stock is extra material or a small amount of unopened material that can be used by the owner during the normal operation of the building. A bundle of carpet square flooring or acoustical ceiling tiles is common and used to repair damage that occurs through normal wear and tear. If a building management system or energy management system is installed with the building, several meetings may be needed to turn over all of the passwords and other operational requirements to the owner's team. Because technology has become more common, closeout documents are often transmitted electronically as searchable files or included as a BIM model.

PROJECT CLOSEOUT STUDY QUESTIONS

1. Which of the following documents typically starts the warranty period?
 - A. final payment
 - B. substantial completion
 - C. completion of punch list
 - D. certificate of occupancy
2. Which of the following is a term used to describe minor incomplete or deficient items that need to be completed before final acceptance of a building?
 - A. punch list
 - B. deficiencies list
 - C. incomplete item list
 - D. pay for completion list

SUSTAINABILITY

SUSTAINABLE BUILDING

The term *sustainability* by definition means something's ability to maintain or sustain itself indefinitely. Charles Kibert indicates that "sustainable construction most comprehensively addresses the ecological, social, and economic issues of a building in the context of its community." Truly sustainable buildings with 100% renewable energy, closed material loops, and full environmental integration are very rare. However, green or high-performance buildings that provide incremental improvements toward sustainability are fairly common and becoming much more mainstream (Kibert). Green buildings use energy, water, and material more efficiently than traditional buildings and attempt to provide a healthier indoor environment for the occupants. In the United States, the most common tangible method for measuring the progression toward sustainability is the LEED rating system. A second but less common rating system in the United States is the Canadian-based Green Globe rating system. Other similar systems that are used internationally include BREEAM in the United Kingdom, Green Star in Australia, and CASBEE in Japan. All have similar goals but different methods for weighing and evaluating green building design.

For more information see Kibert in the list of references.

Leadership in Energy and Environmental Design

The U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) rating system is by far the most common commercial building green rating system in the United States. The first pilot version of LEED dates back to 1998 and continues to evolve with the newest version (v4) introduced in late 2013. LEED focuses on six major aspects of green building. The aspect of energy and atmosphere is given the highest priority.

- energy and atmosphere
- location and transportation
- sustainable sites
- water efficiency
- material and resources
- indoor environmental quality

LEED is a point-based system whereby buildings are awarded levels of certification (certified, silver, gold, and platinum) based on the number of points earned. The points are divided into categories that include the major focus areas listed above as well as categories for innovation and regional priority. LEED establishes minimum green requirements, referred to as prerequisites, that must be met to earn any certification. All other points are optional; however, enough of the optional points must be met to earn a certification.

The USGBC developed a system of credentialing individuals knowledgeable about the LEED rating system and green building in general. The first level is the LEED Green Associate, followed by the LEED Accredited Professional. They also offer the LEED Fellow, for those who have a distinguished career in green building and sustainability.

For more information see Kibert and Halpin & Senior in the list of references.

SUSTAINABILITY STUDY QUESTIONS

1. What is the most common green building rating system in the United States for commercial buildings?
 - A. Green Globes
 - B. LEED
 - C. CASBEE
 - D. Green Star
2. Which of the following is the initial LEED credential available to individuals?
 - A. LEED Green Associate
 - B. LEED V1
 - C. LEED Accredited Professional
 - D. LEED Lt

PROCUREMENT OF RESOURCES

ANSWERS:

1. D.
2. B.
3. D.

DUTIES AND RESPONSIBILITIES

ANSWERS:

1. B.
2. B.
3. A.

JOB-SITE MOBILIZATION ANSWERS:

1. D.
2. A.
3. D.
4. D.
5. C.
6. C.

PROJECT CLOSEOUT ANSWERS:

1. B.
2. A.

SUSTAINABILITY ANSWERS:

1. B.
2. A.



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INSTRUCTIONS FOR PRACTICE TEST

The following practice test contains 100 multiple choice questions similar to the ones you will find on the Level 1 Certified Associate Constructor Certification Exam. The number of questions in each section of the practice test is proportional to the weight of each subject category. A self-score matrix is provided with the answer key at the end of the test. Select the most correct answer provided.

COMMUNICATION SKILLS

1. What would be the most appropriate means for the contractor to communicate to the project owner an unforeseen condition not identified in the soils report?
 - A. Document the issue in the job diary
 - B. Issue a jobsite memorandum
 - C. Draft a construction report
 - D. Write a formal business letter
2. When is the best time to distribute the working agenda to the participants of a meeting?
 - A. As a follow-up to the meeting
 - B. At the beginning of the meeting
 - C. About one day after the meeting
 - D. About one day prior to the meeting
3. The contractor has tasked his project engineer with developing an agenda for a preconstruction meeting with the architect and owner. The project engineer has received numerous emails and RFIs from subcontractors and vendors requesting a wide range of information. Which document is most appropriate to distinguish between appropriate topics for the meeting and topics better addressed through other means?
 - A. General conditions
 - B. General requirements
 - C. Technical specifications
 - D. Supplementary conditions
4. What is the best time to distribute the meeting minutes to the participants?
 - A. At the beginning of the meeting
 - B. About one day after the meeting
 - C. About one hour prior to the meeting
 - D. About one day prior to the meeting
5. Which of the following statements is true about the use of texting as a means of communicating in the construction industry?
 - A. A means of easily and effectively documenting communication
 - B. Appropriate for clarifying but not for formal direction
 - C. Should be completely avoided in construction
 - D. Acceptable for communication if specifically allowed in the contract
6. A subcontractor identifies a significant discrepancy between the architectural and structural drawings. The subcontractor immediately meets with the general contractor at their construction trailer to discuss the discrepancy. The general contractor agrees that this could be a significant change depending on which of the drawings describes the designer's intent. Which of the following actions is the most appropriate in this situation?
 - A. Draft a change order proposal and arrange a meeting with the design team and owner to resolve the conflict.
 - B. Draft an RFI that describes the discrepancy in detail and submit it to the architect immediately.
 - C. Send a short text alerting the design team of the issue and discuss the discrepancy in detail at the next meeting.
 - D. Email the engineer of record to collect relevant background information and follow up with a formal RFI to the architect

7. What are the leadership skills needed to conduct a productive meeting?
 - A. Planning, probing questions, responding critically, and decision making
 - B. Planning, timing, coordinating, probing, responding critically, and following up
 - C. Listening attentively, responding constructively, soliciting all ideas, and matching decision making to the situation
 - D. Coordinating, listening selectively, responding critically, soliciting supportive ideas, and adjusting decision making to the situation
8. Which of the following statements made by the indicated parties below would least likely be made at an owner/architect/contractor progress meeting?
 - A. Contractor: "There are 14 unanswered RFIs on the log."
 - B. Superintendent: "A third party inspector will assist the supervision of the roofing installation."
 - C. Owner: "It is very likely, that change order proposal #23 will be accepted."
 - D. Project manager: "The bond rate for ABC subcontractor is 1.45%"
9. What is a listener's retention percentage of an oral conversation?
 - A. 10%
 - B. 50%
 - C. 60%
 - D. 90%
10. Which of the following communication methods is the most effective way to know that the communication has been understood?
 - A. The sender should ask closed-ended questions and tell the receiver twice.
 - B. The sender should ask open-ended questions and make them speak.
 - C. The sender should ask how they feel and their attitude toward the activity.
 - D. The sender should tell them what to do and get them back to work quickly.

11. Which of the following is the best example of an open-ended question?
 - A. Do you understand what work is supposed to be completed?
 - B. Do you know which shovel to get me from the tool shed?
 - C. What steps are you going to take to complete the activity?
 - D. How do you feel about completing the activities assigned?

