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Engineering Journeyman

Volume 3. Drafting and Design

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THIS IS THE THIRD of four volumes for the Career Development Course 3E551, *Engineering Journeyman*. The material in it pertains to the engineering technology principles that make up the foundation of this career field.

Unit 1 covers fundamentals in the drafting discipline. Unit 2 covers construction management and related skills. Unit 3 covers building information modeling.

A glossary is included for your use.

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For Guard and Reserve personnel, this volume is valued at 16 hours and 4 points.

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Unit 1. Drafting & Design

DRAFTING AND DESIGN IS an important part of civil engineering. Drafting is the way that engineers of all disciplines communicate information and ideas. Design is an illustration of how a constructed product should look and function. Mastering basic information in drafting and design allows you to be closely involved in what the Air Force builds and how we build it. Engineering personnel need these skills to create the blueprints and to review other organizations drawings to ensure that we effectively manage a facility throughout its entire lifecycle. This cradle to grave mentality is at the core of our career field.

1–1. Drafting

Understanding the basic concepts of drafting is the foundation of our career field. We use these concepts when communicating ideas and information needed to get the job done. Engineering, as an industry, has a type of communication all on its own. Drafting is the language that we use to transmit these ideas. Each engineer has a different dialect and, therefore, has different ways of creating initial sketches of an idea. Interpreting and generating these sketches is the starting point for drafting projects. To transform sketches into project drawings, we use a set of standards accepted by the Department of Defense (DOD). This section provides you with an understanding of how these three ideas fit together to get a set of drawings started.

401. Fundamentals of drafting

Geometry and scale are arguably the most fundamental of all our field’s concepts. You could describe our entire range of responsibilities as communicating information as pictures.

Basic geometry

The techniques presented here are simplified methods that have many practical applications. You should practice these methods until they become second nature. Proper practice will increase your skills with both computer and manual drafting tasks. More than that, it will help you understand larger engineering principles and practices.

Line relationships

The entire craft of drafting starts with a point. The point could be anywhere in space; but for now, we will simply imagine it on a piece of paper. Drafting, after all, is a two-dimensional representation of a three-dimensional object. When there is a second point, we call the connection between those points a line. By definition, a line continues through those two points infinitely in both directions. When there is a point A and a point B, we refer to the section between them as a line segment. In this text, we will refer to line segments as lines just to keep things simple.

Lines do not seem complex, but a single line contains a lot of information. There is an angle from its point of origin to its termination. The line could be long or short. Most of these attributes cannot be determined until we add another point. A third point, relative to the first two, defines a plane because there is now length and width but no depth. In figure 1–1, we can see that the segment from “F” to “B,” or FB, is at an angle of 0 degrees (°) while FG is at 90°.

Parallel lines

When two lines are on a plane, never crossing, and always the same distance apart, we say that these lines are parallel. Computer-aided drafting (CAD) programs have an “offset” command that creates a parallel line at a given distance. Manually, we make a parallel line by measuring an equal distance, at right angles, from the original line at two points along its path. Lines AD and FG are parallel in figure 1–1.

Perpendicular lines

Most lines do intersect. When they intersect at a 90° angle, we call them perpendicular or at right angles to each other. For example, see lines AD and BF are perpendicular in figure 1–1.

Polygons

When three or more lines intersect, they form polygons. Polygons can be regular or irregular. Regular polygons have sides of equal, or congruent, length. Squares and equilateral triangles are regular polygons. Irregular have incongruent sides and angles. Scalene triangles and rectangles are irregular polygons (fig. 1–2).

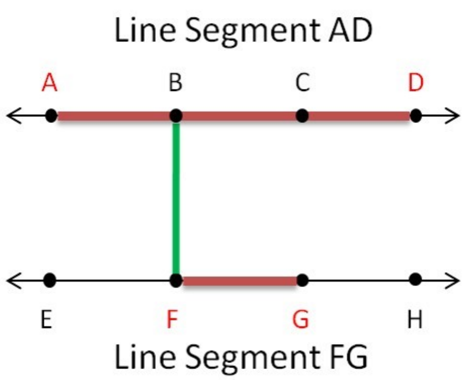


Figure 1–1. Line relationships.

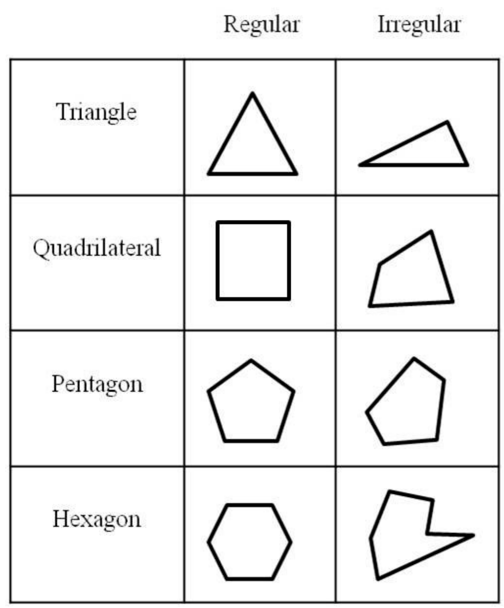


Figure 1–2. Regular and irregular polygons.

Curved lines

When a point moves in a *constantly* changing direction on the surface of a plane, the path it creates is a curved line, or an arc. In other words, each curve, if followed along its given path, would terminate at its own beginning, forming a circle. Therefore, a simple curve is a segment of a circle of a given radius.

Tangency

When we draw a line that just touches a circle at a single point, we call that line tangent to the circle. If a line crosses a circle or arc, even if it crosses two points imperceptibly close, we refer to the line as *secant* to the curve. When a line is tangent to a circle it is naturally at a right angle to the radius.

Complex curves

Complex curves form when two or more curves are joined at their point of tangency. Complex curves have many definitions and iterations. Since we are discussing only drafting, we will limit the discussion to single plane, horizontal curves. These include compound, reverse, and spiral curves as listed in the table.

Type Curve	Description
Compound	Compound curves consist of two simple curves with different radii joined together, and both curving in the same direction.
Reverse	Reverse curves consist of two simple curves joined together, curving in opposite directions.
Spiral	Spiral curves are either incurve or outcurve. Incurve spirals are compound curves with decreasing curve length and radius along the route of defined direction. An outcurve spiral increases in both curve length and radius.

Geometric principles

There are certain basic principles in geometry. Whether using a CAD program or drawing ideas on a scrap of paper, these will help you share your ideas more accurately:

- When measuring the distance between a point and a line, measure along a perpendicular from the line to the point.
- Parallel lines are equidistant from each other at all points.
- Curves are tangent to straight lines or to other curves at only one point.
- Regular polygons have all sides and all angles equal.
- From a given point on a given line, we can draw only one perpendicular.
- The diagonals of a parallelogram bisect each other.
- If two circles are tangent to each other, the straight line joining their centers passes through the point of tangency.
- The major and minor axes of an ellipse divide the figure into four equal segments.
- A sphere appears as a circle in every view.
- Two planes intersect in a line.

Understanding the third dimension

Hypothetically, there are infinite dimensions; but in drafting, we only use the first three—length, width, and depth. The previous principles applied primarily to a two-dimensional representation of the world—either length and width, or width and depth, or length and depth. Fortunately, they also apply to three-dimensional space with a simple twist of our understanding.

What we think of as three-dimensional space, we refer to as a geometric three-parameter model of the physical universe. This is a way of saying everything visible has three parameters—length, width, and depth. Most commonly, we use Cartesian (or analytic) geometry to describe and understand three-dimensional relationships.

Cartesian geometry uses a system of three mutually perpendicular intersecting imaginary lines; we call them X, Y, and Z. Where the place these lines intersect is the zero point, or origin. Extending from the zero point, we divide the lines into equal segments. We give each segment an integer value, either positive or negative, based on the perspective of the observer. Positive integers proceed from zero upward on the Y-axis, from zero to the right on the X-axis, and from zero toward the viewer on the Z-axis. Negative integers proceed in the opposite directions. Figure 1–3 and figure 1–4 are good depictions of how these lines intersect.

All the rules of geometry apply whether in two or three dimensions. With two dimensions, we referred to the area of a polygon; with three dimensions, we focus on volume.

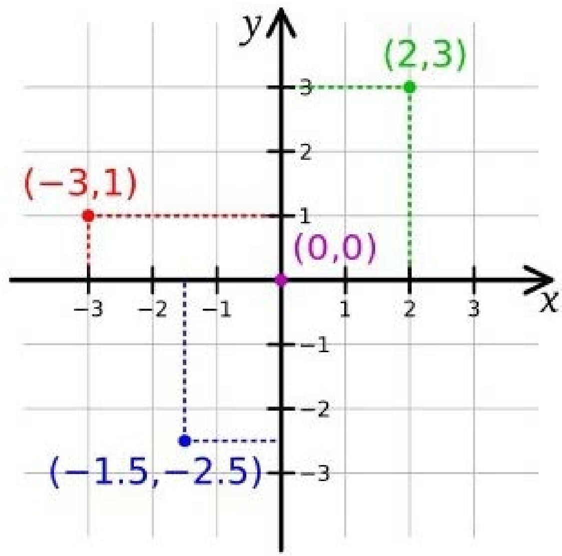


Figure 1–3. X, Y Axis.

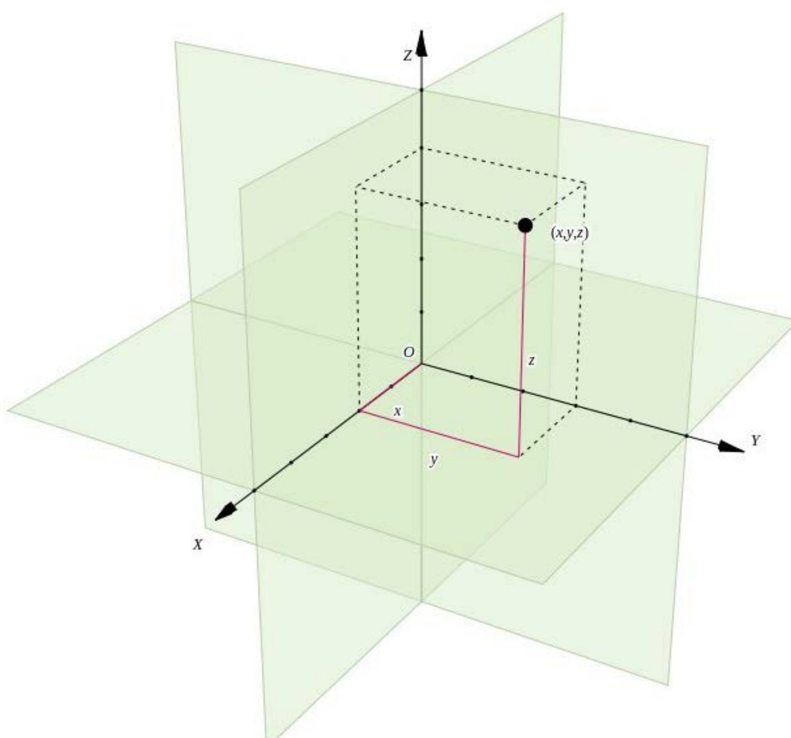


Figure 1–4. X, Y, and Z-axes.

Working with scale

A core skill in drafting is using scale. Scale is the ratio of the size of drawn objects compared to the actual objects. Giving a drawing a consistent scale, users can easily determine real-world sizes. Scales are expressed either as a ratio (1:50) or their actual value (1"=100'). Be sure to show this relationship on the finished drawing. The ratio scale represents units; so, 1:50 means one unit on the drawing equals 50 units for the object. This offers some flexibility because the units could be centimeters, inches, or any other value. The value scale gives specific values so 1”=100’ means one inch on paper equals 100’ for the object.

The term “scale” means both the ratio and the instrument for measuring it. Even though most drafting uses CAD software, which calculates scale, a scale is an essential tool. A printed set of drawings can be difficult to understand without using a scale.

Scales

A scale, used to measure scale, is not a ruler. Rulers, tape measures, yardsticks, and measuring wheels are tools to measure distance. Rulers are broken into progressively smaller increments. United States (US) inches divide into one half (1/2), one-quarter (1/4), one-eighth (1/8), one-sixteenth (1/16), and sometimes one-thirty second (1/32). Decimal rulers reduce either feet or inches into decimals instead of fractions. The decimal expression of 3’3” is 3.25’; for example, 3’6” becomes 3.5’, 3 ¾” becomes 3.75,” and so on.

Scales are also broken into progressively smaller increments. This is to measure the relationship of an image on paper with the actual object. Typically, they are in a triangular with a groove separating each side. This allows six surfaces for scales (fig. 1–5).

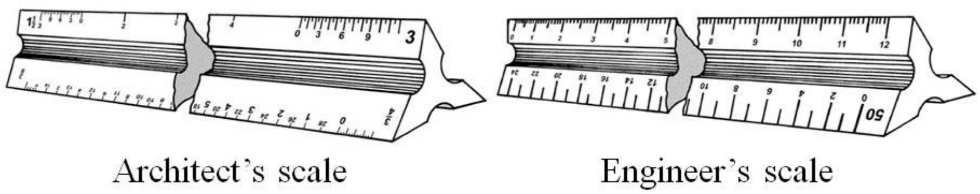


Figure 1–5. Typical scales.

Types of scales

There are two types of scales used to measure the scale of a drawing. These are decimal based, which could divide feet, meters, or any unit of measure into tenths, and traditional (or imperial) units such as feet, inches, and yards. Figure 1–6 shows the divisions on each type of scale.

SCALES		
DECIMAL BASE		
Civil Engineer’s 10, 20, 30, 40, 50, or 60 divisions per inch, representing any given unit such as inches, feet, or miles		
Metric 10, 20, 30, 40, 50, or 60 divisions to the centimeter representing any desired metric unit such as millimeter, centimeter, meter, and so on.		
IMPERIAL (FOOT-INCH) BASE		
Mechanical engineer's		
1" = 1" (full size)	1/2" = 1" (1/2 size)	
1/4" = 1" (1/4 size)	1/8" = 1" (1/8 size)	
Architect's or mechanical engineer's		
12" = 1'-0" (full size)	1" = 1'-0" (1/12 size)	1/4" = 1'-0" (1/48 size)
6" = 1'-0" (1/2 size)	3/4" = 1'-0" (1/16 size)	3/16" = 1'-0" (1/64 size)
3" = 1'-0" (1/4 size)	1/2" = 1'-0" (1/24 size)	1/8" = 1'-0" (1/96 size)
1 1/2" = 1'-0" (1/8 size)	3/8" = 1'-0" (1/32 size)	3/32" = 1'-0" (1/128 size)

Figure 1–6. Standard scale divisions.

Imperial (United States system)

The imperial or US system of measurement has its foundation in base 60, or sexagesimal mathematics. This system ties together distance, geometry, and time. It is an ancient system derived from counting the knuckles on the long fingers on one hand, then multiplying them by the five digits on the other hand. Twelve knuckles times five digits equals sixty. This is why twelves, fives, and sixties are common base numbers when calculating distance, geometry, and time.

Metric system

The main feature of the metric system is the standard set of base units and powers of ten. Millimeters easily convert to kilometers by adding zeros. The fundamental measurement of the metric system is the meter. The meter is equivalent to one ten-millionth of the straight line connecting the earth’s equator with the North Pole.

Civil engineer’s scale

Originally, civil engineer (CE) scales were a tool designed for working with maps. These scales expressed ratios of various units. The six sides are scales of 10, 20, 30, 40, 50, and 60. On each scale, one inch equals that number of units. This means that on the 60 scale of a CE’s scale, one inch equals 60 units, the 30 scale shows 30 units per inch, the 40 scale has 40 units per inch, and so on. Each scale is twelve inches long.