ENGINEERING CONCEPTS

12. Which of the following statements about the following organizations and their justifications of its use is most appropriate when designers develop project specifications?
 - A. Organize building materials by International Building Code chapters to facilitate inspections by the authority having jurisdiction.
 - B. Only use materials tested by Underwriters Laboratories to ensure the highest quality and lowest flame spread rating.
 - C. Use the Construction Specification Institute's organizational system for categorizing construction materials into divisions and sections as it is widely used by the industry.
 - D. Use products endorsed by the American Society for Testing Materials to prevent the likelihood of structural failure.
13. Assume you have a simple beam 16 ft long supported on each end by R1 and R2. There is a concentrated load of 900 lb that is 4 ft from R2. Reaction R1 is pinned 12 ft from the load. Reaction R1 is 225 lb and R2 is 675 lb. What is the maximum bending moment in pounds per foot?
 - A. 900
 - B. 1,800
 - C. 2,700
 - D. 3,600

14. Assume that you are pouring a wall that is 151 ft 4 in. long, 14 ft high and, 1 ft 4 in. thick. The crew's daily placement rate is 375 cy per 8-hr day. How many hours will it take to complete the wall?
- 0.3
 - 2.2
 - 27.0
 - 58.8
15. Using the average soil weights from the table in Figure 1, what is the swell percentage of a loam soil?
- 8.3%
 - 23.8%
 - 31.9%
 - 81.0%
16. Using the psychrometric chart provided in Figure 2, what is the enthalpy of 2 lb. of air given a dry bulb temperature of 75° F and a relative humidity of 50%?
- 28 BTUs
 - 56 BTUs
 - 108 BTUs
 - 128 BTUs
17. An HVAC technician is inspecting an outside condensing unit of an air source heat pump in the summer. The unit is energized and appears to be operating normally. One of the refrigerant lines is cool to the touch and insulated. Which of the following statements is most likely true about this refrigerant line and the phase of the refrigerant in it?
- It is a suction line and the refrigerant is a gas at a relatively low pressure
 - It is a suction line and the refrigerant is a liquid at a relatively high pressure
 - It is a liquid line and the refrigerant is a liquid at a relatively high pressure
 - It is a condensate line and the refrigerant is a gas at a relatively high pressure
18. Which statement most accurately describes how a 3-phase, 120/208V load would be wired?
- One hot, one neutral and one ground conductor
 - Two hot and one neutral conductor
 - Three hot and one neutral conductor
 - Three hot conductors
19. Which fire protection system would be most appropriate for an unconditioned warehouse located in Chicago if the warehouse contains materials such as paper, wood and other type A combustibles?
- Wet pipe system
 - Dry pipe system
 - Deluge system
 - Clean agent system

MANAGEMENT CONCEPTS

20. The owner wants to fast-track a construction project. Which project delivery system best supports this process?
- Partnering
 - Design-bid-build
 - CM agency
 - Design-build
21. An owner has contracted with an engineering firm to address a sinkhole that has developed at the corner of an existing building. The engineer recommends pressure grouting the sinkhole at a minimum of three locations. The engineer estimates it will require between 100 and 250 cubic yards of grout. The engineer assists the owner develop the contractors' bid documents and the scope of work. Which type of contract would be most appropriate for this project?
- Unit price
 - Turnkey
 - Design-bid-build
 - Lump sum

- 22.** A contract is entered into in which the owner holds a contract with the architect and each trade contractor. In addition, the owner holds a contract with a management service company to perform the trade coordination, cost control, and scheduling services. What is this project delivery method called?
- Partnering
 - Joint venture
 - Design-build
 - Construction management
- 23.** A successful contractor operating as a sole proprietor is considering restructuring her company to reduce her personal risk. Which of the following would be the most appropriate action for her to take?
- Leave the company as a sole proprietorship and move the company assets into her personal accounts
 - Create a LLC by filing with the state in which she lives
 - Create a S corporation by filing with the IRS
 - Create a C corporation by filing in a county other than the one she lives in
- 24.** A project engineer has been tasked with writing a purchase order for a large steel package. The owner is a local municipality and is tax exempt. The project engineer is employed by a small business enterprise (SBE) registered with the federal government. When writing the purchase order, which law should be reviewed to ensure the basic rules governing the sale are complied with?
- Davis Bacon Act
 - Uniform Commercial Code
 - National Labor Relations Act
 - Uniform Transportation Code
- 25.** Which graphical measurement tool is a bar chart that displays a frequency distribution?
- Histogram
 - Pareto chart
 - Pie chart
 - Fishbone chart
- 26.** A contractor submits a bid for a large commercial project relying on a bid from a steel subcontractor. The contractor is awarded the project; however, when attempting to award the subcontract, the steel subcontractor retracts their bid. The next lowest steel bid was 10% higher. Which of the following is the most appropriate legal argument for the contractor to make if seeking restitution?
- Consideration intact
 - Legal purpose established
 - Promissory estoppel
 - Equitable adjustment
- 27.** Using the financial statements provided in Figures 3a and 3b, calculate the working capital for this company at the end of the year?
- \$176,177
 - \$733,154
 - \$1,463,403
 - \$1,633,389
- 28.** Using the financial statements provided in Figures 3a and 3b, calculate the current ratio?
- 0.47
 - 1.00
 - 2.07
 - 4.36
- 29.** Using the financial statements provided in Figures 3a and 3b, calculate the quick ratio (acid test)?
- 0.23
 - 0.48
 - 1.00
 - 2.07

MATERIALS, METHODS, AND PROJECT MODELING AND VISUALIZATION

- 30.** Which piece of equipment and attachment would be the most efficient method to excavate inside a cofferdam?
- Shovel with a 3-cy bucket
 - Backhoe with a 3-cy bucket
 - Crane with a clamshell attachment
 - Crane with an auger attachment

- 31.** Which of the following is the most efficient temporary form system to support freshly placed concrete poured continually in a vertical direction?
- A. Tilt-up form system
 - B. Flying form system
 - C. Lift slab form system
 - D. Slip form system
- 32.** Which CSI division contains the bidding requirements for a project?
- A. 00
 - B. 01
 - C. 01–49
 - D. 02–49
- 33.** A junior architect has been tasked with providing an additional product submittal requirement to the bid documents before they are released to the contractors. Where would the most appropriate place for the requirement be located?
- A. Revised invitation to bidders
 - B. General conditions in the contract agreement
 - C. Part 3 of the applicable section of the specifications
 - D. Supplemental conditions in the project manual
- 34.** The technical specifications reference ASHRAE as a publisher of numerous technical standards. What does the acronym ASHRAE stand for?
- A. American Steel Housing Rating Association of Engineers
 - B. Associated Structural Hoists Rating Association of Engineers
 - C. American Society for Heating, Refrigerating and Air Conditioning Engineers
 - D. Associated Society for Home Rating Air Equipment
- 35.** Select which party is typically responsible for designing temporary structural formwork?
- A. Owner
 - B. Engineer of record
 - C. Contractor/vendor
 - D. Architect
- 36.** Which of the following systems is designed to carry the total vertical load of a structure?
- A. Piling
 - B. Cofferdam
 - C. Timber shoring
 - D. Cribbing and tiebacks
- 37.** During a construction project, a contractor used an area of the site for parking. The site was originally vegetated with grass and small bushes before it was cleared for parking. After it rained, this area was often muddy causing trucks and equipment to get stuck. Gravel was put down on two separate occasions to mitigate this problem. The parking area is now scheduled to be built on. Which would be the most appropriate piece of equipment to compact the soil?
- A. Backhoe
 - B. Sheepsfoot
 - C. Smooth wheel roller
 - D. Wheel tractor scraper
- 38.** Using only the information provided in Figure 4, which concrete beam is most likely to be under the lowest tensile stress?
- A. 1B4
 - B. 1B10
 - C. 1B3
 - D. 1B5
- 39.** Using the information provided in Figure 5, which of the following is a claim that can be made?
- A. Contractor is to purchase a unit manufactured by McQuay
 - B. The unit must have a minimum SEER of 7.5
 - C. The unit has a cooling capacity under 1 ton
 - D. The roofing structure will not carry the dead weight of the unit

BIDDING AND ESTIMATING

- 40.** Which of the following items would not typically be included with the instruction to bidders (ITB) bid document?
- Insurance requirements
 - Description of the project
 - Subcontractors the prime contractor proposes to use
 - Date and time the bids are due to the designer
- 41.** Which party has the design liability for a prescriptive specification?
- Owner
 - Contractor
 - Architect/engineer
 - Code official
- 42.** The contractor submits a bid for \$1,303,071 with the appropriate forms. They receive a notice of award letter indicating that their bid has been selected. The contractor decides not to accept the contract. Which of the following statements is a likely outcome?
- They will lose the amount of their bond premium.
 - They will lose the amount of their bid bond face value.
 - As long as the letter or contract has not been signed, they can withdraw without ramifications.
 - They will lose the amount of their performance bond face value.
- 43.** Using the bond premium schedule below, what is the bond premium for a \$2,755,000 project?
- First \$5,000 = \$12.00/\$1,000
 Next \$2M = \$6,000 + \$7.25/\$1,000
 Next \$2.5M = \$20,500 + \$5.75/\$1,000
- \$19,974
 - \$45,373
 - \$55,974
 - \$66,341
- 44.** The plans call for the contractor to drive, pull, and salvage steel sheet piling 15 ft deep. The estimated quantity is 12,000 sq ft of contact area (SFCA). Given the crew makeup as shown in Figure 6, an 8-hr workday, and a crew daily output of 545 SFCA, how many total work hours are expended per day?
- 28
 - 32
 - 60
 - 100
- 45.** The plans call for the contractor to drive, pull, and salvage steel sheet piling 15 ft deep. The estimated quantity is 12,000 sq ft of contact area (SFCA). Given the crew makeup as shown in Figure 6, an 8-hr workday, and a crew daily output of 545 SFCA, what is the productivity rate expressed in work hours per unit (W/hr/Unit)?
- 0.059
 - 0.110
 - 9.083
 - 17.031
- 46.** Given a rectangular cofferdam that is 60 ft wide × 100 ft long and 10 ft deep and enclosed with a 3-ft toe, how many total SFCA are required for the sheet piling?
- 3,200
 - 4,160
 - 6,000
 - 60,000
- 47.** Given the information provided in Figure 7 for a rectangular cofferdam that is 60 ft wide × 100 ft long and 10 ft deep and enclosed with a 3-ft toe, approximately how many total board feet (BF) are needed for all of the cofferdam components, including waste?
- 16,164
 - 22,826
 - 25,565
 - 27,229