Architect’s scale

Architect scales measure, or draw, the size of an object on a scaled drawing in feet and inches. Each side of the scale actually has two scales, which begin at zero and read from either left to right, or right to left. Before the tick marks for the scale begin, there are a series of smaller marks. These smaller marks represent divisions of a foot. The scales on each side are the scale and its half. This means that the three and the 1 ½ are on the same side but read in opposite directions. On the 1/8 scale, we know that each increment equals one foot when read from left to right, but only the 4 and 8 are shown (fig. 1–7). The 1, 2, 3, 5, 6, and 7 are implied. The other numbers, 42, 44, and 46, are from the 1/16 scale which is read from right to left.

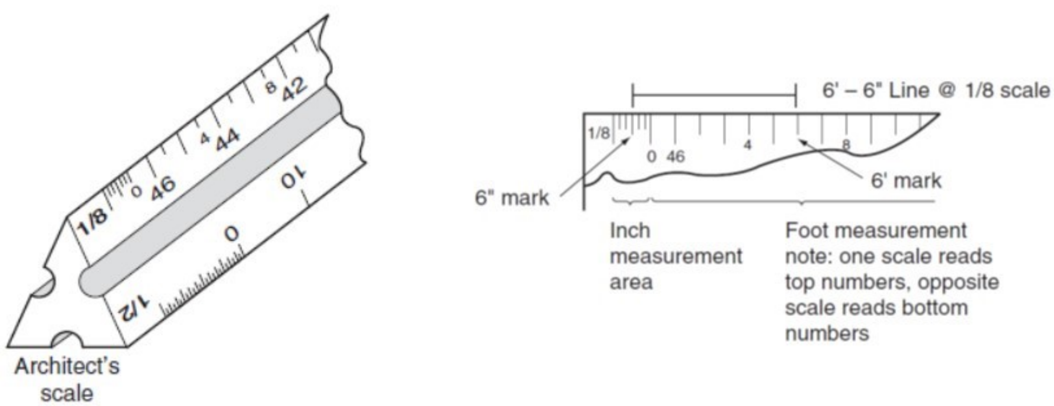


Figure 1–7. Reading an architect’s scale.

Reading architect’s scales

Regardless of which scale you use, the first step is to determine the scale of your drawing. We indicate the scale in the title block. Imagine the drawing is at 1/8. Look at figure 1–7. Place the 1/8 scale on the line to be measured with the zero mark at the beginning. Look to see where the other end of the line falls. In this example, it falls closest to the six, but it is a little longer. This means the line, drawn at 1/8, represents six feet plus some inches. Because the 1/8 scale is small, individual inch marks do not fit in the inch scale. Each mark represents two inches. Here, the right end of the line falls at six feet, the left end of the line falls at six inches.

Reading engineer's scales

An engineer's scale will not give you inches like an architect's scale (fig. 1–8). Instead, measurements are always in ratios of one inch. The greatest benefit of using this scale is the numbers on the scale can represent any unit. One inch on a piece of paper could equal ten feet, thirty miles, or even fifty light years. Regardless of the specified unit, the scales label as 1:10, 1:20, 1:30, and so on.

Using this scale is similar to but simpler than the architect's scale. There are no inch marks to read and there is only one scale per side. Similar to the architect's scale, not all the numbers are on the scale. On the 60 scale, for example, one inch equals 60 units, but we assume the number 60 is there. Figure 1–8 shows a 1:10 scale measuring feet.

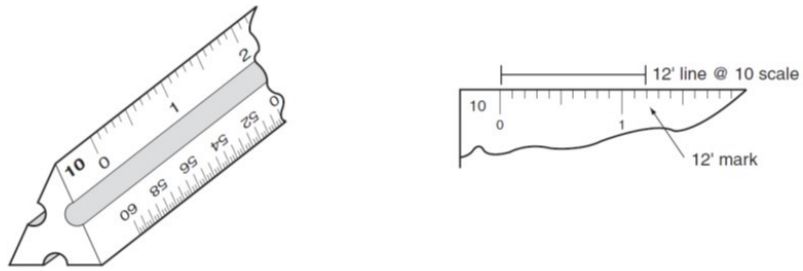


Figure 1–8. Reading an engineer's scale.

402. Interpret and create engineering sketches

Drawings allow us to explore ideas and find solutions to problems. Often, it is not practical to sit at a computer and draft a whole idea. Instead, simply draw a sketch of your intent. At other times, engineers will offer scraps of paper—even napkins—with ideas they developed. Before we can draft a single thing, you may need to create a sketch or figure out what an engineer is trying to express.

Sketching techniques

With a good understanding of geometric principles and scale, we can now move on to sketching. This is the first step in moving from idea to workable project on paper.

Vanishing point

The first thing to understand is the vanishing point. From a graphical perspective, the vanishing point is the place on the horizon, in the picture plane where a set of parallels appear to intersect. There could be one, two, five, or infinite vanishing points depending on how many sets of parallel lines exist. When the edges of an object appear drawn at different scales because of perspective, this effect we call foreshortening. Most sketching uses two points in the various views. Figure 1–9 shows points A and B as vanishing points with the edges closest to them appear drawn to a smaller scale.

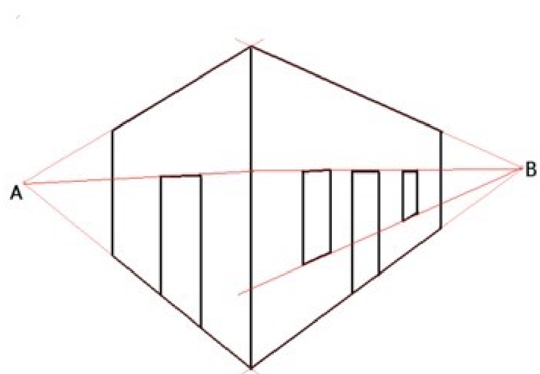


Figure 1–9. Two-point perspective.

Pictorial sketching

Pictorial sketching is just what it sounds like—sketching a rough picture of the object. This is where some basic art skills come in. Depending on the object, you may need to show it from one of several types of views. The most common views are axonometric, oblique, and perspective.

Axonometric

Axonometric simply means to measure along axes. These drawings have at least one major surface angled toward the single plane of projection. What makes axonometric views useful is the scale of distant features is the same as near features. Pictures look distorted because this is not how vision or photography works. This type is useful if scale is important while showing different sides of a structure or object. There are three types of axonometric projection: isometric, diametric, and trimetric (fig. 1–10).

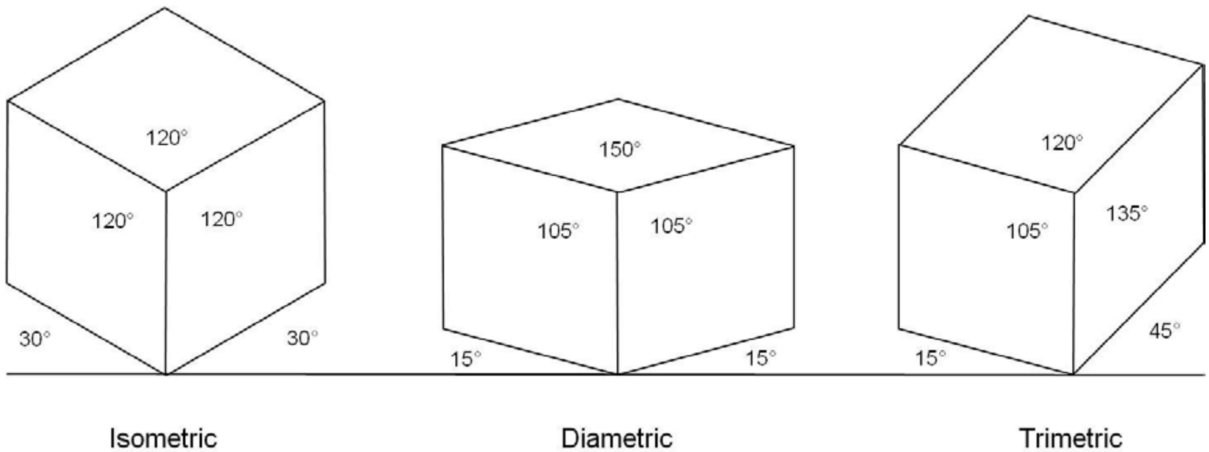


Figure 1–10. Axonometric projections.

<u>Isometric</u> is the most common type of axonometric projection. Three faces are equally inclined toward the drawing surface and drawn to the same scale with no foreshortening of the edges. Typically, we draw the object tilted toward the viewer 30° from horizontal. In a cube, this creates symmetrical 120° angles in the corner closest to the viewer.

<u>Diametric</u> projections are similar but with two faces equally inclined. Typically, at a 15° angle, this makes a cubed object appear to have 105° angles between the inclined faces, and 150° on the top corner. Just like isometric, we draw the edges to the same scale with no foreshortening, but the top surface appears compressed.

<u>Trimetric</u> shows all three axes tilted unequally from the plane of view. All edges have the same scale, but there are no consistent or symmetrical angles. All three surfaces appear compressed different amounts (degrees).

Oblique

An oblique projection has the primary surface drawn to scale on the picture plane (fig. 1–11). Projection lines extend from the corners and are parallel to each other. We draw the distant, not-visible surface the same scale as the front. While the projection lines can be at any angle, calculating their length is simpler when they are at 45°. This way, their length is drawn at one-half (1/2) the actual length.

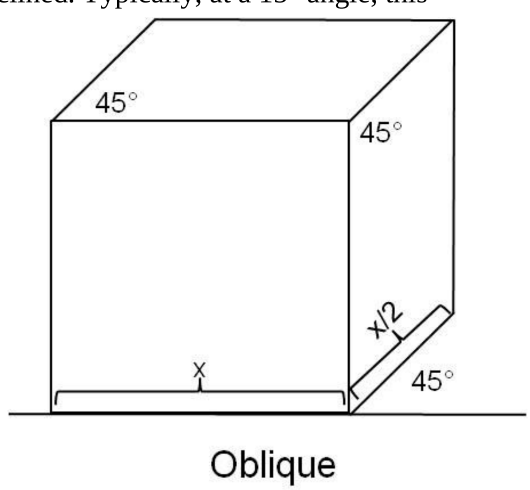


Figure 1–11. Oblique projection.

Perspective

Perspective sketching shows an object as it would appear if looking at it from some given distance. These look like photographs or paintings. Architects use perspective drawings to show buildings and structures as completed projects. This helps them visualize the final appearance and evaluate the overall design in terms of size, materials, arrangement, utility, and structural detail.

Orthographic projections

Although orthographic projections are more common in mechanical drafting specifically, it is still important to be familiar with them. Orthographic projections are a drawing of an object with the top and right side drawn so they line up with the original. Sometimes there will also be the left side and the bottom, and even the rear. There will also usually be a drawing of the object in one of the axonometric, oblique, or perspective projections with isometric being the most common. Figure 1–12 shows a basic orthographic projection.

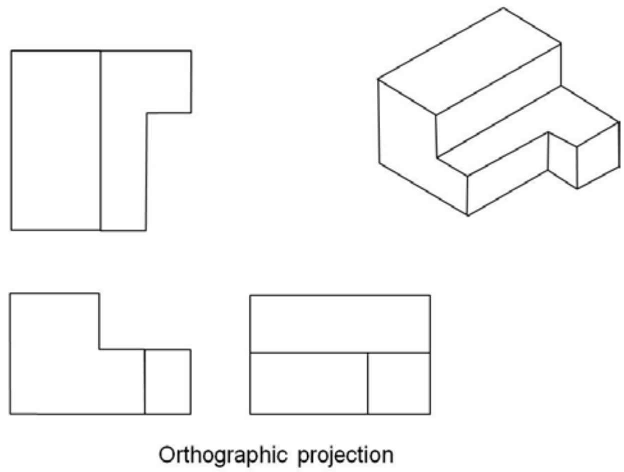


Figure 1–12. Orthographic projection.

Architectural sketches

Architects sketch to show improvements to facilities and grounds on installations. During wartime or deployed conditions, you may sketch to decide where utilities and temporary facilities belong. Understanding site, building, and detail sketches can help your mission. The primary uses for sketching are:

- Transmit ideas graphically.
- Preliminary planning.
- Show objects orthographically when needed.
- Drawing in critical situations.
- Technical notes.

These uses are not all inclusive. Use sketching whenever the situation arises.

Site sketches

Site sketches are used for new construction or landscaping. When considering a new facility, this gives an engineer important information. Utility locations, paved areas, existing buildings, and obstacles that affect the design or location are all important to the designer. It is important that you develop a proper site sketch. This provides planners with the basic information about the area without waiting for a complete drawing. With enough information, planners can determine if the site is feasible.

Site sketches contain a lot of information. Numbers or addresses of the site, direction and length of property lines, building corners, location of accessory buildings, walkways, fences, easements, and utilities all go on the sketch. You will also include construction area boundaries and show rough locations of where major utilities enter or cross the area.

Building sketches

Building sketches are developed when a facility is being renovated or having a system upgrade. This gives planners information about size, shape, and type of materials used in construction. For system upgrades, building sketches show location of the existing unit and if there is any damage from the old system. These can also help maintain record drawings (discussed later in this volume) for design purposes. Locations of facility features such as doors, windows, and walls should also be included in the building sketch.

Detail sketches

Detail sketching is usually very technical. Though they have no scale, detail sketches depict common structural shapes such as beams, channels, tees, bearing piles, and columns.

When drawn to an exaggerated size, features are highlighted which are too small to be shown on other sketches. Detail sketches of a single piece of equipment gives a complete description of its form, dimensions, and construction. Because it is very detailed, you should be very familiar with the component or equipment. When interpreting detail sketches, you should consult with the engineer as often as needed for best accuracy. You should be familiar with the specific symbology and methodology for the discipline you are sketching. Ultimately, a complete and accurate set of working drawings helps construction workers properly complete the job. Sketching is the beginning of the construction process; so, the entire process begins as well.

Elevations

Elevation drawings are helpful with getting a good sense of how the finished structure will look. Elevations are different from projections because they are non-perspective drawings. Looking at an elevation drawing, you will see the actual dimensions of the building. Many elevations also show material textures, shadows, and colors to better depict the structure. See sheet A–2 (Elevations) in the drawing set for an example of construction elevations.

Floor plans

Floor plans show a cut away of a building's floor from a bird's eye view. They show the outside shape of the building, the location, size and shape of rooms, and the length, thickness and type of the walls. If possible, when drawing the floor plan of an existing building, visit the building to get accurate measurements. If planning a new building, work with the engineer and planner to be sure the room and outside dimensions are correct.

Utilities

Utility sketches show sections of a structure needing special attention. Sometimes they show details of components in a utility system such as pumps, lift stations, or valves. To prevent clutter, a single line represents the path each utility takes through the site. If there are existing structures, they also show where utilities connect.

403. Utilizing computer-aided design and drafting standards

Since drafting is a skill used all over the world in nearly every culture, it is critical to have set standards for expressing ideas in CAD format. The primary standards are American National Standards Institute (ANSI), Architectural Graphics Standard (AGS), or International Standards Organization (ISO).

The ISO is a standard-setting organization. Different national standards organizations send representatives to the ISO to develop and set international standards. The ISO, then, is a combination of multiple national standards. Each national standard covers the topics of paper sizes, notes, numbering systems, geometric dimensioning and tolerances, abbreviations, welding symbols, roughness symbols, and electrical symbols.

AGS is a set of drafting standards covering architecture, landscaping, interiors, and planning. This has been one of the industry standards for almost eighty years. Each standard is available in a book or digital format. The AGS provides a resource to help solve some tough drafting problems of how to represent site excavation, relationship of structures, wall details, and much more.

ANSI is a private, non-profit organization that oversees the development of voluntary consensus standards for products, services, processes, systems, and personnel in the US. They also coordinate US standards with international standards providing American products worldwide.

Within the DOD, we use the architectural engineering and construction (A/E/C) standard. The DOD has a large number of agencies with drafting capabilities and unique requirements. In order to provide a single standard for the DOD and federal government, the Computer-Aided Drafting and Design/Geographic Information System Technology Center (CGTC) for Facilities, Infrastructure, and Environment developed the A/E/C-computer-aided drafting and design (CADD) standard. This standard incorporates existing industry, national, and international standards. These standards address the entire life cycle of facilities within the DOD.

The A/E/C CAD-Building Information Management Library

With all the disciplines to consider, it can seem overwhelming to generate so many drawings for a project. In almost any drawing projects, there are items and features that are the same from one project to another. We design and install things like fire hydrants, sidewalks, bollards, and so forth, the same way almost everywhere. Common detail drawings like this are part of the database managed by the Computer-Aided Drafting-Building Information Management (CAD-BIM) Technology Center.

The CAD-BIM Technology Center is a central organization, which manages CAD standards. Their information assists in the design, construction, and operation of military construction and civil works projects. The information is available to Army, Navy, and Air Force personnel. In addition, architectural, engineering, and construction firms under contract with the DOD are encouraged to access the information. The most current release, at this time, is number five.

Library access

The CAD-BIM library is online at https://cadbimcenter.erdc.dren.mil/. Here you will find a large amount of resources to get your drafting project done on time and to standards.

As shown in Figure 1–13, this link takes you to the CAD-BIM Technology Center home page. In the upper right-hand corner, select the “Login” link.

On the login page, you will have a few options. Since you should have your Common Access Card (CAC) readily available, select the “CAC only” tab (fig. 1–14).

Once you have confirmed your account, you will see figure 1–15. For our purposes now, select the “CAD” button. We discuss the “BIM” button in the next unit. The “Bentley ELA for USACE” button is for a software platform used primarily in Europe by the US Army Corps of Engineers and is not applicable for almost all Air Force Civil Engineering applications. Bentley produces MicroStation CAD products.

The next set of links, shown in figure 1–16, are the “A/E/C CAD Standard,” the “CAD Details Library,” the “CAD Drafting Standard,” and the “US National CAD Standard.” The “A/E/C CAD Standard” link navigates to previous releases of the A/E/C CAD Standard, as well as, several border sheets, line styles, patterns, symbols, and templates. These are for both AutoCAD and MicroStation products.

Figure 1–13. CAD-BIM Technology Center Home Page.

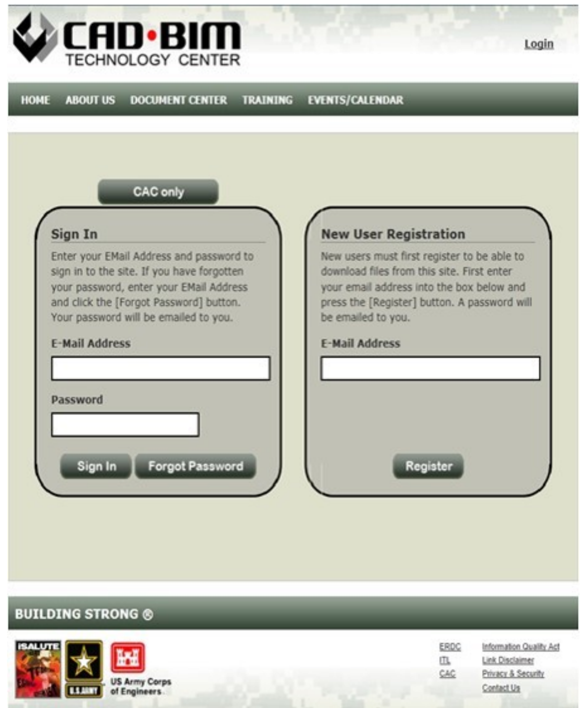


Figure 1–14. Login page.

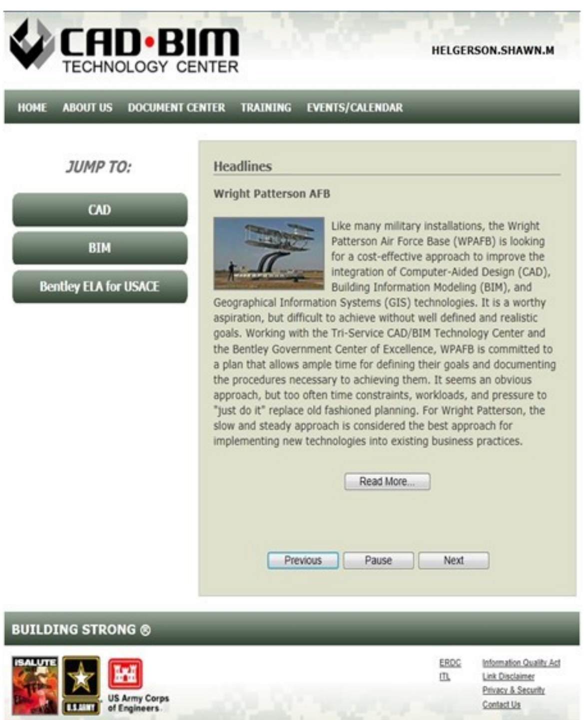


Figure 1–15. CAD tab.

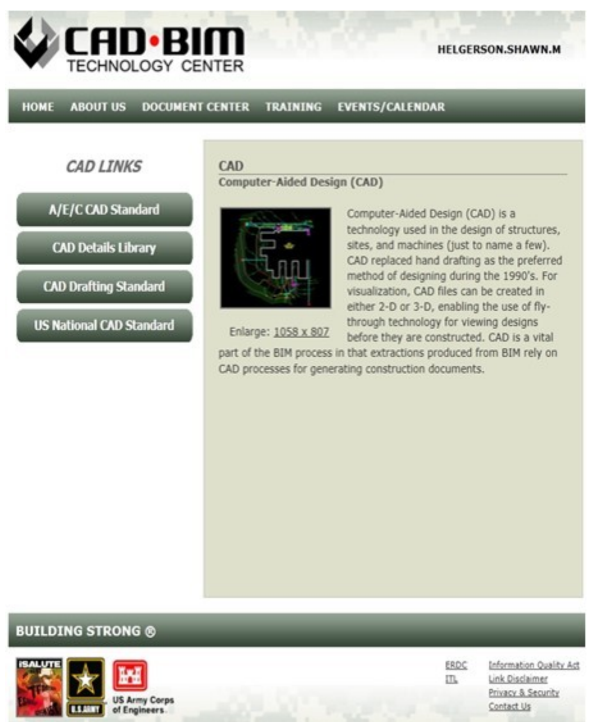


Figure 1–16. Links.

The “CAD Details Library” link is a good starting point for project design (fig. 1–17). In case you cannot read the disclaimer in the figure, it states that the details provided in the library are for project development. Each construction project will be unique. Many features in the library meet specific construction criteria; it is very important that you work with the project designer to confirm the accuracy of specific details.

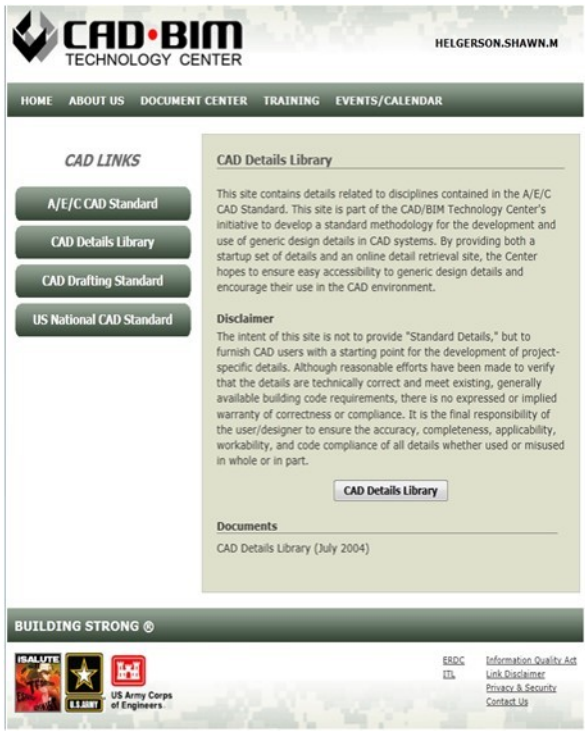


Figure 1–17. CAD Details Library link.

After navigating to the CAD details library, there is a drop down set of folders similar to those found in other computer directories. Figure 1–18 shows the detail found within the civil/water supply/flow indicator detail file path. The letters “N.T.S.” in the detail title indicate that this drawing is not to scale and will need to scale when added to a project.

Figure 1–18. Detail.

In the lower left-hand corner of the image is a blue link, which reads “AutoCAD (DWG).” Select this link to download a copy of the .dwg file for use in drawing projects. Check to be sure these files save to the correct file folder.

The back button will restore the CAD links page. Below the “CAD Details Library” link are the CAD Drafting Standard and the US National CAD Standard. The drafting standard link navigates to a .pdf copy of the standard for download. The last link is for a CAD standard not currently available to Air Force personnel or within our immediate scope of reasonable expectations.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

401. Fundamentals of drafting

1. Describe parallel lines.

2. Explain the difference between regular and irregular polygons.

3. What makes a line tangent?

4. What are three types of complex curves?

5. What is the difference between a ratio and an actual value scale?

6. What are the two types of scales used to measure a drawing?

402. Interpret and create engineering sketches

1. List the three most common views used in pictorial sketching.

2. Describe an isometric projection.

3. Draw a cube in an oblique view.

403. Utilizing computer-aided design and drafting standards

1. What are the three primary standards used in design and drafting?

2. Provide the URL for the online CAD-BIM library.

1–2. Design

As a set of drawings evolves from an idea to a finished product, they become more complex. Each type of engineer, whether civil, structural, mechanical, or electrical, work to create sheets specific to their fields. Each sheet type has its own set of symbols and practices to represent the work to perform. Additionally, we organize each drawing file a common place and way to allow easy access by everyone involved in project development and design review. This section illustrates basic concepts for working with different types of engineers and organizing the files used to transmit their ideas.

404. Produce technical drawings

As members of civil engineering, we need to know how to understand and create drawing sets. A set of drawings contains all the disciplines necessary to construct a particular facility or complete a project. While this list could be extensive, we will limit the discussion to the basic crafts—civil, structural, architectural, mechanical, and electrical.

Civil

Civil drawings show a variety of information. Also called a site drawing, you find the general layout of a construction project that includes grading, landscaping, utility systems, proposed and existing facility layout, property lines, and improved surfaces. There could be several sheets in a set of civil drawings. The first sheet has a location map, soil boring log, legends, a site plan, and small details or detail identifiers. Civil drawings have a letter “C” in the title block.

Preliminary work

A lot of research goes in to developing civil plans. Remember that these need to give an accurate a depiction as possible of the existing and proposed conditions. The best place to get accurate existing conditions is from a surveyor. Try to obtain a copy of the surveyor prepared field notes or sketches of the proposed site. You may also visit the site to make your own notes as necessary for you to depict the status of the site. Once you have developed an initial drawing, compare the existing to the proposed work this will help you to see the ‘big picture’ for the project. Once you have a good site picture, consult with the project’s engineer for any concerns you have regarding the information you received, as well as the information you acquired through your site visits and drawing search.

Computer-aided drafting work

Review the cover sheet (fig. 1–19) in the drawing set. On the left is the sheet list table. In this set of drawings, the civil sheets are C–1 through C–5. In order, they are the site plan, grading plan, utility plan, demolition plan, and civil details.

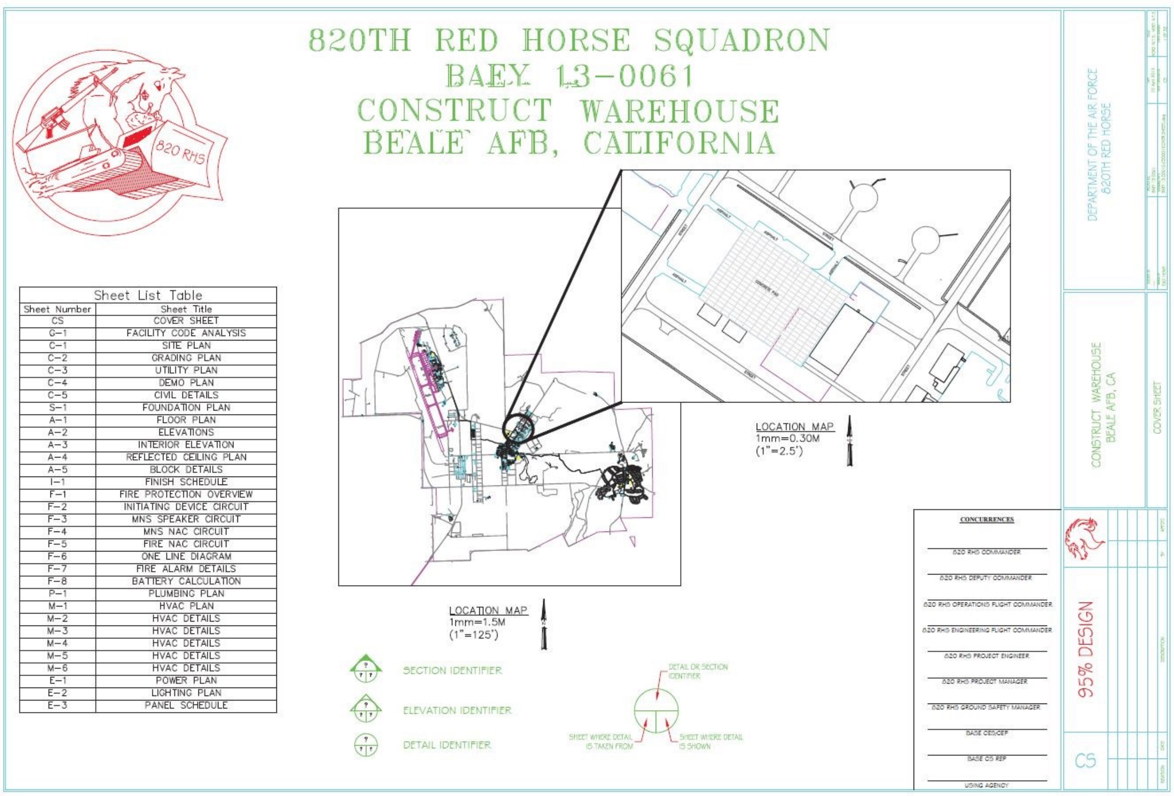


Figure 1–19. Project cover sheet.

Site plans show the site as it is along with proposed facilities. It depicts the type of pavement, location of utilities, street names, topographic contours, and building numbers. A grading plan shows the finished slope, or grade, of the construction site. This is where heavy equipment operators will find information about how to create drainage away from the facility and the final elevation of earthwork prior to construction. Utility plans show the communications, electrical, water, sanitary sewer, and natural gas lines near the construction site. Demo plans show what features need removal. Civil details contains specific information about construction methods throughout the site.

Structural

The materials and methods of construction influence structural drawings. Structural engineering is concerned with the analysis and design of force resisting systems for facilities and other structures. This includes the load-bearing capacity, shear resistance strength, roof, and framing systems. Structural drawings depict structural members and their relationship to one another. Structural drawings include foundation plans, framing plans, column and beam details, other details sections, and schedules (fig. 1–20). General notes provide allowable stresses of all design materials. Refer to the glossary for structural drawing terms.