- 48.** Using the information provided in Figures 8a and 8b, how many cubic yards of concrete are needed for the walls (excluding foundation and slab)?
- 101
 - 120
 - 135
 - 155
- 49.** Using the information provided in Figures 8a and 8b, how many bank cubic yards of soil must be excavated and removed? Assume the existing grade is 204 ft and that excavated soil is being used for backfilling.
- 40
 - 350
 - 1,070
 - 9,633,601

BUDGETING, COSTS, AND COST CONTROL

- 50.** Using Figure 9a what is the budgeted unit work hours in work hours per unit for the column forms?
- 0.045
 - 0.171
 - 0.241
 - 5.838
- 51.** Using Figure 9a what is the weekly unit work hours in work hours per unit for the column forms?
- 0.007
 - 0.195
 - 4.919
 - 5.118
- 52.** Using the information provided in Figure 9a what is the to date unit work hours in work hours per unit for the column forms?
- 0.011
 - 0.241
 - 3.821
 - 4.148
- 53.** Using the information provided in Figure 9a what are the total earned work hours for the column forms?
- 19
 - 27
 - 465
 - 2,387
- 54.** Using the information provided in Figure 9a what is the total projected work hours at completion for the column forms?
- 27
 - 104
 - 602
 - 2,472
- 55.** Using the information provided in Figure 9a what is the projected gain/loss in work hours for the column forms?
- (174)
 - 325
 - 1,897
 - 2,396
- 56.** Using the information provided in Figure 9b what is the budgeted unit cost in dollars per unit for the concrete footings?
- 0.047
 - 21.45
 - 137.25
 - 256.00
- 57.** Using the information provided in Figure 9b what is the week labor unit cost in dollars per unit for the concrete footings?
- 0.70
 - 1.43
 - 3.14
 - 14.60
- 58.** Using the information provided in Figure 9b what is the to date unit cost in dollars per unit for the concrete footings?
- 0.32
 - 3.14
 - 20.13
 - 5,125.00

59. Using the information provided in Figure 9b what is the total projected cost at completion for the concrete footings?

- A. 81.41
- B. 803.84
- C. 5,150.72
- D. 10,615.00

60. Using the information provided in Figure 9c what is the current projection for the quantities of piles in vertical linear feet (VLF)?

- A. 680
- B. 5,300
- C. 5,980
- D. 6,700

PLANNING, SCHEDULING, AND SCHEDULE CONTROL

61. Which statement is true about the critical path?

- A. Is the shortest string of activities through the schedule
- B. Is the longest string of activities through the schedule
- C. Has zero total float but possibly some free float in the activities
- D. Includes all activities that are impossible to compress their duration any further

62. How is *free float* defined?

- A. The amount of slack in a node
- B. The amount of slack between activities
- C. The amount of slack within a series of activities
- D. The amount of slack accumulated throughout the logic network

63. Which types of activities are considered first when compressing the length of a project?

- A. Zero float and least cost to compress
- B. Zero float and highest cost to compress
- C. Highest floats and least cost to compress
- D. Highest floats and highest cost to compress

64. How is the term *fast tracking* defined in construction?

- A. Planning and scheduling the design
- B. Overlapping execution of the construction activities
- C. Finalizing the design and procurement before construction begins
- D. Overlapping execution of the design, procurement, and construction

65. What is the name of the term for shifting the activities within their available free floats to produce a uniform workforce and reduce the maximum resource usage requirements?

- A. Crashing
- B. Crew utilization
- C. Resource leveling
- D. Time-scaled networking

66. What is the best source for developing the list of activities for the logic network and schedule?

- A. General requirements
- B. Technical specifications
- C. Financial reports and balance sheets
- D. Estimate and earned work hour report

67. How is total float defined?

- A. The amount of slack in a node
- B. The amount of slack within an activity
- C. How much a series of activities can be delayed without delaying a project
- D. The amount of slack accumulated throughout the logic network

68. Using the information provided in Figure 10, what is the total number of days to complete this sequence of activities?

- A. 13
- B. 14
- C. 18
- D. 31

69. Using the information provided in Figure 10, what are the critical activities for this logic network?

- A. B, G
- B. A, C, F
- C. A, D, E, G
- D. A, C, F, G

- 70.** Using the information provided in Figure 10, what is the total float for activity B?
- A. 0
 - B. 1
 - C. 2
 - D. 8
- 71.** Using the information provided in Figure 10, what is the free float between activities B and G?
- A. 0
 - B. 2
 - C. 4
 - D. 6

CONSTRUCTION SAFETY

- 72.** The Safety Standards utilize the abbreviation 29 CFR Part 1926. What does the acronym CFR stand for?
- A. Code of Federal Register
 - B. Code of Federal Regulations
 - C. Construction Federal Register
 - D. Construction Federal Regulations
- 73.** Which part of the OSHA Standards is designated for record keeping?
- A. 5(a)(1)
 - B. 1904
 - C. 1910
 - D. 1926
- 74.** According to OSHA, which document must the supervisor complete immediately after an accident by describing the accident in detail?
- A. Insurance forms
 - B. OSHA's Summary of Work-Related Injuries and Illnesses (Form 300A)
 - C. OSHA's Log of Work-Related Injuries and Illnesses (Form 300)
 - D. OSHA's Injury and Illness Incident Report (Form 301)
- 75.** When and where must a project's OSHA Summary of Work-Related Injuries and Illnesses (Form 300A) be posted?
- A. All year long and easily accessible to all employees at the job site
 - B. All year long and in the project manager's office at the home office
 - C. February 11–April 30 and accessible to all employees at the job site
 - D. For three months and in the employees' break room at the home office
- 76.** According to OSHA, what is the name of the violation where the firm or designated person is aware that a hazardous condition exists, knows that the condition violates a standard, and makes no effort to eliminate the safety hazard?
- A. Willful violation
 - B. Serious violation
 - C. De minimis violation
 - D. Other-than-serious violation
- 77.** The pipefitting subcontractor is required to lay pipe in a trench that is 10 ft deep and 3 ft wide with vertical walls and no sloping or other protection. The trench was dug by the excavator. The general contractor supervised the work but had no employees in the trench. The concrete subcontractor told the general contractor and excavator that the trench needed to be sloped or shored before their employees could work in the trench. During the OSHA inspection, OSHA observed the general contractor at the trench supervising the pipefitter in the trench. Which contractor(s) would receive a citation for an unsafe trench?
- A. Pipefitting only
 - B. Pipefitting and excavator
 - C. Pipefitting, excavator, and general contractor
 - D. Pipefitting, excavator, general contractor, and concrete subcontractor
- 78.** What is the maximum horizontal travel distance to retrieve a fire extinguisher for a project under construction?
- A. 10 ft
 - B. 25 ft
 - C. 75 ft
 - D. 100 ft

- 79.** OSHA mandates that fall protection must be in place for difference in elevations greater than how many vertical feet?
- Any distance
 - 6 ft
 - 10 ft
 - 15 ft
- 80.** What is the elevation of the top guardrail from the floor to protect against falls on a leading edge?
- 21 in $\pm$ 1 inch
 - 25 in $\pm$ 2 inches
 - 35 in $\pm$ 3 inches
 - 42 in $\pm$ 3 inches
- 81.** How many feet must the side rails of an extension ladder extend beyond the upper landing service?
- 1 ft
 - 2 ft
 - 3 ft
 - 4 ft

CONSTRUCTION GEOMATICS

- 82.** The job site has a primary vertical control point with a reference benchmark of 100 ft. An instrument is set up with an HI of 5.42 ft above the BM. A grade stake is set at an elevation of 96 ft. What is the height reading on the rod at the grade stake?
- 1.42 ft
 - 4.00 ft
 - 5.42 ft
 - 9.42 ft
- 83.** Using the information provided in Figure 11, what is the benchmark elevation at IP #4?
- 864.62
 - 889.90
 - 896.27
 - 902.64
- 84.** A superintendent wants to check if a 25' high block wall is within tolerances. Which of the following tools and their use would be the most appropriate?
- Use a plumb bob to measure the vertical plane
 - Use a building level to determine its length
 - Use a total station to quantify the number of blocks
 - Use a pinellas rod to measure against a horizontal plane
- 85.** What issue would a surveyor most likely need to account for when using a steel 300' measuring tape?
- Tape stretching when pulling lengths
 - Calibrating the length markers on tape
 - Inconsistencies in markers between foot intervals
 - Expansion of the tape in warm weather
- 86.** Which of the following situations would be most advantageous for using an inverted philadelphia rod?
- Verifying a highway grid layout
 - Verifying the elevation of ceiling mounted ductwork
 - Verifying a building footing layout
 - Verifying the elevation of a piece of equipment
- 87.** A superintendent needs to layout the perimeter strip footings, batter boards and utility lines for a new structure adjacent to an existing building. Which single piece of equipment would be most useful to complete this task?
- Compound prism level
 - Dumpy level
 - Detroit theodolite
 - Total station
- 88.** Which of the following grades is common on U.S. highways?
- 4%
 - 15%
 - 50%
 - 96%

- 89.** A contractor is preparing a site logistics plan and notices on the site plan that at the north boundary of the project the topographical lines are very close together. Which of the following would likely be an appropriate action to take?
- A. Bring in additional fine grade fill
 - B. Evaluate alternatives to silt fencing
 - C. Locate the construction trailer there
 - D. Clear and grub that area at the start of the job

PROJECT ADMINISTRATION

- 90.** Which of the following contract documents would be inappropriate to use if the scope addressed material costs, labor units, rental equipment and taxes?
- A. Purchase order
 - B. Contract
 - C. Scope of work
 - D. Change order
- 91.** A clause in the Subcontract Agreement states that "the Subcontractor binds themselves to the Contractor for the performance of the Subcontractor's work in the same manner as the Contractor is bound to the Owner for such performance under Contractor's contract with the owner." Which category would this contract clause fall under?
- A. Flow down
 - B. Arbitration
 - C. Condition precedent
 - D. Promissory estoppel
- 92.** Which of the following terms is the most favorable to the purchaser?
- A. Cash on demand
 - B. 3/20 Net 60
 - C. 2/20 Net 60
 - D. 2/10 Net 20
- 93.** Which party typically obtains the general building permit?
- A. Owner
 - B. Subcontractor
 - C. Contractor
 - D. Architect/engineer
- 94.** If an employee wanted to increase the amount of taxes withheld from their paycheck, which would be the most appropriate form to ask for from the HR department?
- A. I-9
 - B. W-2
 - C. W-4
 - D. 1099
- 95.** Which of the following are the best steps when receiving materials?
- A. Inspect delivery, note damages, count items and compare to the bill of lading
 - B. Inspect delivery, note damages, count items and compare to the accounting terms
 - C. Review specifications, follow up on materials orders and call for delivery date
 - D. Award contract, vendor prepare shop drawings, fabricate, review and deliver
- 96.** A new hospital is in the preconstruction phase and the architect of record has drafted the project agreement. The agreement calls for the architect to be the initial decision maker for any contractor disputes that arise on the project including any claims that allege errors and omissions against them. The general contractor wants that provision stricken from the project agreement because they believe that the design team should not be ruling on their own potential errors or omissions. Which justification and action is the most appropriate?
- A. The clause is patently unethical and should be removed
 - B. Designers are unable to make unbiased ruling on their own work so it should be removed.
 - C. While not unethical, perceptions can be more important than reality and it should be removed.
 - D. If the designer does not render an opinion then the error and omissions insurance is voided and as such should remain.

- 97.** Which duties change as a person moves up an organizational chart?
- A. Technical skills increase and negotiation skills decrease
 - B. Administration skills decrease and technical skills increase
 - C. Analysis skills increase and communication skills increase
 - D. Communication skills decrease and administration skills decrease
- 98.** A contractor receives an invitation to bid a project located in Miami on June 1st and provides a bid to the owner on July 1st. The bid documents indicate that the start of the project is August 1st and has a duration of 365 calendar days. The contractor is awarded the contract on July 15th with the notice to proceed given on August 15th. During the construction of the job, there are five days lost due to rain. When is the contractor required to complete the project by?
- A. August 1st the following year
 - B. August 6th the following year
 - C. August 15th the following year
 - D. August 20th the following year
- 99.** While the designer is inspecting the building and creating a punch list it is discovered that the flooring contractor installed a substantially inferior carpet than what was indicated in the specification. After the deficiency was discovered, could the contractor obtain a certificate of occupancy from the AHJ?
- A. No, the AHJ does not issue a certificate of occupancy until the contracted work is 100% completed
 - B. No, the AHJ does not issue a certificate of occupancy until the owner has beneficial occupancy of the building
 - C. No, the AHJ does not issue the certificate of occupancy
 - D. Yes, it isn't a life safety issue so a certificate of occupancy could be issued
- 100.** Review the following task descriptions and indicate which would be the most appropriate to report progress on a field superintendent's daily log.
- A. Poured concrete for the columns.
 - B. Installed rebar and poured concrete.
 - C. Poured 75 cy concrete, placed rebar, and stripped forms for columns D1–D4.
 - D. Poured 75 cy concrete, placed rebar, and stripped forms for the building.