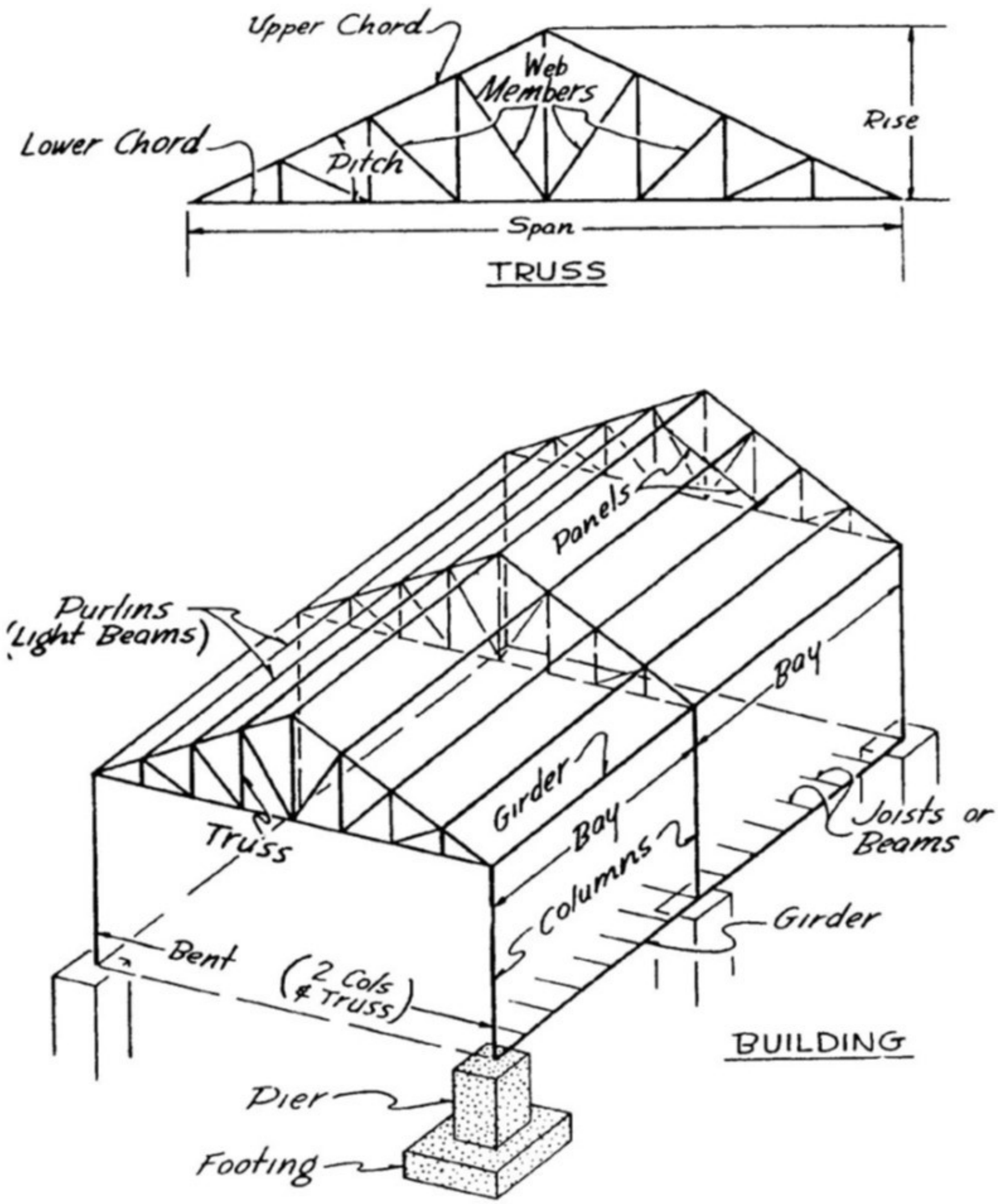


Figure 1–20. Structural members.

Classification of structural drawings

We build facilities in phases, each focused on various materials. Structural drawings depict these phases and materials within a drawing set. Almost all projects include the types of drawings described in the table.

Classification	Description of structural drawings
Foundation plan	The foundation or masonry plan should contain detail drawings of all foundations, walls, piers, and so forth, that support the structure. The plans should show the loads on the foundations, the depths of footings, spacing if piles where used, the proportions of the concrete, the quality of the masonry and mortar, the allowable weight the soil can support, and all data necessary for accurately locating and constructing the foundations.
Framing plan	Framing plans show the size, number, and location of the structural members (steel or wood) constituting the building framework. The floors, walls, and the roof each have separate framing plans. The floor-framing plan must specify the sizes and spacing of joists, girders, and columns used to support the floor. Detailed drawings must be added, if necessary, to show the methods of anchoring joists and girders to the columns and foundation walls or footings. Wall framing plans show the location and method of framing openings and ceiling heights. Roof framing plans show the construction of the rafters used to span the building and support the roof. Roof plans show size, spacing, roof slope, and associated details.
Column plan	Column plans are top view floor plans of each floor of a structure showing the location, size, and material of each column.
Other structures	Also called non-building structures, these include attached and detached structures. These could be pump houses, mechanical rooms, shelters, sheds, and so forth.
Elevations	Any part of the facility, as a whole or in part, drawn from other than a top-down view. These could be full side elevations of section showing wall construction, or a vertical depiction of the entire facility.
Sections	Sectional views, or sections, provide important information regarding height, materials, fastening and support systems, and concealed features. They show how a structure looks when cut vertically by a cutting plane to include materials above and below the surface. The cutting plane is not necessarily continuous but, as with the horizontal cutting plane in building plans, may be staggered to include as much construction information as possible. Like elevations, sectional views are vertical depiction. Detail drawings have large scales to illustrate finer parts of construction. This enhances clarity and provides information that does not fit on elevation or plan views. We classify details as typical or specific. Typical details show how to build more than one area, like a continuous wall or foundation. Specific details show how to install unique items like bollards or doorframes.

Architectural

Architectural drawings develop a design idea into a feasible proposal for construction. They show boundaries, contours, and outstanding features of the construction site. Most importantly, they are technical drawings of how the architectural components fit together.

Typically, they include floor plans, interior and exterior elevations, reflected ceiling plans, and their own detail sheets. Within a drawing set, they do not include finish details. These are the specifics of door and window types, floor and ceiling materials and more. We place finish details, even though they are architectural, in a separate drawing set—the “I” set. This is where door, window, and finish schedules belong.

Mechanical

Mechanical features and plans are typical components of construction projects. Mechanical functions of a facility are those that use mechanical advantage to circulate liquids or gases, such as water or air. This includes any system of air handling, pipes, pressurized gas storage, and the machines associated with them.

To organize drawing sets, we divide specific mechanical functions into different subsets such as fire protection, heating, ventilation, air conditioning (HVAC), and plumbing.

Each fire protection system contains electrical circuits and components, systems of pipes, lighting systems, control panels, and communication systems. Because of their complexity, it is necessary to keep these individual systems separated from their counterparts. Power plans need to be separate from fire protection electrical wiring and so on. Remember, the purpose of a set of drawings is to communicate complex systems from the engineer to the construction workers.

Electrical

In most cases, drawing the electrical wiring diagram over the existing floor plan is a good idea but be sure it has its own layer. For large or complex structures or very busy drawings, it is best to draw them separately. Because it is not practical to depict the location of individual wires in a facility, only the general circuits are shown. A few of the most important electrical plans are the power plan, lighting plan, and the panel schedule.

Power plan

The power plan shows how electricity moves through the facility to electrical outlets, powered equipment (doors, windows, etc.), mechanical systems, and power panels. At the end of each circuit on sheet is a double arrow. This indicates a home run—where the positive and negative wires run the same path back to the circuit breaker panel.

Lighting plan

Lighting plans show the organization and distribution of lights throughout a facility. It also shows how the lights are connected on a circuit and to which switches they are connected.

Panel schedule

The panel schedule may be the most important part of the electrical plan. It describes how the power panel is organized. This is where electricians will look to see how to arrange the wires distributed throughout the facility. Later, when the time comes for maintenance on the facility, electricians and other technicians will know which circuit goes to specific systems.

While there is a lot of information about the power panel that pertains to electricians specifically, some basics are worth noting. Notice the columns labeled “AMP” and “CB AMP.” These refer to the amperage of the circuit and the circuit breaker that can handle the amperage. The circuit breaker must always have a larger capacity than the amperage going through the circuit.

Details

Detail drawings can be shown either on the same page as the item needing elaboration or on a separate detail sheet. They are large-scale drawings showing the builders of a structure how its parts are connected and placed. Details do not use a cutting-plane indication, but they relate closely to sections since sections often use parts of detail drawings. Detail drawings show the construction at and around doors, windows, and eaves. We use detail drawings whenever the information provided in elevations, plans, and sections is not clear enough for the person on the job. We also group detail drawings so that viewers correlate more easily between detail and general drawings.

405. Create and maintain drawing files and directories

Proper naming conventions for electronic drawing files allow CAD users to determine the contents of a drawing without actually displaying the file. They also provide a convenient and clear structure for organizing drawing files within project directories.

These naming conventions may seem complex; however, remember that CEs work with many other disciplines and organizations and in varying locations. Some locations will use MicroStation products, while others use only AutoCAD, and others may use only BIM-related software. We use the following naming conventions with that diversity in mind.

Model file naming convention

The model file naming convention has four mandatory fields: project code, discipline designator, model file type, and user-defined sequencing number (fig. 1–21). All fields must be used and in the correct sequence.

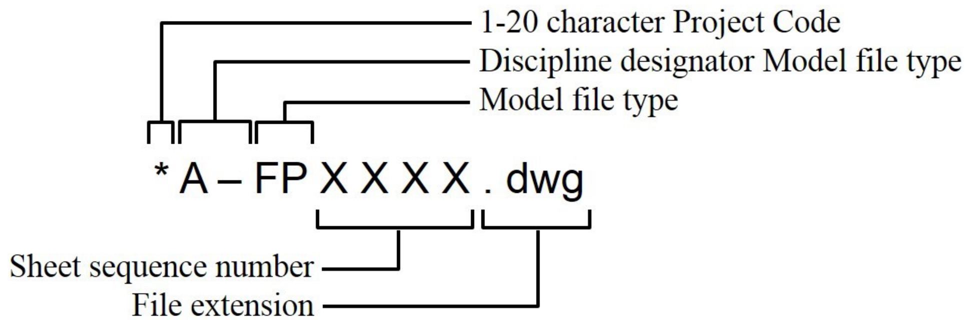


Figure 1–21. Model file naming convention.

Project code

Typical CE project codes include a base specific four-letter designator, the fiscal year in which the project was developed, and a sequence number of projects developed at the same time. The sequence number always has four digits for consistency. For example, the four-letter designator for Beale Air Force Base in California is BAEY. For example, a project to construct a warehouse developed in fiscal year 2013 was the sixty-first project developed. The project number would then be BAEY 13–0061 (see sheet CS in drawing set).

Following the project code field, the first two-character field represents the discipline designator. There are two levels of discipline designators. Level one is the basic discipline such as architectural, structural, electrical, civil, and so forth. Level two designators are the subcategories of each discipline. For example, under the category of civil plans (with a C designator) there may be demolition plans (CD), improvement plans (CI), or notes (CN). Refer to A/E/C Standard R5 for a list of level two designators. If there is no level two discipline designator, use a hyphen "-" as a space holder.

The next two-character fields represent the model file type. There are well over one hundred different model file types in the A/E/C Standard R5. This two-letter code further divides each of the level one and two discipline designators into more subcategories. Under landscaping, the categories include detail (DT), irrigation plan (IP), landscape plan (LP), and so on.

The final four-character field sequences all the previous categories. For example, if there are seven sheets of architectural elevations, number them 0001 through 0007. In addition, if there is more than one floor to a building, the user-defined characters can specify first, second, or third floor with F1, F2, or F3. Individual CE units are responsible for developing standards for user-defined characters.

Putting it all together, a model file, where the user-defined designation for floor plan is FP, which is the third file of the first-floor floor plan of the architectural interiors of a project on Beale Air Force Base, put together in fiscal year 2013, and the sixty-first project programmed we name BAEY130061AIFPF103.dwg.

Sheet file naming convention

The previous material was just for the model files. Remember, it takes a series of joined model files to create a sheet file. Fortunately, naming sheet files is not nearly as complicated.

The sheet type naming convention also has four mandatory fields: project code, discipline designator, sheet type designator, and sheet sequence number. Similar to the format for model file naming, all fields must be used and in the correct sequence (fig. 1–22). Figure 1–23 shows sheet type designators.

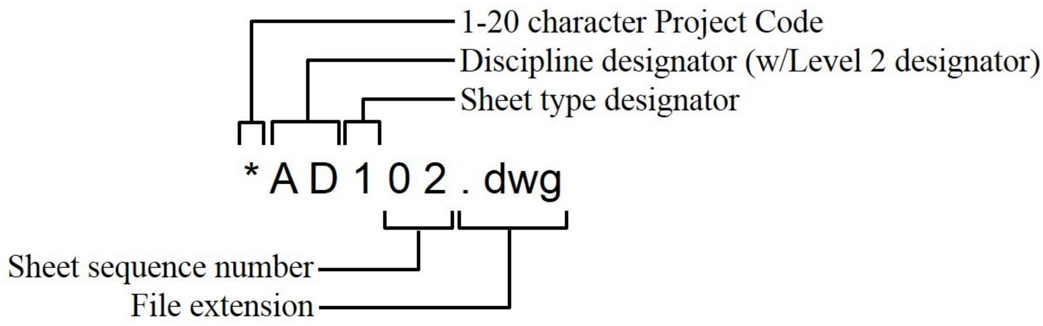


Figure 1–22. Sheet type naming convention.

Sheet Type	Designator
General (symbols legend, notes, etc.)	0
Plans (horizontal views)	1
Elevations (e.g., vertical views, profiles, etc.)	2
Sections (e.g., sectional views, cross sections, etc.)	3
Large Scale Views (plans, elevations, or sections that are not details)	4
Details	5
Schedules and Diagrams	6
User Defined	7
User Defined	8
3D Representations (isometrics, perspectives, photographs)	9

Figure 1–23. Sheet type designator.

After the project code field, the discipline designator field is the same as the model file naming instructions. Be certain to use either a level two designator or a level one and a dash.

If the sheet sequence number goes above 99 sheets for a particular discipline, the user might want to consider using the level 2 designator in the discipline designator to divide the sheets under a broad discipline. In addition, sheet sequence numbers do not always need to be strictly sequential. It is permissible to skip numbers in a sequence (A–108, A–109, and A–113, for example). This will permit insertion of future sheets during the design process.

For example, the sheet file name for project BAEY 13–0061, architectural floor plan, and sheet sequence two should be BAEY130061A–108. BAEY130061 is the project code, A– is the discipline designator, 1 is the sheet type designator, and 08 is the sheet sequence number.

Coordination between sheet file name and sheet identifier

When assigning a sheet identifier (for use in the sheet identification block, reference bubbles, etc.), use the discipline designator, the sheet type designator, and the sheet sequence number (fig. 1–24). Make sure that this sheet identifier is the same for the electronic file name and in the sheet identification block.

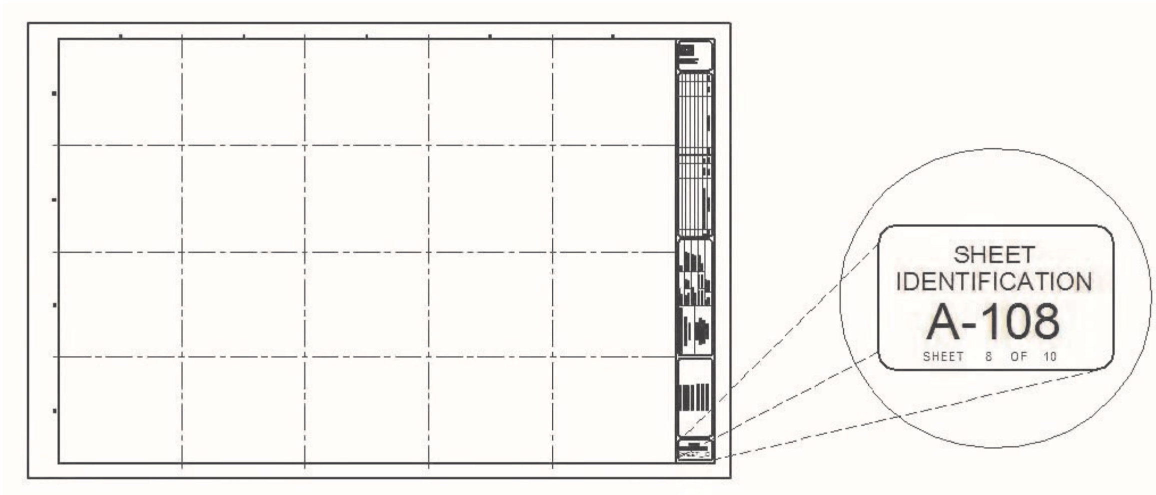


Figure 1–24. Border sheet title block with sheet identification block.

Border sheets

Earlier, we spoke briefly about border sheets. These are among the most critical components of a drafting project. Proper naming, size, and contents of a border sheet are critical to overall efficiency of construction project completion. Title blocks for all these sheet sizes are available for download from the CAD-BIM Technology Center discussed earlier.

Sheet sizes

Typical A/E/C projects, considered legal contract documents, will be prepared on ANSI D sheets. We use ANSI E sheets for large maps like installation master plans or drawings for civil projects. A1 sheets are typically used for international projects and A0 for larger a scale. There may also be other industry standards used depending on specific customer requirements. Figure 1–25 lists the most common sheet sizes.

ANSI		Architectural		ISO	
Mark	Size in inches	Mark	Size in inches	Mark	Size in inches (mm)
F	28.0 x 40.0	F	30.0 x 42.0	NA	NA
E	34.0 x 44.0	E	36.0 x 48.0	A0	33.1 x 46.8 (841 x 1189 mm)
D	22.0 x 34.0	D	24.0 x 36.0	A1	23.4 x 33.1 (594 x 841 mm)
C	17.0 x 22.0	C	18.0 x 24.0	A2	16.5 x 23.4 (420 x 594 mm)
B	11.0 x 17.0	B	12.0 x 18.0	A3	11.7 x 16.5 (297 x 420 mm)
A	8.5 x 11.0	A	9.0 x 12.0	A4	8.3 x 11.7 (210 x 297 mm)

Figure 1–25. ANSI, Architectural, and ISO sheet size comparison.

Title block

Using a vertical title block in the right-hand margin or the border sheet provides the most usable drawing space. It also ensures that the most prevalent and pertinent information remains at the bottom right of the sheet (fig. 1–26). The title block must include the:

- Designer identification block.
- Issue block.
- Management block.
- Project identification block/sheet title block.
- Sheet identification block.

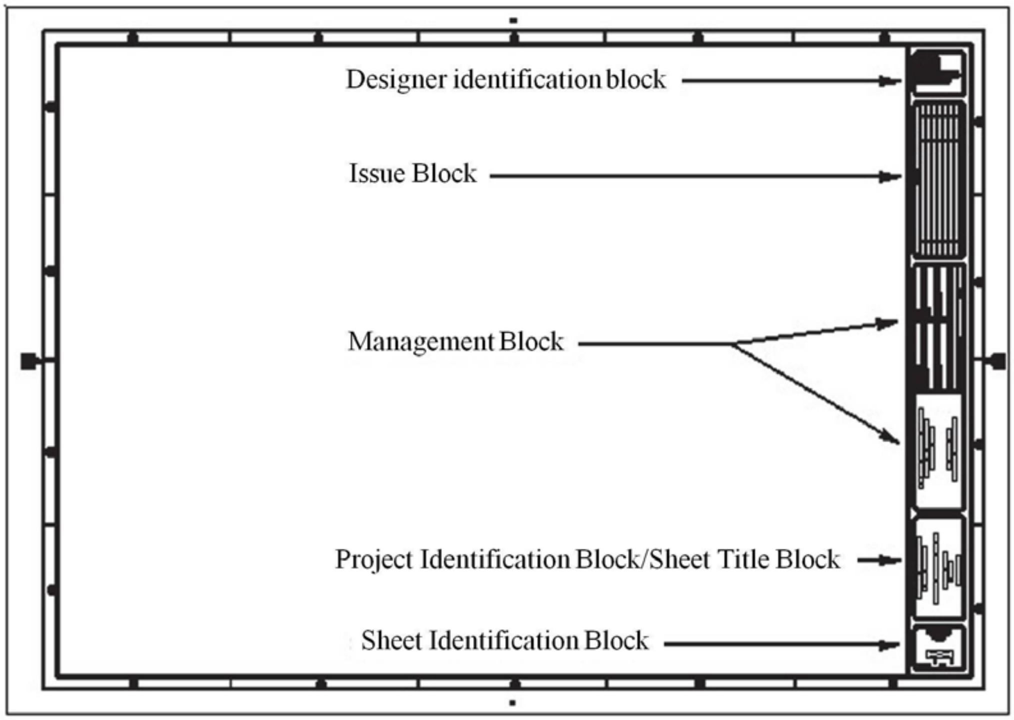


Figure 1–26. Sheet identification blocks.

Designer identification block

The designer identification block contains the logo or name of the agency that designed the sheet. We sometimes expand this space by reducing the size of the issue block to accommodate professional seals when required.

Issue block

The issue block contains a history of revisions, addenda, and/or clarifications to the sheet. Place the first entry on the lower left-hand line of the issue block and make subsequent entries above it.

Management block

The management block contains information about the designer, reviewer, and submitter. We also use this block to maintain filing information about the drawing, such as the file name, plot scale, and drawing code; we sometimes plot this information outside the drawing sheet cut line. If an architectural and engineering firm has developed the drawings, there is room for information about the firm in the lower left portion of the block.

The management block can also contain authorization block information. This is, typically, where the principals of the design agent would sign drawings, either for a whole project or by individual disciplines. Sometimes a disclaimer is included stating whether the project was designed by a government agency or through a contract with a government agency.

Project identification block/sheet title block

The project identification block/sheet title block contains two sets of information. First, the project name is identified, possibly with the location or phase of the project identified. If small enough, we place a project logo in this block. The second set of information contains a description of the content of the sheet (e.g., architectural floor plan). If more than one type of information is present on the sheet (i.e., plans, schedules, details), the most important information determines the sheet title.

Sheet identification block

The sheet identification block contains the sheet identifier discussed earlier. It is optional to add a space for sheet count. If a drawing has one hundred thirty-three (133) sheets, the sheet count would read, 1 of 133 on the first page, 76 of 133 on the seventy-sixth page, and so on. Do not add these numbers until the drawings are complete.

Detail identifiers

This may seem out of place, but all the preceding information was important in order to understand the last part of notation. While there is a large variety of notation available and authorized on the CAD-BIM Technology website, few are more important than the section, elevation, and detail identifiers.

Because of the limitations of space within a drawing set, details about how specific items are constructed are in a separate location within the drawing set. Section, elevation, and detail identifiers provide a bookmark to establish the relationship between a particular component, section, or view of a feature. Each of them divides into the detail identifier, the sheet the detail came from, and the sheet we drew the detail.

Figure 1–27 demonstrates how we distinguish each identifier from the others. Note that the circle, common to each, divides into three sections. The top section lists the specific section, elevation, or detail identified. We draw these either on the same sheet or on a detail sheet labeled alphabetically–A, B, C, D, and so forth. The bottom half of the circle divides in two. The left half contains the sheet number on which the reference is located. The right half contains the sheet number referencing the detail itself (section, elevation).

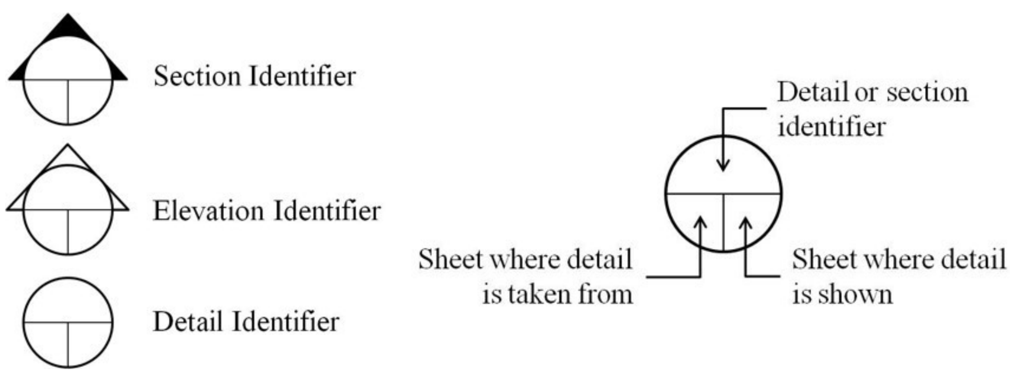


Figure 1–27. Section, elevation, and detail identifiers.

Section identifiers

Section identifiers mark the location of general sections or typical methods of construction, which may span large areas. Wall details, pavement joints, and foundation cross sections use section identifiers. We draw section identifiers with a darkened triangle at the top of the circle (fig. 1–27).

Elevation identifiers

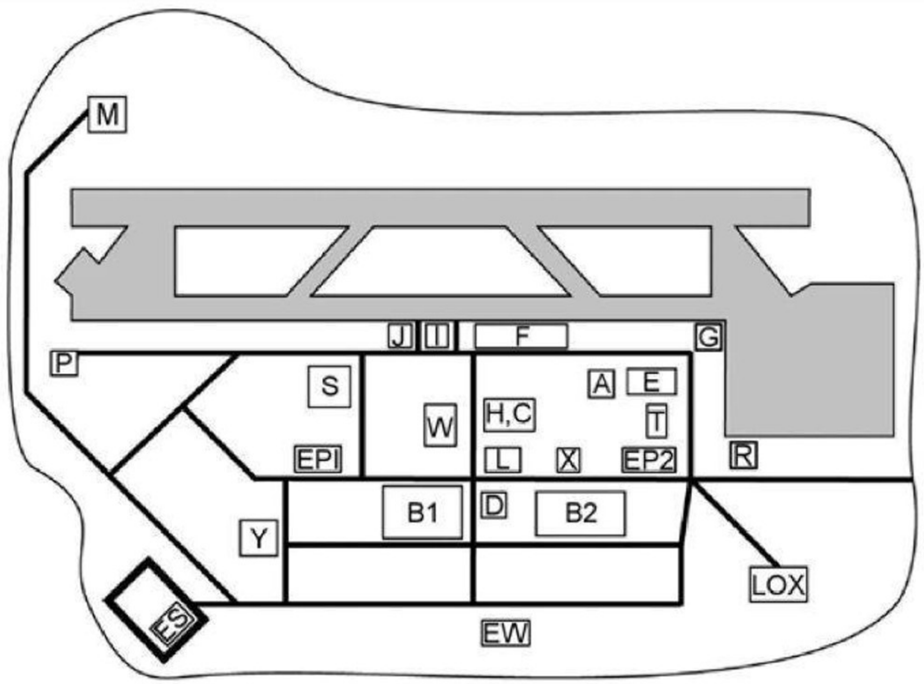
Elevation identifiers are just what they sound like. They reference the elevation of the facility. We draw them with an unfilled triangle at the top of the circle (fig. 1–27).

Detail identifiers

Detail identifiers are similar to section identifiers in that they show specific construction details. For example, we reference the methods of installing doors, bollards, or concrete pads using detail identifiers. We draw them as a circle without a triangle at the top of the circle (fig. 1–27).

Keynote identifiers

Another type of identifier is for general keynotes. We use these when there are manufacturer's specifications and notes for a piece of equipment such as air conditioner units or generators. Keynote indicators are hexagons rather than circles. We divide them in half horizontally with a note in the top and the bottom. The top half indicates the type of unit such as, air handler unit (AHU), air conditioner unit (ACU), and generator (GEN). The bottom half indicates which model or capacity for a specific use within a project. Unlike section, elevation, and detail identifiers, page references for keynote indicators are *not* included in the keynote as they are in detail identifiers because we insert keynotes at the end of the applicable section. Mechanical keynotes will be in the last pages of the mechanical set of drawings. Electrical keynotes will be in the last pages of the electrical drawings. Figure 1–28 shows a keynote indicator for air conditioner unit number four.



A	Avionics	**F**	Maintenance	**P**	POL
B	Billeting	**G**	Squadron Ops		(Petroleum
C	Chaplain	**H**	Support Group		Oil Lubricants)
D	Dining Hall	**I**	Emergency Svcs	**R**	Alert
E	Engineering	**J**	Aerial Port	**S**	Supply
EP	Power Plant (s)	**L**	Laundry	**T**	Transportation
ES	Sewage Treatment	**LOX**	Liquid Oxygen	**W**	Wing HQ
EW	Water Plant (s)	**M**	Munitions	**X**	Medical Fac.
				Y	Comm Plant(s)

Figure 1–28. Keynote indicator.

Maintaining drawing vaults

Every building, road, water line, or anything else that was constructed on an installation has a set of drawings. We keep these drawings in a special room designated the “vault.” Managing a vault is a unique challenge.

Electronic or hard copy

Until recently, all record drawings were hard copies stored in flat file drawers in a room with reinforced walls and a heavy steel door. Some units still have these rooms. The reason for the special location of drawings is that many of these documents have significant historical and, more importantly, legal value. For example, the Air Force tested jet engines at Edwards Air Force Base for super-sonic travel before people were able to break the sound barrier. All the drawings of the buildings, runways, sled tracks, test stands, and so forth, were stored in the drawing vault, managed by engineering. In addition, these drawings are often the only record of how a facility was constructed. When an engineer has to plan an addition to a building or someone in the shops needs to troubleshoot an electrical problem, the record drawings are the first place they look.

Due to personnel cuts, deployments, and the inexpensive access to computer memory, most drawing vaults migrated to electronic vaults. Now, a handful of installations have electronic vaults with no hard copies at all. Most installations have a mixture of CAD drawings, scanned drawings, and traditional hard copy drawings.

As an Airman, you need to be familiar with the drawing file system and produce originals and/or copies for customers. Unfortunately, not all bases use the same filing system for record drawings. It is your responsibility to learn how your installation files drawings.

Another common task is to scan full size drawings from the vault into the electronic filing system. You will also convert CAD drawings into the Adobe portable document format (PDF) and file them appropriately. All modern CAD programs have an option to plot or publish a drawing to the PDF. Just select “Adobe PDF” as the printer in the print menu. Pull down the list of printers/plotters available in the CAD program print menu and there will be an option to print/plot to the PDF. This creates an electronic file, which you can then name and file appropriately.

Currently, there is no official guidance on establishing a filing structure for an electronic drawing vault. Each installation has unique mission requirements and their systems have evolved organically.

Servers

Most of your work will be on a desktop computer. However, storing files there causes problems. This is why we use networked computers to access servers. Storing files on servers enables coworkers to access and share files. If files are on your desktop computer, no one else can see or use them if you are on leave or if you get sick.