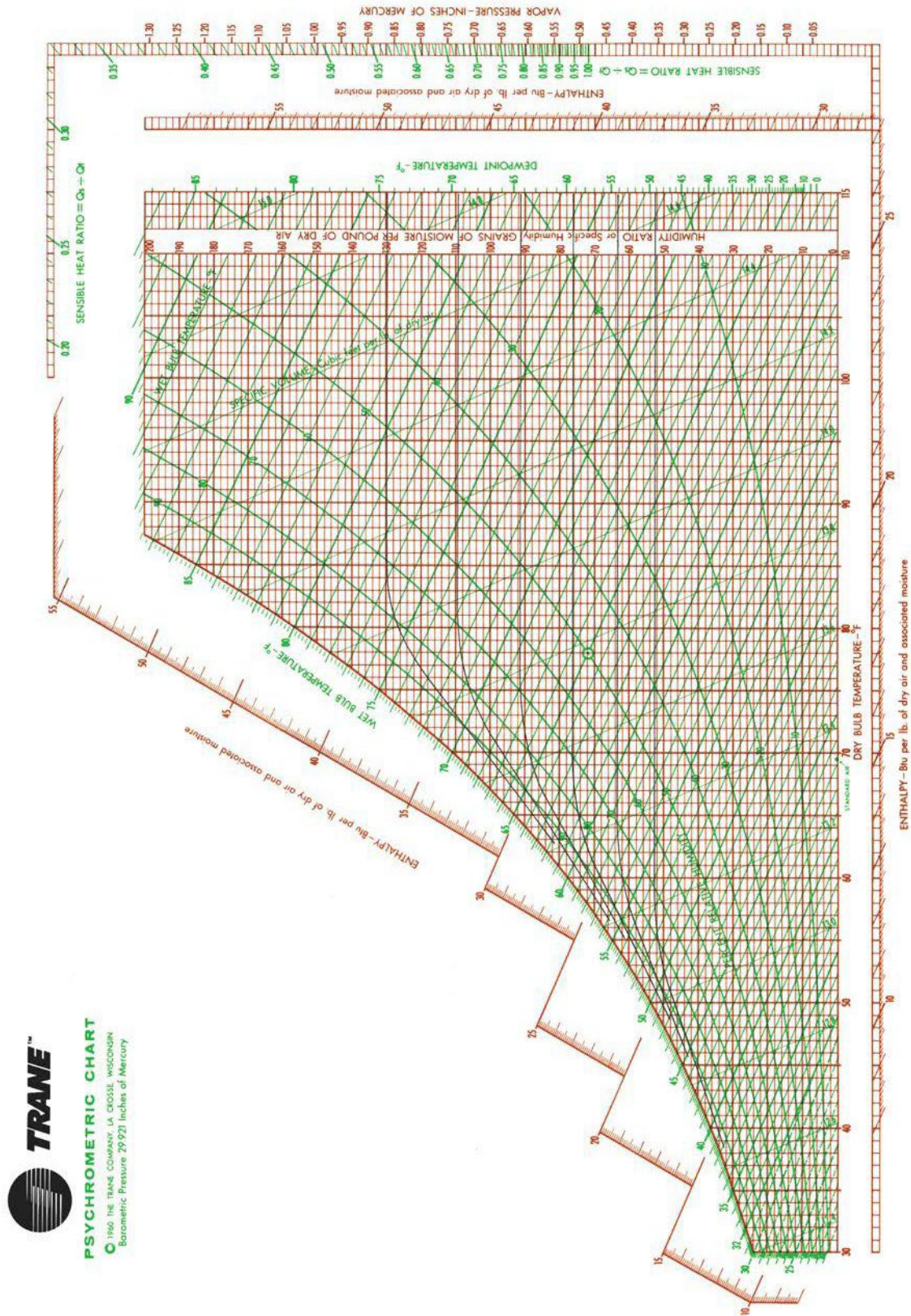
FIGURES TO USE WITH PRACTICE TEST

Figure 1 Soil Table

AVERAGE SOIL WEIGHTS AND VOLUME CHANGE FORMULAS

SOIL TYPE	LCY	BCY	CCY 100% STANDARD PROCTOR	CCY 100% MODIFIED PROCTOR	LOAD FACTOR
Clay - Dry	2050	2675	2835	3159	.81
Clay - Natural Bed Wet	2800	3400	3575	3959	.82
Sand - Dry	2420	2740	3362	3510	.85
Sand - Damp	2760	3130	3362	3510	.85
Gravel - Damp	2623	2980	3375	3645	.85
Common Earth - Dry	2185	2883	3375	3510	.80
Common Earth - Moist	2463	3160	3375	3510	.79
Loam	2100	2600	2835	3150	.81
Sw % = $\frac{(BCY - LCY)}{LCY} \times 100$		Load Factor (LF) = $\frac{100\%}{(100\% + \% \text{ Swell})}$			
Sh % = $\frac{(LCY - CCY)}{CCY} \times 100$		LCY x LF = BCY			
Shrinkage Factor (SF) = $\frac{CCY}{BCY}$		BCY x SF = CCY			

Figure 2 Psychrometric Chart



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Figure 3a Financial Statements

BALANCE SHEET		
Assets	End of Year	End of Previous Y
Cash	\$ 260,631.00	\$ 233,171.00
Contracts Receivable	423,731.00	385,259.00
Inventory	640,020.00	517,936.00
Prepaid expenses	91,433.00	85,559.00
Total Current Assets	\$1,415,815.00	\$1,221,925.00
Property, Plant, Equipment	2,317,500.00	2,089,336.00
Accumulated Depreciation	(753,917.00)	(764,900.00)
Cost Less Accumulated Depreciation	1,563,583.00	1,324,436.00
Total Assets	\$2,979,398.00	\$2,546,361.00
Liabilities and Owners' Equity	End of Year	End of Previous Y
Accounts Payable - Operating	281,915.00	242,294.00
Accrued Operating Expenses	142,246.00	126,264.00
Income Tax Payable	8,500.00	15,018.00
Short-Term Debt Payable	250,000.00	196,113.00
Total Current Liabilities	682,661.00	579,689.00
Long-Term Debt Payable	833,334.00	650,000.00
Total Liabilities	\$1,515,995.00	\$1,229,689.00
Capital Stock	509,722.00	489,167.00
Retained Earnings	953,681.00	827,505.00
Total Owners' Equity	\$1,463,403.00	\$1,316,672.00
Total Liabilities & Owners' Equity	\$2,979,398.00	\$2,546,361.00
INCOME STATEMENT FOR THE YEAR		
Contract Revenues	4,406,806.00	
Cost of Contracts Completed	2,773,417.00	
Gross Margin	1,633,389.00	
Operating Expenses	1,263,032.00	
Depreciation Expense	10,983.00	
Operating Earnings	359,374.00	
Interest Expense	88,333.00	
Earnings before Taxes	271,041.00	
Income Tax Expense	94,864.00	
Net Income	176,177.00	

Figure 3b Financial Statements

CASH FLOW STATEMENT FOR THE YEAR	
Cash Flows from Operating Activities	
Net Income from Income Statement	176,177.00
Contracts Receivable Increase	(38,472.00)
Inventory Increase	(122,084.00)
Prepaid Expenses Decrease	(5,874.00)
Depreciation Expense	85,383.00
Accounts Payable Increase	39,621.00
Accrued Expenses Increase	15,982.00
Income Tax Payable Decrease	(6,518.00)
	<u>(31,962.00)</u>
Cash Flow Adjustments to Net Income	
Cash Flow from Operating Activities	<u>144,215.00</u>
Cash Flows from Investing Activities	
Purchases of Property, Plant & Equipment	(\$354,028.00)
Proceeds from Disposals of Property, Plant & Equipment	29,498.00
Cash Used in Investing Activities	<u>(\$324,530)</u>
Cash Flows from Financing Activities	
Short-Term Debt Borrowing	53,887.00
Long-Term Debt Borrowing	183,334.00
Capital Stock Issue	20,554.00
Dividends Paid Stockholders	(50,000.00)
Cash from Financing Activities	<u>207,775.00</u>
Increase (Decrease) in Cash during Year	27,460.00

Figure 4 Concrete Beam Schedule

Concrete Beam Exercise - Schedule

Mark	No.	Beam Size (inches)		Reinforcing							#3 Stirrups							2" BB
				Bottom			Top				Total		Col. # O.C.			Support Bars		
		Width	Depth	No.	Size	Length	No.	Size	Length	Mark	No.	Mark	#	OC	OC	No.	L	
1B1	2	12	24	4	6	20'-8"	2 4	6 6	15'-8" 16'-0"	6A1	17 17	3A3 3A2	3 4	6" 6"	10" 8"	2 3	21' -7"	5
1B2	1	24	10.5	7	7	12'-8"	4 7	6 7	9' -4"	6A4	16 16	3A6 3A5		4" 4"	8" 8"	4	2' 0"	4
1B2A	1	24	10.5	7	7	12'-8"	4 7	6 7	11' -1"	6A4	16 16	3A6 3A5		4" 4"	8" 8"	4	2' 0"	4
1B3	6	24	10.5	6	7	17' -2"	8	7	11'- 1"		20 20	3A6 3A5		4" 4"	8" 8"	4	2' 0"	4
1B4	1	24	10.5	4	8	13' -4"	8	8	11' -1"		10 10	3A6 3A5		4" 4"	8" 8"	----	----	4
1B5	2	24	10.5	4	8	14' -3"	4	6		6A7	20 20	3A6 3A5		4" 4"	6" 8"	2	7' -0"	4
1B7	1	24	10.5	8	9	22' -9"	4 3	7 8	14' -6"	7A9	26 26	3A6 3A5		6" 6"	8" 8"	2	11' -0"	5
1B10	1	12	33	2	6	15' -2"	2	5	15' -8"		12 12	3A3 3A11		6"	12"	4	16' - 8"	4
1B12	2	12	18	3	6	13' -9"	2	5		5A15	8 8	3A3 3A16		8" 8"	12" 12"	----- -	-----	4

Figure 5 Mechanical Schedule

AIR HANDLING UNIT SCHEDULE										
MARK	LOCATION	SERVICE	MODEL	CFM	S.P.		O.V.	RPM	H.P.	REMARKS
					EXT.	TOTAL				
AHU-1	MECH RM 107	LOWER LEVEL	LML-122	10,100	1 1/4"	2 1/4"	1417	1291	7 ½	1,2