Servers are powerful computers located outside the CE facility. Your computer is one of many connected to a large network of computers. All Air Force (AF) computers connect to a system called the Air Force Network (AFNet). AFNet allows computer managers to better centralize services like email and data storage. This significantly improves network security and standardization.

When servers and personal computers linked together, forming a network, these can be either a local area network (LAN) or a wide area network (WAN). LAN implies computers within a building, office area, or installation. Most LANs are limited to small scale and remote locations. WAN implies communication over a broad area or region.

There are different types of servers. Some only store files while others handle more active tasks like printing or email management. Storage servers can be divided into different parts and each part used for different purposes—this is called partitioning. Picture a chest of drawers as a partitioned server. One drawer for one person or shared with a few people. Another drawer could have only pants while another uses the top drawer for socks and the rest is t-shirts.

Best practice example

ERM 99 CES Working Files Folder (S:) contains the working electronic files (fig. 1–29). That folder has each of the shop codes for the squadron with “CEN” being engineering flight. Next is “3_BUILDING_VAULT.” The “3” is a designator for the software telling it to sort the folders in numerical order rather than alphabetical. There are times when more frequently used or important folders will be toward the top of a folder structure for ease of access. The 99th Civil Engineer Squadron (CES) is responsible for maintaining files for more than one installation. This could be the case if there are satellite bases or if there is a joint basing structure with Air Force CEs holding responsibility for installation maintenance. The “1_NELLIS” folder lists each building in numerical order.

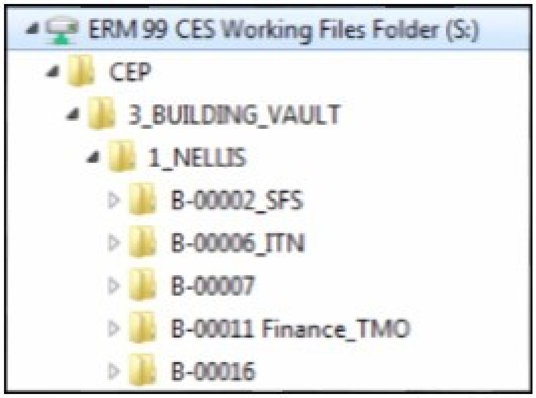


Figure 1–29. S drive configuration.

Figure 1–30 shows the folder structure for building 180. The “B–00180_F35AGE” folder contains as-built drawings. From there, the folders split by project title. Each project folder contains the documents and drawings for the project. For this section, we are most concerned with the “DRAWINGS” folder.

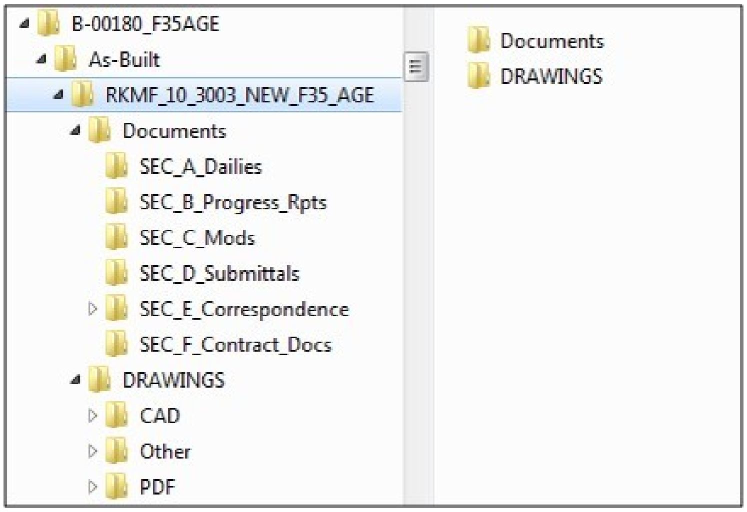


Figure 1–30. Building folders.

Within the DRAWINGS folder are CAD, Other, and PDF files (fig. 1–31). This figure also has the CAD and PDF file folders shown side by side. While CAD and PDF are self-explanatory, “Other” is reserved for several other types of drawing files such as jpg, tiff, bmp, or a host of others. Note that the folder structure within CAD and PDF are the same and they are both missing folders for cover sheets, general notes, and site plans. This is because those sheets are stored within the CAD and PDF folders respectively. This method enables an individual to open the PDF folder, browse the table of contents on the cover sheet, find a specific drawing, and browse directly to it.

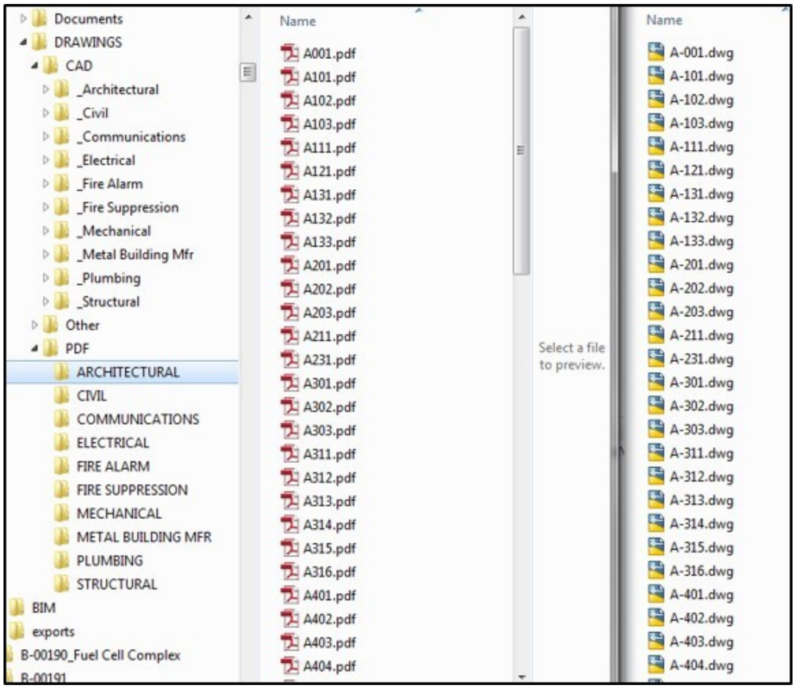


Figure 1–31. Building folders.

Hard copies

Most installations still have traditional drawing vaults full of flat file drawers and hanging file frames. Even with the prevalence of electronic media, there is still a significant place for large size paper drawing files.

During the cycle of project design, there are set review periods. Before sending a set of drawings to contracting or given to the shops for construction, the set of drawings must go through the thirty-five (35), sixty-five (65), ninety-five (95) and one hundred (100) percent review process. Because there are several parties involved in the review process, it is often most convenient to have a full set of full size drawings easily available for review. These design drawings will have the percent designator in the title block. For ease of access, these are stored on a hanging drawing rack (fig. 1–32). The spine of each drawing set will have the project title. As the respective crafts and engineers review the drawings, the designated drafter is responsible for ensuring those changes are made to the digital file.

Flat files are stored in a typical flat file drawer system (fig. 1–33). We group the drawers by building number or specific utility. We further divide utility maps into different sections within the installation. Typically, the utilities will include sewer, water, compressed natural gas, electrical, communications, and storm sewer. Within the drawers, the files will be stacked according to project number with the newest being on top.

When researching flat files, remember there may be a complex system of cross reference. For example, if you are looking for the location of a specific water line close to a building, that file may not be located in the water utility drawer. It may be necessary to look at the as-built drawings by building to check if the water line's construction was part of the original construction project.

The most important practice when managing flat files is putting them away properly and immediately. In addition, it is very important to limit the individuals with access to the drawings. The status of the as-built drawings is the responsibility of the engineering flight. While engineers and craft personnel are perfectly capable of retrieving and reviewing drawings, it is your responsibility to put them away properly.

Figure 1–32. Hanging file frame.

Figure 1–33. Flat file system.

Update record drawings

Record drawings, also called as-built drawings, will be digital or hard copy. Digital drawings will be either vector (.dwg, .dgn), or raster (.jpg, .tiff, .bmp). Whether digital or hard copy, there will be times when we need to make changes or updates to the drawings of record.

As-built drawings are the final drawings and contain modifications, field changes, shop drawing changes, design changes, and every change that approved and made during construction. Below is a basic list of necessary steps to ensure the accuracy of as-built drawings:

- If you replace a sheet to the drawings, use the same sheet size, scale, and legend as the sheet taken out.
- Be sure to include all changes made from the final inspection performed by the project manager or quality assurance personnel in the construction management element.
- Use written explanation to describe changes.
- Use clear lettering.
- Refer to specific actions instead of referencing change order numbers or related documents
- Be sure to add revision notes and corrections to affected section view, general notes, specific notes, profiles, and schedules.
- Add all related shop drawings to as-built drawings.
- Update the index sheet to show latest drawing changes or additions.
- Be specific when making notes to underground utilities, showing exact location, depth, and material used.
- When finished, stamp title sheet with, “RECORD DRAWING AS-BUILT” including contractor’s name, date, and other relevant information.
- If there are no changes made to a sheet, label the sheet “As-Built.”
- If there are changes or modifications to a sheet, label it “Revised As-Built.”
- Prepare a final compact disc read-only memory (CD-ROM) with the as-built drawings and be sure the drawings are stored in the appropriate electronic database or server location.

Existing/demolition model file naming

There are instances when a facility needs renovation and the as-built designs need to reflect the revised conditions. We do not make these revisions on existing as-built model files but on copies to ensure the original as-builts remain unchanged.

We add a model file type, existing/demolition (XD), to the standard to allow users to revise as-built files. This model file type aids users in separating existing-to-remain items from items to be demolished.

For example, you have an existing as-built floor plan model file for building 1000, 2nd floor. For the current project, walls will be demolished and new walls constructed on the 2nd floor. First, make a copy of the original as-built file (B1000A-FPF2XX.dwg) and name it B1000RENA-XDF2XX.dwg where B1000REN is the Project Code, A- is the Discipline Designator, XD is the Model File Type (Existing/ Demolition Plan), and F2XX are user-definable characters (F2=Floor 2). Open this file and move all demolition items to demolition layers. When the new items in the floor plan are drawn, open a new model file called something like B1000RENA-FPF2XX.dgn/.dwg where B1000REN is the Project Code, A- is the Discipline Designator, FP is the Model File Type (Floor Plan), and F2XX are user-definable characters (F2=Floor 2). Name the final file B1000RENA-XDF2XX.dwg and reference it with the demolition levels/layers turned off. Use the floor plan active layers to construct the new items for that project.

406. Conducting design review

As a design team member, engineering personnel must be familiar with the project execution process. There are two primary methods to design projects for contract action. We accomplish designs either with an in-house design team or by a commercial architect-engineer (A-E) design firm.

The term "in-house design" refers to a design done by the CE squadron personnel. The design team provides design services for a client (using agency) on the base.

A-E design refers to work contracted to a private A-E firm. Engineer flights quickly select a reliable firm in various ways. The project designer's main responsibilities are writing the statement of work (SOW), preparing the design fee estimate, assisting contracting in negotiating the design fee, reviewing and coordinating design submittals, and processing the 100 percent design documents for contract action.

When we discover design flaws during construction or after completion, the project designer is responsible for working with contracting to ensure correction through the A-E and/or that A-E pays damage.

Project familiarization

Prior to design start, we perform an initial investigation for a better understanding of the project requirements. This consists of two parts: research and organization of information.

We search several common sources when conducting research. The Department of Defense (DD) Form 1391, FY_ Military Construction Project Data, discussed later in this volume, is an excellent starting point. The CE work request form may also have valuable information. Some of the most valuable information often comes from the crafts in the operations flight. These people have first-hand experience in the maintenance and repair of the base facilities. It is also helpful to look at contract documents and drawings from similar past projects. In all cases, the research should include a visit to the site for initial investigation of conditions prior to the pre-design conference. When project familiarization is complete, we consider the project to be at the 10 percent stage.

Open-end contracts

During the design phase or the review phase, it may become apparent that an open-end contract can serve the customer's needs best. We refer to open-end contracts as indefinite delivery indefinite quantity (IDIQ) contracts. Indefinite delivery means jobs could come at any time. Indefinite quantity means projects could fit within a large range of scope.

An IDIQ contract enables the base civil engineer (BCE) to have one contractor under contract for a given type of work. Unlike normal contracts, which have a definite start date, finish date, and a specific project, IDIQ contracts have more flexibility. IDIQ contracts typically have an initial performance period of one year with four options to extend up to a 5-year contract. This allows the BCE to have one contractor on standby for a certain kind of work with the option to rebid the contract each year should the contractor underperform.

IDIQs are especially useful when the base has a variety of small and recurring requirements, including maintenance, repair, and minor construction. The Operations Flight Recurring Work Program (RWP) is a method to ensure the accomplishment of routine maintenance on base facilities. If, for example, staffing is a problem or there is a specific required skill set, IDIQ contracts can fulfill the RWP program. Two common examples of IDIQ contracts are roofing repair or road paving.

Review stages

Several functional agencies complete project review during the design process. There are at least seven but sometimes eight review stages. These stages are the *functional* review, *contracting* review, *operations flight* review, *fire protection flight* review, the *constructability* review, the *final* review, the

BCE review, and sometimes the *command* review. During design reviews, functional agencies provide comments in writing.

Functional review

In the functional review by the using organization, the project designer guides the customer through the entire design process to help the customer fully understand the drawings and specifications in relationship to their requirements. This ensures customers know what they are getting.

Contracting review

During the contracting review, base contracting reviews all project documents, to include sets of drawings and specifications. When contracting returns the project review comments, the project designer incorporates the appropriate comments in the design package. The project designer sends a reply to contracting indicating the action taken on each comment. It is essential to the success of the entire design process that engineering and contracting work together to accomplish mutual goals.

Operations flight review

The operations flight review is to ensure the design drawings and specifications meet operability and maintainability requirements. The operations flight determines if contract maintenance is required or if the hiring of additional personnel is necessary to perform maintenance. The review also ensures building system components are easily accessible for routine maintenance and replacement. Experienced facility maintenance personnel ensure designs do not include specifications of a system that would be non-maintainable. One objective of the project design is to select systems, components, and arrangements, which reduce future maintenance. Such facility systems include exterior and interior finishes, windows, and roofs for buildings. Maintenance points and maintainable controls for mechanical systems and adequate shutoff points and looping for utilities distribution systems are considered. Storm water drainage, adequate edge containment techniques for pavements and corrosion control for buried systems and components are reviewed.

Fire protection flight review

The fire protection flight review ensures the drawings and specifications meet fire safety, life safety, and code compliance. They also ensure the design meets local fire fighting operational requirements (i.e., accessibility to facility, location of fire hydrants, etc.).

Constructability review

We, engineering, complete the constructability review. This review is a common sense check. You check to see if what, and how, the project designer wants built or repaired is clearly described. The goal of the review is to both reduce the likelihood of delays in bid openings or potential modifications during construction, which causes wasted effort, higher construction costs, subsequent contractor claims, increased administrative effort, and delayed contract completion.

In order to ensure that a constructability review is thorough, it is important to make a plan. The most common plan can be broken into six sections. The following checklist, as a suggestion built on best practices and experiences, is not comprehensive but shows the breadth of the questions you will consider during the constructability review.

Constructability Review Checklist	
Section I. General	Yes No N/A
Should the project be broken into phases to allow agency functions to continue?	
Have access and haul routes for the contractor been considered?	
Is there a basic understanding of what is expected? Is the scope of work clear?	