1 BASED ON McQUAY
2 PROVIDE 4" HIGH RAIL UNDER UNIT

Figure 6 Productivity Information

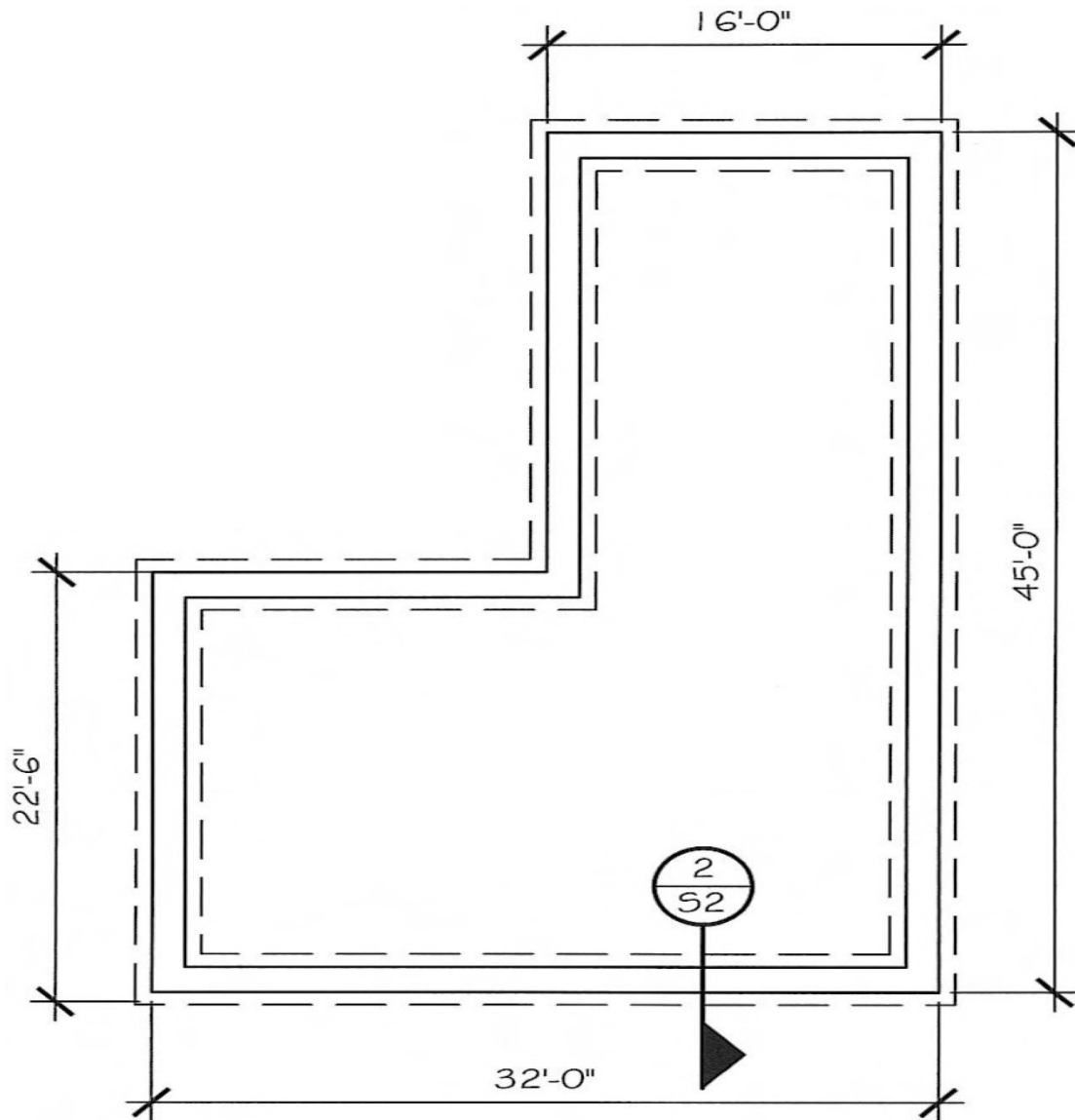
CSI DIVISION & SECTION	02250	Shoring & Underpinning
CLASSIFICATION NUMBER	400	Sheet Piling
LINE ITEM NUMBER	1300	15' Deep exc., Drive, Extract & Salvage

No.	CRAFT	Hourly Rate
1	Crew Leader(s)	\$27.20
4	Pile Drivers	\$22.80
2	Crane Operators	\$25.26
0.5	Oiler(s)	\$18.00

Figure 7 Wood Sheet Pile Material and Unit Cost Information

Material	Size	Prices or Percentages
Sheet Piling (Toe = 3 feet)	3" x 13"	\$550.MBF
Wales - 3 lines around the outside perimeter	6" x 8"	\$550.MBF
Braces - 3 lines, 12 Pcs per line, each 60 feet long	6" x 6"	\$550.MBF
Nails - 12 Lbs/100 Square Feet Contact Area		\$35/Box, Box = 50 Lbs
Salvage Value		60%
Transportation & Shipping		\$3.78/MBF
Sales Tax on Materials		4%
Timber Waste Factor	12%	

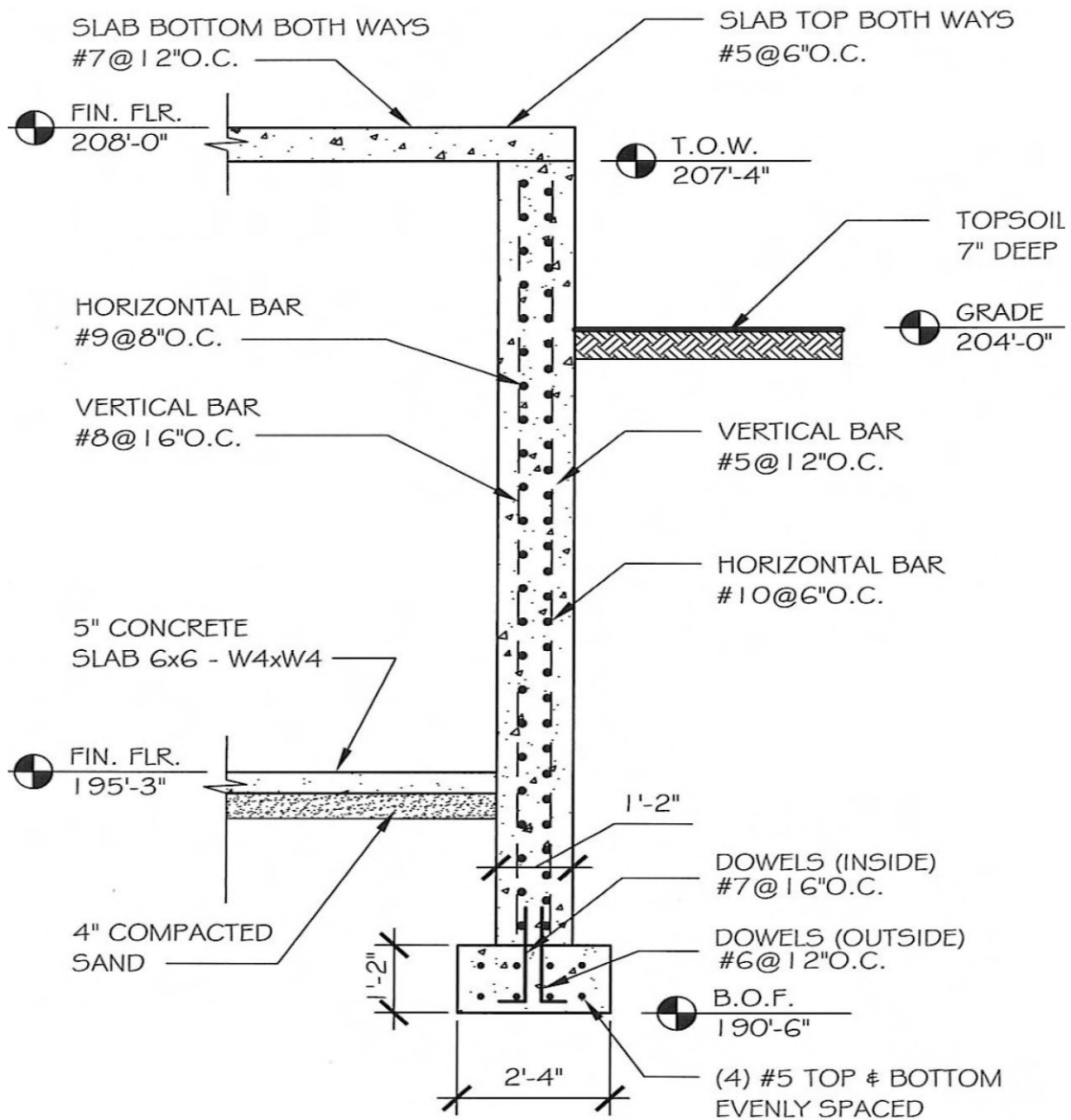
Figure 8a Excavation Plan View



E & C PROBLEM PLAN

SCALE: 1/8" = 1'-0"

Figure 8b Excavation Section



2
S2

E & C PROBLEM DETAIL

N.T.S.