Constructability Review Checklist	
Are there any clear ambiguities of what is expected? Is the scope of work clear?	
Does design comply with Command and Base Architectural Standards?	
Section II. Construction site	
Do the plans accurately depict obvious as-built conditions?	
Will temporary utilities be readily available if the project documents offer them?	
Spot check the elevations. Do the plans seem relatively accurate?	
Do the plans indicate sodding, or some means for quick turf establishment in problem areas? Do the plans address turf establishment at all?	
Do the plans accurately depict the locations of utilities?	
Section III. Architectural/Structural	
Do the plans clearly distinguish the difference in existing a new work?	
Does the room finish schedule include information on all rooms indicated to receive work?	
Do the specifications call for all color selection submissions at one time?	
Does the door finish schedule include information on all rooms indicated to receive applicable work? Does it agree with the specifications?	
Is dimensioning clear? Do the dimensions shown agree with the indicated scale?	
Section IV. Mechanical/Plumbing	
Do the plans show where all new gas, water, sewer lines, and so forth, connect to existing?	
Do all plumbing fixtures connect to domestic water supply, and sanitary drains?	
If there is a fire sprinkler system, are there sprinkler heads in all rooms?	
Do the plans allow adequate ceiling height to install new ductwork at worst-case intersection?	
Is there a schedule of performance on the plans, or in the specifications for all mechanical equipment?	
Section V. Electrical	
Do all light fixtures agree with the reflected ceiling plan?	
Do the plans and electrical riser diagrams show the locations of panel boards?	
Do the specifications require that all electrical work be in accordance with the latest edition of the NEC?	
Does the contractor need to provide temporary power in the event of panel removal? If not, is this acceptable?	
Does electrical equipment shown scheduled or sized on plans agree with schedules or sizes in specifications?	

Constructability Review Checklist	
Section VI. Environmental	
Are there any environmental contaminants that may be present in existing equipment or on site?	
Are there any environmental materials that can be recycled or recovered?	
Has the project been reviewed by a base environmental representative?	

Final review

The final review is actually the final step before it goes to the BCE. The chief of the engineering flight and the chief of contracts conduct the final review.

BCE review

The BCE conducts a review of the completed project documents, specifically the specifications and drawings, with the assistance of the deputy base civil engineer, chief of the engineering flight, chief of contracts, and the project designer (as required).

Command review

The command reviews projects on a selected basis, usually to ensure site adequacy based on site investigations, provision of special technical requirements, adherence to Air Force criteria, correction of design errors and omissions before contract award, safety and fire protection, reliability and maintainability, energy efficiency, structural integrity, and constructability. Command reviews are particularly important for hospitals and top-secret facilities.

At the final design stage, there should be no design changes. If the design team did a good job keeping the user(s) involved, changes should be limited to clarifications, misspelled words, and typos. Any other change will require written justification from the requester. Change approval occurs only for equipment or mission changes and only after approval of a work request (AF Form 332, Base Civil Engineer Work Request).

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

404. Produce technical drawings

1. What are the basic craft drawing sets found in most construction projects?

2. What do we show on a framing plan?

3. List the most important electrical plan sheets.

405. Create and maintain drawing files and directories

1. Name the parts of the model file naming convention.

2. Breakdown the project code “BAEY 12–0061.”

3. Define the parts that make up the sheet file name “BAEY130061A–108.”

4. List the sheet sizes A through F for both ANSI and Architectural sizes.

406. Conducting design review

1. What are the eight review stages?

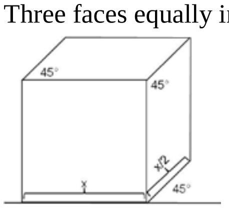
2. What is the goal of the constructability review?

Answers to Self-Test Questions

401

1. Two lines, never crossing, always the same distance apart.
2. Regular polygons have sides of equal length. Irregular polygons have uneven sides and angles.
3. When the line touches a circle at a single point.
4. (1) Compound.
   (2) Reverse.
   (3) Spiral.
5. The ratio scale represents units, of any type, while the actual value is specific to the units used.
6. Decimal and traditional (or imperial).

402

1. (1) Axonometric.
   (2) Oblique.
   (3) Perspective.
2. Three faces equally inclined toward the drawing surface and drawn to the same scale.
3. 

Oblique

403

1. (1) ANSI.
   (2) AGS.
   (3) ISO.
2. https://cadbim.usace.army.mil.

404

1. (1) Civil.
   (2) Structural.
   (3) Architectural.
   (4) Mechanical.
   (5) Electrical.
2. Size, number, and location of the structural members constituting the building framework.
3. Power plan, lighting plan, and panel schedule.

405

1. (a) Project code.
   (b) Discipline designator.
   (c) Model file type.
   (d) User-defined sequencing number.
2. "BAEY" is the base specific designator, "12" is the fiscal year the project was developed, and "0061" is the sequence number of projects developed in that fiscal year.
3. "BAEY 13–0061" is the project code, "A" is the discipline designator, "1" is the sheet type, and "08" is the sheet sequence number.
4. ANSI: A 8.5x11, B 11x17, C 17x22, D 22x34, E 34x44, F 28x40.
   Architectural: A 9x12, B 12x18, C 18x24, D 24x36, E 36x48, F 30x42.

406

1. (1) Functional.
   (2) Contracting.
   (3) Operations flight.
   (4) Fire protection flight.
   (5) Constructability.
   (6) Final.
   (7) BCE.
   (8) Command reviews.
2. To both reduce the likelihood of delays in bid openings or potential modifications during construction, which causes wasted effort, higher construction costs, subsequent contractor claims, increased administrative effort, and delayed contract completion.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (401) By what name do we refer to the space between any points A and B?
   a. Angle.
   b. Point line.
   c. Line segment.
   d. Perpendicular line.

2. (401) The ratio of the size of drawn objects compared to their actual counterparts is called
   a. scale.
   b. size ratio.
   c. representation.
   d. engineering comparison.

3. (402) A basic orthographic projection shows an object from how many different views?
   a. Two.
   b. Four.
   c. Eight.
   d. Twelve.

4. (402) What name do we give to a roofless cutaway of a build from a bird's eye view?
   a. Detail.
   b. Sketch.
   c. Elevation.
   d. Floor plan.

5. (403) What is the web address for the computer-aided drafting-building information modeling (CAD-BIM) library?
   a. Https://usace.army.mil.
   b. Https://cadbim.army.mil.
   c. Https:// cadbimcenter.erdc.dren.mil.
   d. Https://usace.army.mil/cadbim/library.

6. (404) Which technical drawing set contains a general layout of the construction project?
   a. Civil.
   b. Electrical.
   c. Structural.
   d. Mechanical.

7. (404) Which engineering discipline is concerned with the circulation of liquids or gases, such as water or air?
   a. Civil.
   b. Electrical.
   c. Structural.
   d. Mechanical.

8. (405) In the model file naming convention, what comes last just before the file extension?
   a. Model file type.
   b. Sheet sequence number.
   c. 1–20 character project code.
   d. Discipline designator model file type.

9. (405) Which of these is *NOT* found in the project code portion of the model file naming convention?
   a. Base specific designator.
   b. Initials of project draftsperson.
   c. Fiscal year project was developed.
   d. Sequence number of projects developed at same time.

10. (405) At a minimum, the title block includes all the following *EXCEPT*
    a. storage index.
    b. management block.
    c. designer Identification.
    d. project identification block.

11. (405) What type of detail identifier marks the location of general sections or typical methods of construction?
    a. Detail.
    b. Section.
    c. General.
    d. Elevation.

12. (406) Who completes the constructability review?
    a. Fire department.
    b. Operations flight.
    c. Contract squadron.
    d. Engineering flight.

Please read the unit menu for unit 2 and continue ➔

Unit 2. Construction Management

CONSTRUCTION MANAGEMENT is the next step in drafting and design work. We base construction on sets of drawings. Those projects, when funded, transfer to the construction management element of engineering flight. In construction management, you are responsible for ensuring construction occurs as agreed to in the contract. As a foundation for this responsibility, you need to understand the structure of the construction management element, the documentation that explains what the contract is to do, and what you are to do as the eyes and ears of the government on the job site. Communication skills are important since you will be the center of a web of players working together to provide the Air Force with the tools it needs to execute its mission.

2–1. Construction Management

Regarding construction management, our job is to protect the taxpayer. This means ensuring that the Air Force gets the products it pays for from contractors. Engineering personnel play a large role in the execution of construction contracts. We provide the technical knowledge and are a liaison between the civil engineering and contracting squadrons. Here, we look at how we structure construction management in order to get a clear idea of where you fit into the process.

407. Construction management

Construction inspectors in the construction management element are responsible for oversight of assigned contracts. These tasks involve providing surveillance, conducting inspections, and ensuring quality performance. The main responsibility of construction management personnel is to ensure the government receives quality and complete work as outlined in government or A-E produced contract documents (i.e., specifications and project drawings).

Cradle to grave

Projects sometimes happen very quickly but typically develop over long periods. Assignment to construction management commonly involves working on projects programmed years before you arrived at a duty station. Because this is often the case, having a cradle-to-grave approach is important. We accomplish this through management practices that extend from design through construction completion. Engineering flights will have individual policies and practices to ensure continuity. It is the responsibility of the construction inspector, once assigned to a project, to become familiar with all aspects of a project all the way back to its inception in the planning and programming phases.

Inspector responsibilities

All construction inspectors must be familiar with all appropriate regulations, manuals, engineering technical letters (ETL), and internal operating instructions pertaining to the contracts element. They conduct constructability reviews of assigned projects prior to solicitation and coordinate all facility work with affected base organizations to minimize mission impact or to develop alternate operating procedures. They inspect construction sites at least once a day during routine work and during all phases of critical construction. Inspections will, at a minimum, address the following issues:

- Construction and personnel safety.
- Site cleanliness and control of debris and materials.
- Communication with contractor superintendent.
- Resolution of potential conflicts between users and base organizations.
- Monitoring the progress of construction.

The construction inspector maintains a contract folder to consolidate all contract information prior to and during construction. An experienced inspector can control contract cost and performance growth rate. Good foresight, attention to potential problems, and timely correction or contract modifications all ensure uninterrupted contract performance. The inspector looks for ways to reduce contract cost and/or performance period by deviations in contract specifications that would still satisfy the requirements of the project.

Contract start

As soon as a project awards, the construction inspector assigned to that project will begin recording the construction progress data. Recording begins at the pre-construction meeting. Prior to the pre-construction meeting, the using agency inspects the job site. We record any problem areas or existing damages not part of the contract. During this site inspection, discussion of any phasing on the project that will affect the user’s operation through moves, inconveniences, location of storage sites, and so forth. A memorandum for record stating any problems or damages noted is prepared.

Notice to proceed

Before the contractor can begin work, they need a formal letter called the notice to proceed. This is a legal document between the contractor and the government stating the contract performance start date and duration, or performance period. Issue of this letter occurs after technical reviews and negotiations between the contractor and the contracting officer are complete. The letter indicates that all parties have agreed on quantities, line items, prices, scope of work, and performance time.

Pre-performance conference

Base contracting will prepare formal minutes from the pre-performance conference, with a copy forwarded to the construction inspector for inclusion in the folder. Before commencing with construction, the contractor will set up the construction site in accordance with the contract’s construction site standards and notify the construction inspector of conditions not consistent with the contract.

Construction permits

Depending on the scope of the project, several permits could be required. Different states, local authorities, and installations have unique requirements for what types of work need a formal permit. The most common types of permits are environmental, asbestos, and lead paint. Projects close to or within the airfield usually need special permits and waivers. Early identification of permit requirements in the design phase speeds up the start of construction. The construction inspector is not responsible for initiating the permits; the project designer is. However, before construction begins, the construction inspector needs to ensure the necessary permits are in place.

Air Force Information Management Tool 103

The Air Force (AF) Information Management Tool (IMT) 103, Base Civil Engineering Work Clearance Request, (fig. 2–1) is the last form completed prior to construction. The AF IMT 103, often incorrectly called a *dig permit*, allows the BCE to approve execution of any construction. Both contract and in-house work require completion of the AF IMT 103.

The front of the AF IMT 103 has a list of shops, crafts, or organizations, which need to approve the form. Each organization needs to sign the form indicating its approval for the work to proceed. The back of the AF IMT 103 should have a description of the work-taking place along with necessary precautionary measures to avoid safety hazards and damage to existing systems. All AF IMTs 103 must have an accurate, current map of the specific area showing roads, sidewalks, buildings, utilities, airfield clear zones, or quantity-distance (QD) arcs within the area.

While each installation may have a unique process to complete the Form 103, the essentials are the same. The persons or organization performing the work must complete, submit, and obtain approval prior to beginning work. Engineer assistants (EA) are often involved in the processing of work clearance requests but should *not* complete them for other persons or organizations.

Military construction programming

Military construction, or MILCON, is construction on a larger scale. By definition, MILCON includes any construction, development, conversion, or extension of any kind carried out with respect to a military installation. It includes all construction work necessary to produce a complete and usable facility or a complete and usable improvement to an existing facility. Typically, these are projects too large in scope to use the operations and maintenance (O&M), or Simplified Acquisition of Base Engineer Requirements (SABER) programs. EAs normally have very limited involvement in MILCON projects. Most often, the United States Army Corps of Engineers (USACE) manages all MILCON projects on AF installations.

Project justification

The installation programmer must prepare strong, accurate justification data for MILCON projects. Justification preparation is one of the most important actions in MILCON program development, which all DOD organizations record on a DD Form 1390, FY_ Military Construction Program. Variations from sizing guidance in Air Force Manual (AFMAN) 32–1084, *Facility Requirements*, must be justified.

MILCON process

For the planning and programming of major facility construction projects, find guidance in Air Force Instruction (AFI) 32–1021, *Planning and Programming Military Construction (MILCON) Projects*. The MILCON program includes construction projects for all types of buildings, airfield pavements, and utility systems costing $750,000 or more. It can also include repair projects costing over $750,000 or more, but repair projects receive funding through O&M programming.

BASE CIVIL ENGINEERING WORK CLEARANCE REQUEST
(See Instructions on Reverse)

DATE PREPARED: 20160301

1. Clearance is requested to proceed with work at 6007 Cooley Ave on Work Order No. 6007 Cooley Ave, Contract No. NA, involving excavation or utility disturbance per attached sketch. This area [X] has [ ] has not been staked or clearly marked.

2. TYPE OF FACILITY/WORK INVOLVED

[X] A. PAVEMENTS	[ ] D. FIRE DETECTION & PROTECTION SYSTEMS	[ ] G. AIRCRAFT OR VEHICULAR TRAFFIC FLOW
[ ] B. DRAINAGE SYSTEMS	[ ] E. UTILITY [ ] OVERHEAD [ ] UNDERGROUND	[ ] H. SECURITY
[ ] C. RAILROAD TRACKS	[ ] F. COMM [ ] OVERHEAD [ ] UNDERGROUND	[ ] I. OTHER

3. DATE CLEARANCE REQUIRED: 20160315	4. DATE OF CLEARANCE: 20160312	
5. SIGNATURE OF REQUESTING OFFICIAL: Shawn Helgerson	6. TELEPHONE NO.: 954-9733	7. ORGANIZATION: 364 TRS

ORGANIZATION	REMARKS (*Use Reverse for additional comments*)	REVIEWER'S NAME AND INITIALS
8. BASE CIVIL ENGINEERING — A. ELECTRICAL DISTRIBUTION	364 TRS	SMH
B. STEAM DISTRIBUTION	364 TRS	PPJ
C. WATER DISTRIBUTION	364 TRS	RHS
D. POL DISTRIBUTION	364 TRS	LRS
E. SEWER DISTRIBUTION	364 TRS	LOL
F. ENVIRONMENTAL	364 TRS	LMAO
G. PAVEMENTS/ GROUNDS	364 TRS	AMC
H. FIRE PROTECTION	364 TRS	ACC
I. ZONE ______	364 TRS	ATD
J. OTHER *(Specify)*	364 TRS	OHG
9. SECURITY POLICE	364 TRS	BFF
10. SAFETY	364 TRS	LMK
11. COMMUNICATIONS	364 TRS	WRT
12. BASE OPERATIONS	364 TRS	YRG
13. CABLE TV	364 TRS	GTG
14. COMMERCIAL UTILITY COMPANY [X] TELEPHONE [X] GAS [X] ELECTRIC	Pulaski County Utility & Underground Stuff	FML

15. OTHER *(Specify)* ______

16. REQUESTED CLEARANCE [X] APPROVED [ ] DISAPPROVED

17. TYPED NAME AND SIGNATURE OF APPROVING OFFICER *(Chief of Operations Flight or Chief of Engineering Flight)*: Harriet Q. Berkenmeier

17a. DATE SIGNED: 20160312

AF IMT 103, 19940801, V3 PREVIOUS EDITIONS ARE OBSOLETE.