Figure 9a Earned Work Hour Report Information

DESCRIPTION	QUANTITIES			UNIT	EXPENDED WORKHOURS		WORKHOURS		UNIT WORKHOURS			PROJECTED	
	BUDGET	WEEK	TO DATE		WEEK	TO DATE	EARNED	BUDGETED	BUDGET	WEEK	TO DATE	COMPLETION	GAIN/ LOSS
Col. Forms	2499	87	112	SFCA	17	27		428					
Concrete Ftg	256	25	40	CY	40	85		360					
Concrete Wa	453	30	34	CY	40	44		634					
Footing Frms	2417	210	410	SFCA	42	102		499					
Wall Forms	25,560	1880	3090	SFCA	364	664		5544					

Figure 9b Labor Cost Report Information

CODE	DESCRIPTION	QUANTITIES			UNIT	EXPENDED COST		TOTAL BUDGET \$	UNIT COST			PROJECTED	
		BUDGET	WEEK	TO DATE		WEEK \$	TO DATE		BUDGET	WEEK	TO DATE	COMPLETION	GAIN/ LOSS
	Col. Forms	2499	87	112	SFCA	223	355	8022					
	Concrete Ftg	256	25	40	CY	365	805	5490					
	Concrete Walls	453	30	34	CY	394	431	9669					
	Footing Form	2417	210	410	SFCA	449	1038	8154					
	Wall Forms	25,560	1880	3090	SFCA	3812	6855	90370					

Figure 9c Project Cost Summary Report Information

CODE	ITEM	ORIGINAL ESTIMATE	SCOPE CHANGE	REVISED ESTIMATE	EXPENDED		COMMITTED	TOTAL EXPEND	CURRENT PROJECTION	PROJECTED GAIN (LOSS)
					WEEK	TO DATE				
035600	PILES									
	Quantity	6700 VLF	(720)	5980 VLF		680	0	680		
	Workhours	618 WHR	(67)	551 WHR		78	0	78		
	Labor	16817	(1900)	14917		1360	0	1360		
	Material	45225	(4675)	40550		10000	23470	33470		
	Equipment	16040	(1400)	14640		7600	9360	16960		
	Subcontract	0	0	0		7000	0	7000		
		78082	(7975)	70107		25960	32830	58790		

Figure 10 Schedule Sequence and Logic Relationships

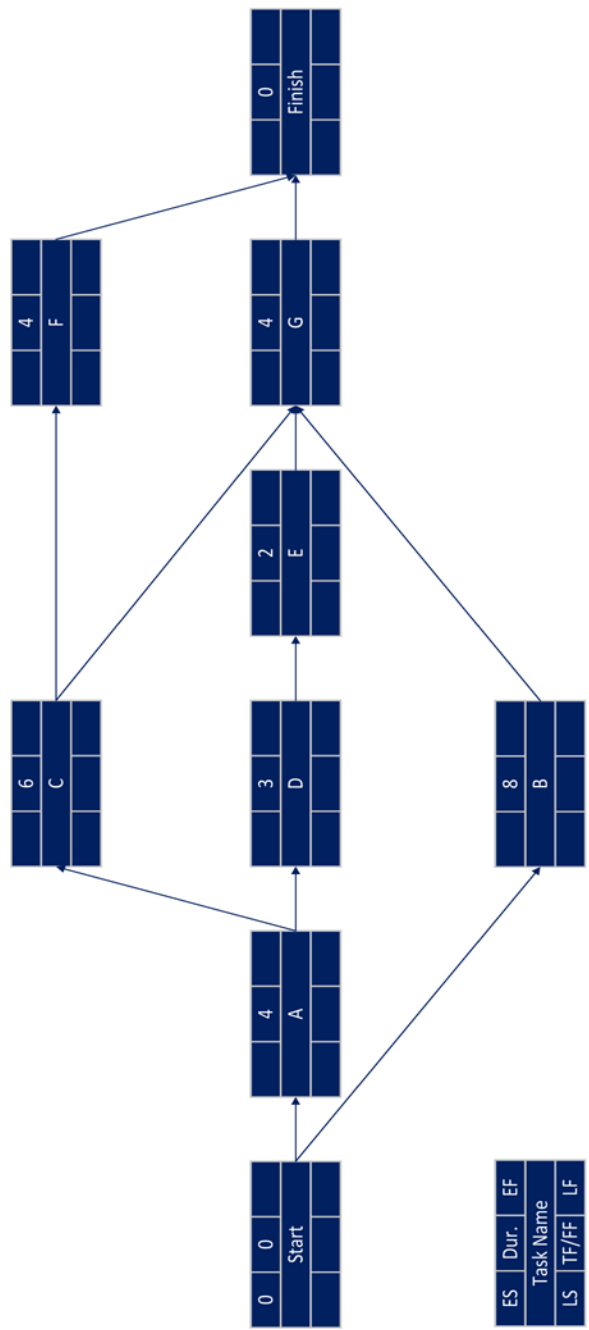


Figure 11 Surveying Log

IP	BM Elev.	BS Rod Reading	HI	FS Rod Reading	TP Elev.
#1	877.26	7.45		3.10	
#2		7.12		1.10	
#3		4.44		2.17	
#4	???				

COMMUNICATION SKILLS

1. D
2. D
3. B
4. B
5. B
6. B
7. C
8. D
9. A
10. B
11. C

MATERIALS, METHODS, AND PROJECT MODELING AND VISUALIZATION

30. C
31. D
32. A
33. C
34. C
35. C
36. A
37. C
38. B
39. D

ENGINEERING CONCEPTS

12. C
13. C
 - $225 \times 12 = 2,700$
14. B
 - $(151.33 \text{ ft} \times 14 \text{ ft} \times 1.33 \text{ ft}) \times (1 \text{ cy}/27 \text{ cft}) = 104.6 \text{ cy}$
 - $375 \text{ cy}/8 \text{ hr} = 46.9 \text{ cy/hr}$
 - $104.6 \text{ cy}/46.9 \text{ hr/cy} = 2.2 \text{ hr}$
15. B
 - $\text{SW}\% = ((\text{Bcy}/\text{Lcy}) - 1) \times 100$
 - $(2,600/2,100) - 1 \times 100 = 23.8\%$
16. B
 - 28BTUs/lb from figure 2
 - $28\text{BTUs/lb} \times 2\text{lb} = 56\text{BTUs}$
17. A
18. C
19. B

BIDDING AND ESTIMATING

40. C
41. C
42. B
43. B
 - First 5K = $\$5,000/1,000 \times \$12.00 = \$60$
 - Next 2M = $\$6,000 + (2,000,000/1,000) \times \$7.25 = \$20,500$
 - Next 2.5M = $\$20,500 + (2,755,000 - 2,005,000)/1,000 \times \$5.75 = \$24,813$
 - $\$60 + 20,500 + 24,813 = \$45,373$
44. C
 - $1 \times 8 + 4 \times 8 + 2 \times 8 + .5 \times 8 = 60$
45. B
 - $60 \text{ Whr}/545 \text{ SFCA} = 0.110$
46. B
 - $60 + 100 + 60 + 100 = 320 \text{ Inft}$
 - $320 \text{ Inft} \times 13 \text{ ft} = 4,160 \text{ SFCA}$

MANAGEMENT CONCEPTS

20. D
21. A
22. D
23. B
24. B
25. A
26. C
27. B
 - $1,415,815 - 682,661 = \$733,154$
28. C
 - $\$1,415,815/\$682,611 = 2.07$
29. C
 - $(\$260,631 + \$423,731)/\$682,661 = 1.00$

47. C

- $VLF = 320 \text{ lnft} / (13 \text{ in.} / 12 \text{ in.}) = 296 \text{ PCS}$
- $296 \text{ PCS} \times 13 \text{ ft long} = 3,848 \text{ VLF}$
- $\text{Piling} = 3,848 \text{ VLF} \times (3 \text{ in.} \times 13 \text{ in.}) / 12 = 12,506 \text{ BF}$
- $\text{Wales} = 3 \text{ lines} \times 320 \text{ ft} = 960 \text{ lnft}$
- $960 \text{ lnft} \times (6 \text{ in.} \times 8 \text{ in.} / 12 \text{ in.}) = 3,840 \text{ BF}$
- $\text{Braces} = 3 \text{ lines} \times 12 \text{ PCS/line} \times 60 \text{ ft long} = 2,160 \text{ lnft}$
- $2,160 \text{ lnft} \times (6 \text{ in.} \times 6 \text{ in.} / 12 \text{ in.}) = 6,480 \text{ BF}$
- $\text{Subtotal} = 12,506 + 3,840 + 6,480 = 22,826 \text{ BF}$
- $\text{Waste} = 22,826 \text{ BF} \times 12\% = 2,739 \text{ BF}$
- $\text{Total board feet} = 22,826 + 2,739 = 25,565$

48. A

- $\text{Length of wall at centerline: } 14.83 \text{ ft} + 43.83 \text{ ft} + 30.83 \text{ ft} + 21.33 \text{ ft} + 16.00 \text{ ft} + 22.5 \text{ ft} = 149.32 \text{ ft}$
- $\text{Depth of wall: } 207.3 \text{ ft} - (190.5 \text{ ft} + 1.17 \text{ ft}) = 15.63 \text{ ft}$
- $\text{Width of wall: } 1.17 \text{ ft}$
- $\text{Volume: } (149.32 \text{ ft} \times 15.63 \text{ ft} \times 1.17 \text{ ft}) / 27 = 101 \text{ cy}$

49. B

- $\text{Shape 1} = 45 \text{ ft} \times 16 \text{ ft} \times 8.75 \text{ ft} / 27 = 233.33 \text{ cy}$
- $\text{Shape 2} = 22.5 \text{ ft} \times 16 \text{ ft} \times 8.75 \text{ ft} / 27 = 116.66 \text{ cy}$
- $\text{Total} = 233.33 + 116.66 = 350 \text{ Bcy}$

BUDGETING, COSTS, AND COST CONTROL

50. B (see figure S1a)

- $428 / 2,499 = 0.171$

51. B (see figure S1a)

- $17 / 87 = 0.195$

52. B (see figure S1a)

- $27 / 112 = 0.241$

53. A (see figure S1a)

- $112 \times .171 = 19$

54. C (see figure S1a)

- $2,499 \times .241 = 602$

55. A (see figure S1a)

- $428 - 602 = (174)$

56. B (see figure S1b)

- $5,490 / 256 = 21.45$

57. D (see figure S1b)

- $365 / 25 = 14.6$

58. C (see figure S1b)

- $805 / 40 = 20.13$

59. C (see figure S1b)

- $256 \times 20.12 = 5,150.72$

60. C (see figure S1c)

- $6,700 - 720 = 5,980$

PLANNING, SCHEDULING, AND SCHEDULE CONTROL

61. B

62. B

63. A

64. D

65. C

66. B

67. C

68. B (see figure S2)

69. D (see figure S2)

70. C (see figure S2)

- $10 - 8 \text{ or } 2 - 0 = 2$

71. B (see figure S2)

- $\text{ES next} - \text{EF}$

- $10 - 8 = 2$

CONSTRUCTION SAFETY

72. B

73. B

74. D

75. C

76. A

77. C

78. D

79. B

80. D

81. C

CONSTRUCTION GEOMATICS

82. D

- $5.42 + 4.00 = 9.42 \text{ ft or}$

- $105.42 - 96.00 = 9.42 \text{ ft}$

83. B (see figure S3)

- $877.26 + 19.01 (\text{total BS}) - 6.37 (\text{total FS}) = 889.90$

84. A

85. D

86. B
87. D
88. A
89. B

PROJECT ADMINISTRATION

90. A
 • Purchase orders do not include labor.
 91. C
 92. B
 93. C
 94. C
 95. A
 96. C
 • Mr. Ethics Blog dated November 2015
<https://www.professionalconstructor.org/blogpost/1122991/Mr-Ethics?tag=&DGPCrSrt=&DGPCrPg=3>
 97. C
 98. C
 • 5 day rain delay can be expected in Miami, FL and is not justification for a change order.
 99. D
 100. C

Self-Score Test Results

Subject Area	Correct	Total Questions	Percentage (pass>70%)
Communication Skills		11	
Engineering Concepts		8	
Management Concepts		10	
Materials, Methods, ...Visualization		10	
Bidding and Estimating		10	
Budgeting, Costs, and Cost Control		11	
Planning, Scheduling, and Schedule Control		11	
Construction Safety		10	
Construction Geomatics		8	
Project Administration		11	
Total Score			
Pass>70%		100	

Figure S1a Earned Work Hour Report Information SOLUTION

EARNED WORKHOUR REPORT

PROJECT NAME
PROJECT NUMBER

DESCRIPTION	QUANTITIES			UNIT	EXPENDED WORKHOURS		WORKHOURS		UNIT WORKHOURS			PROJECTED	
	BUDGET	WEEK	TO DATE		WEEK	TO DATE	EARNED	BUDGETED	BUDGET	WEEK	TO DATE	Completion	(gain/Loss)
Wall Forms	2499	87	112	SF	17	27	19.15	428	.171	.195	.241	602	(174)
Concrete Footings	256	25	40	CY	40	85	56.4	360	1.41	1.60	2.125	544	(184)
Concrete Walls	453	30	34	CY	40	44	47.6	634	1.40	1.33	1.29	586	+48
Footings Forms	2417	210	410	SFCA	42	102	84.5	499	.206	.200	.249	601	(102)
Wall Forms	25560	1880	3090	SFCA	364	664	670.53	5544	.217	.194	.215	5493	+51

Figure S1 b Earned Labor Cost Report Information SOLUTION**LABOR COST REPORT**

CODE	DESCRIPTION	QUANTITIES			UNIT	EXPENDED COST		TOTAL \$	UNIT COST			PROJECTED	
		BUDGET	WEEK	TO DATE		WEEK	TO DATE		BUDGET	WEEK	TO DATE	COMPLETION	GAIN/LOSS
	Wall Forms	2499	87	112	SF	\$223	\$355	\$8022	\$3.21/SF	\$2.56/SF	\$3.17/SF	\$7921.83	\$100.17
	Concrete Footings	256	25	40	CY	\$364.60	\$804.97	\$5490	\$21.45/CY	\$14.58/CY	\$20.12/CY	\$5150.72	#339.28
	Concrete Walls	453	30	34	CY	\$394.08	\$430.54	\$9669	\$21.34/CY	\$13.14/CY	\$12.66/CY	\$5734.98	\$3934.02
	Footing Forms	2417	210	410	SFCA	\$449.05	\$1038.25	\$8154	\$3.37/	\$2.14/	\$2.53/	\$6115.01	\$2038.99
	Wall Forms	25560	1880	3090	SFCA	\$3811.70	\$6854.99	\$90,370	\$3.54/SF	\$2.03/SF	2.22/SF	\$56,743.02	\$33626.98

Figure S1 c Project Cost Summary Report Information SOLUTION

FORECAST the Current Projection column as follows:

QUANTITY - Project the REVISED ESTIMATE column

WORKHOURS - Project using the Straight Line Method

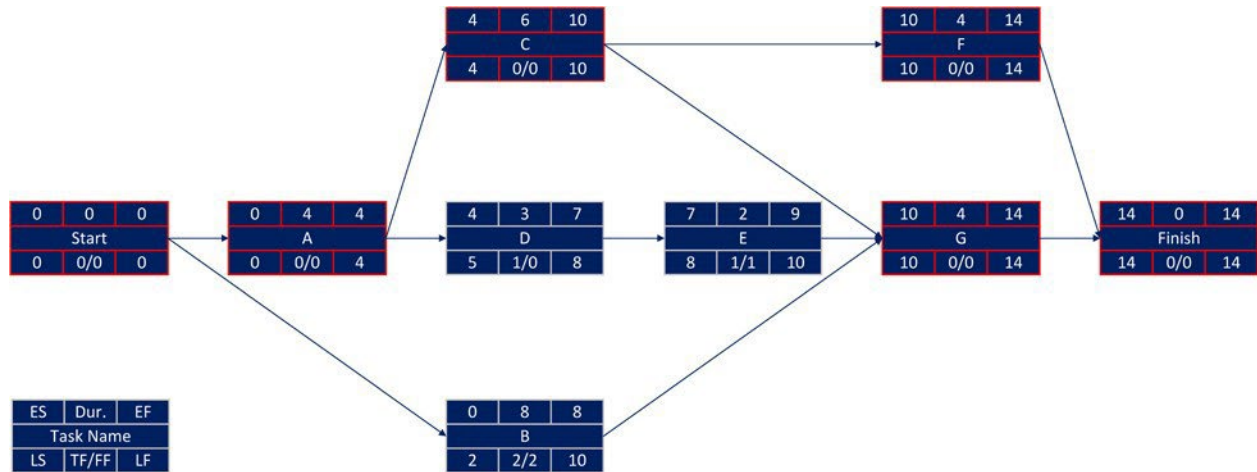
LABOR COST - Project using the Straight Line Method

MATERIAL COST - Project the REVISED ESTIMATE column

EQUIPMENT COST - Project the TOTAL EXPENDED column

SUBCONTRACT COST - Project the TOTAL EXPENDED column

ITEM	ORIGINAL ESTIMATE	SCOPE CHANGES	REVISED ESTIMATE	EXPENDED		COMMITT	TOTAL EXPENDED	CURRENT PROJECTION	PROJECTED GAIN/LOSS
				PERIOD	TO DATE				
Piles									
Quantity	6700 VLF	(720)	5980 VLF		680 VLF	0	680 VLF	5980 VLF	0
Workhours	618 WHR	(67)	551 WHR		78 WHR	0	78 WHR	686 WHR	(135) WHR
Labor	16817	(1900)	14917		1360	0	1360	\$11960.00	\$2957
Material	45225	(4675)	40550		10000	23470	33470	\$40550.00	0
Equipment	16040	(1400)	14640		7600	9360	16960	\$16960	(\$2320)
Subcontracts	0	0	0		7000	0	7000	\$7000.00	(\$7000)
	78082	(7975)	70107		25960	32830	58790	\$76470.00	(\$6363)

Figure S2 Schedule Sequence and Logic Relationships SOLUTION**Figure S3 Surveying Log SOLUTION**

IP	BM Elev.	BS Rod Reading	HI	FS Rod Reading	TP Elev.
#1	877.26	7.45	884.71	3.10	881.61
#2	881.61	7.12	888.73	1.10	887.63
#3	887.63	4.44	892.07	2.17	889.90
#4	889.90				



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