INSTRUCTIONS

The BCE work clearance request is used for any work (contract or in-house) that may disrupt aircraft or vehicular traffic flow, base utility services, protection provided by fire and intrusion alarm system, or routine activities of the installation. This form is used to coordinate the required work with key base activities and keep customer inconvenience to a minimum. It is also used to identify potentially hazardous work conditions in an attempt to prevent accidents. The work clearance request is processed just prior to the start of work. If delays are encountered and the conditions at the job site change (or may have changed) this work clearance request must be reprocessed.

18. REMARKS. *(This section must describe specific precautionary measure to be taken before and during work accomplishment. Specific comments concerning the approved method of excavation, hand or powered equipment, should be included.)*

Repair pavement on running track next to base fitness center.

AF IMT 103, 19940801, V3 *(REVERSE)*

Figure 2–1. AF IMT 103.

408. Simplified Acquisition of Base Engineering Requirements program

Developing a construction project from customer request to post-final inspection is a complex, time-consuming process. If a civil engineer squadron tried to complete this process for every request, customers would wait years. The solution is the SABER program. SABER allows the BCE to have a construction contractor already under contract. This makes the SABER contract a kind of IDIQ.

SABER expedites contract execution of BCE requirements by reducing design work and acquisition lead times. It is particularly well suited for reducing the BCE work order backlogs and accomplishing non-complex construction, maintenance, and repair requirements. SABER complements, rather than replaces, an installation's contract program. SABER is very similar to a civil engineering requirements contract. It allows the BCE to define a general scope of work and, then, issue delivery orders against the contract, eliminating the hassle of competitive bid.

A SABER contract includes a collection of detailed task specifications encompassing most types of real property maintenance, repair, and construction work. A SABER contract sets a guaranteed minimum and maximum cost for the contract. The initial contract duration is usually for one year with four 1-year renewal options, like any other IDIQ contract.

Unit price book

The unit price book (UPB) establishes a set cost for work performed under a SABER contract. While some tasks may have a pre-negotiated price, the UPB allows the government and the contractor to determine the cost of a project given its scope. For each of the tasks, the UPB identifies a unit of measure and a corresponding unit price. SABER contracts include options for work in years beyond the initial performance period.

Depending upon the source of data used, UPBs may contain from 20,000 to 70,000 line items. The Army Corps of Engineers and various commercial companies (including RS Means, Lee Saylor, Berger, and Marshall and Swift) have developed different databases. The key to the quality of a UPB is the tailoring of the base data (which are priced at various locations, nationally) to reflect accurate local construction costs. Localization is the critical step in preparing the SABER contract technical documentation because it ultimately determines the accuracy of project costs. We use a "multiplier" to localize the vast amount of data in a UPB. A multiplier takes a national standardized price of a material and by multiplying the price by the multiplier, we get a close estimate of local material and/or labor costs for that line item.

Delivery order

A delivery order (DO), in the case of SABER, is a document from the government to the contractor ordering the completion of work under an existing IDIQ contract. The civilian sector refers to SABER as delivery order contracts (DOC). The Army refers to the same system as job order contracts (JOC).

The contracting officer issues SABER DOs after brief negotiations with the contractor. Because all prices are set at the beginning of the contract in the UPB, each individual DO becomes, in effect, a fixed-price contract. When the contractor receives the DO, the DO becomes the notice to proceed.

Advantages

Many organizations use some sort of delivery order contract for completing small or reoccurring tasks. While it may seem obvious that there are cost advantages by not having to re-solicit contractors for each project, there are several other subtle advantages described in the table below.

Delivery Order Contract Advantages	
Type	**Description**
Improved customer service responsiveness	After initial contract award, DOs for individual projects estimate, propose, negotiate, and issue in 3 to 4 weeks. This represents a dramatic reduction from the months required to solicit and award individual construction contracts. In addition, incorporating changes to requirements is quicker.
Enhanced ability to accomplish backlogged work orders	SABER also accommodates “hot” projects that usually require resources over and above in-house capabilities or otherwise interrupt the RWP. Appropriate SABER projects should be determined based on the past performance of a SABER program and the individual contractor. If a SABER program or contractor is consistently completing projects at a lower square foot cost than a competitively bid project, then the base should reasonably send the program more projects. On the other hand, if the SABER program is costly or a poor performer, then more projects should use alternate contracting methods.
Additional resources to the BCE	SABER provides a capability to perform work that is unaffected by deployments, training, inspections, and other activities that affect the shop workforce.
Added fiscal flexibility	Associate units can, and are usually willing to, fund their own projects in order to have quality work performed in a responsive, timely fashion.

Scope and limitations

The SABER program has great potential, but it also has its limitations. SABER complements the traditional construction program, *not* replace it. It is best suited to reduce BCE work order and contract backlogs and accomplish non-complex construction, maintenance, and repair requirements that meet certain criteria.

Single skillset projects

While SABER is an IDIQ contract, it is for small design and construction projects. Most strictly, IDIQ contracts are for a specific purpose. Using SABER for projects such as large asphalt, painting, or other predominately-single skill/material jobs can cost significantly more than a competitively bid contract or IDIQ. One reason is that it is virtually impossible to quantify all of the elements that would be required to build economy of scale factors for each line item in the UPB. In addition, a contract designed for specific tasks such as painting or paving can often procure materials at better rates because of larger quantities.

Service contracts

Due to statutory requirements, SABER cannot perform non-personal services subject to the provisions of the Service Contract Act. An example is a DO predominately to install carpet when the labor involved exceeds $2,500. The Department of Labor classifies work as subject to the Davis Bacon Act or services to which the Service Contract Act applies. Their guidance defines as construction services such as carpet installation, landscaping, asbestos removal, and building demolition when the work is incidental to a larger construction project. If the preponderance of the work involves the services cited, although there may be some incidental-related construction work, the project falls under the Services Contract Act and, legally, SABER cannot perform it.

Delivery order cost

The recommended minimum/maximum values for DO are $5,000 to $700,000. For projects with values outside that range, the DO concept using a pre-priced UPB may result in excessive project costs. Other contract programs, or in-house work orders, may be more appropriate. Larger projects are more likely to go beyond the advertised intent of the program. Projects may exceed $700,000 if fully warranted by economic and/or mission requirements and if approved by the installation commander.

SABER execution procedures

Many of the principles applied in the execution of general contracts also apply to SABER contracts. Ethics and standards of conduct do not change. The importance of inspections remains consistent. Since SABER contracts do not have to go for bid with each project, many processes are streamlined. Along with having a dedicated contractor to complete DOs, there is a dedicated team of military and civilian employees to oversee only SABER contract.

Project assignment

CE manages and processes all work orders through the Work Order Review Board (WORB) to determine in-house personnel or contract accomplishment. The WORB sends contract projects to the engineering flight for completion; the engineering flight chief may determine if the project goes competitive bid, IDIQ, or SABER. Base development assigns a project number to projects selected for SABER accomplishment and loads the project information into its tracking database (fig. 2–2).

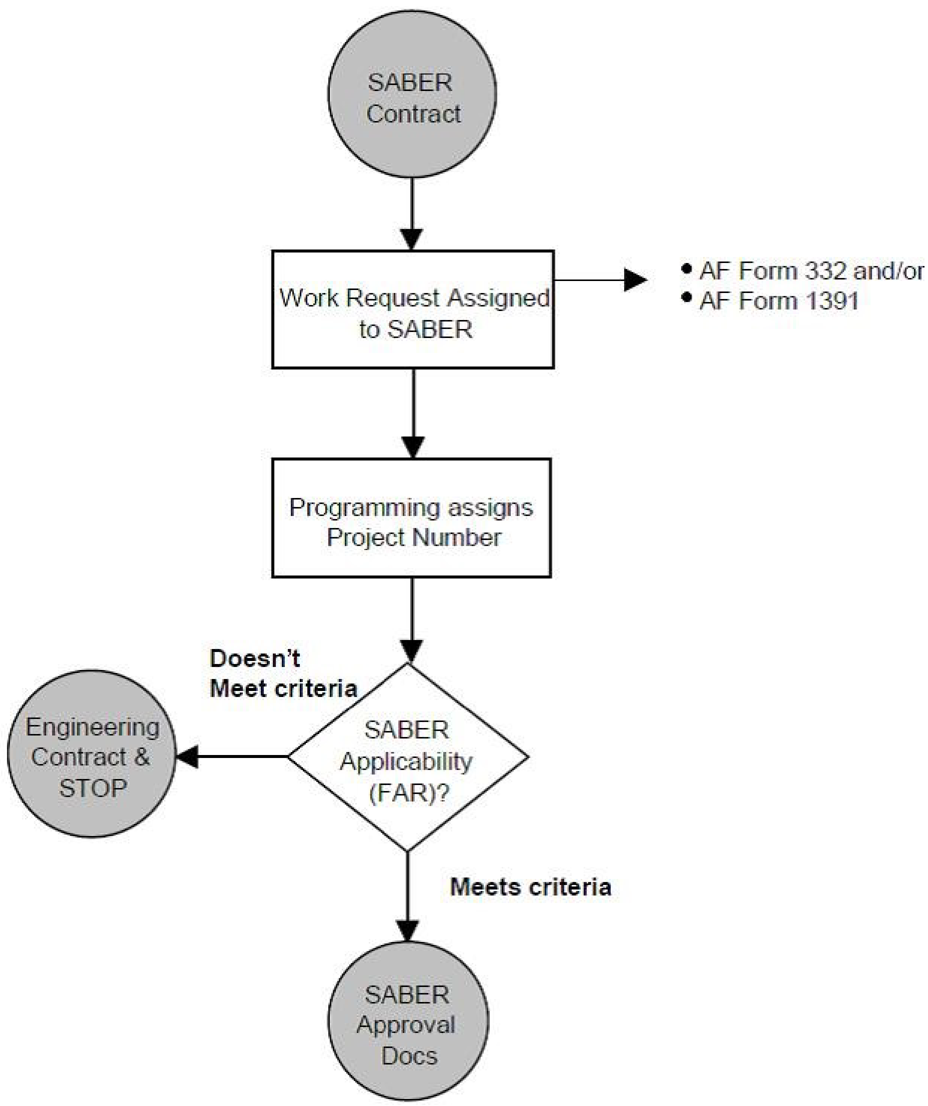


Figure 2–2. SABER contract administration process.

Design

The preliminary design phase is essentially the same as in other contracts. The project manager will develop a proposed SOW and a programming or budgetary estimate. Projects must comply with AFI 32–1024, *Standard Facilities Requirements*, and Air Force Manual (AFMAN) 32–1084, *Facility Requirements*. If work requirements on the AF Form 332, Base Civil Engineer Work Request, need alteration after discussions with the requester, it will need re-approval by the approving authority. This is also true if the SABER estimate exceeds the approved amount on the AF Form 332 by 25 percent.

Documentation and close out

The forms and practices applied to normal, or requirements, based contracts apply to SABER as well. Before work can begin, an AF IMT 103 and other appropriate permits must be in place. As the project proceeds, there are several forms that need to be completed, reviewed, approved, and filed.

Multiple award construction contracts

Multiple award construction contracts (MACC) are similar to SABER contracts in that they are IDIQ contracts awarded to contractors without foreknowledge of the work to be done. We award MACC type IDIQs to three or more contractors at the same time (simultaneously); these contractors bid on task orders within the MACC. This helps the government get the best price by promoting competition while increasing the speed at which each task order executes. Each contractor is guaranteed an agreed upon dollar amount of work per year.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

407. Construction management

1. When does issue of the notice to proceed occur?

2. Give the definition for MILCON.

3. Though MILCON can include repairs over $750,000, what kind of programming are they normally included in?

408. Simplified Acquisition of Base Engineering Requirements program

1. For each task, what two things does the UPB identify?

2. Explain the purpose of a DO.

3. Who determines whether a project is completed in-house or by a contract?

4. What is the difference between a SABER IDIQ and a MACC?

2–2. Contract Documentation

Documenting agreements between the government and contractors is critical. It is the most powerful tool the government has to protect itself and enforce the legality of a contract. The documentation is of mutual benefit, too. Contractors who execute a project well get positive reviews and a higher chance of receiving future contracts. You are the steward of this documentation leading up to and during execution of construction contracts. When questions arise or when the contractor does something outside of the contract, it is your job to provide the references with answers and/or expectations.

409. Prepare preliminary contract documents

Before a project begins, several documents need to be in place. Assembling these documents help the planners develop and document the project. These documents also paint the initial picture for the users, contractors, and all other parties involved in the project construction.

Preliminary design drawings

Preliminary drawings are the initial plans for projects prepared by the designer or A-E firm during the early planning or promotional stage of building development. When we develop projects for SABER, JOCs, Rapid Engineer Deployable Heavy Operational Repair Squadron Engineer (RED HORSE), and some CE in-house design projects, an EA will often build the preliminary design drawings. They provide a means of communication between the designer and the user. The drawings are not for construction but for exploring design concepts, material selection, preliminary cost estimates; approval by the customer; and a basis for the preparation of finished working drawings.

Building a drawing set

Most of the design work incorporated into the preliminary drawings contains the site plans, architectural floor plans, elevations, building sections, preliminary finish schedule and furniture layouts, interior/exterior mechanical and electrical data, and civil and structural details. These are the first draft of the final contract drawings. When developing these drawings, work closely with the designer to ensure they align with the SOW and specifications.

Preliminary design drawings are not sketches but built from sketches. These are the 35 percent design drawings. Because CAD files can be large and not all viewers have access to CAD programs, make sure to plot the drawings as PDF files to submit along with the CAD files.

The drawing set should include, at a minimum, a title sheet with a location map, a sheet list table, project name, number and location, and the appropriate sheet template with the appropriate information accurately filled out. It should also include all appropriate drawing disciplines such as civil, structural, architectural, fire protection, plumbing, mechanical, and electrical as needed.

Develop statement of work

The purpose of a SOW is telling “what” needs doing instead of “how” to do it. The SOW needs to define requirements in clear language, identifying specific work to be completed. Individually tailored, SOWs must consider the period of performance, deliverable items, and the desired degree of performance flexibility. A well-written SOW can prevent disagreement, misunderstanding, and eventual disputes between the government and the contractor as to the expectations of the work to perform.

The SOW and specifications are interdependent documents. We develop SOWs first to provide a framework for the specifications.

Key components

Contractors and construction management teams need to know as much about a project ahead of time as possible. It helps them develop a plan and accurate cost estimates for material, equipment, and workforce. While all projects vary, there are eight pieces of information common to all contract construction projects:

1. Introduction/background.
2. Scope of work.
3. Period of performance.
4. Place of performance.
5. Work requirements.
6. Schedule/milestones.
7. Acceptance criteria.
8. Other requirements.

Introduction/background

The introduction/background is where the contractor finds a general description of the project. It also highlights how the project supports the mission. SOWs often accompany a request for proposal (RFP), so the SOW introduction and background is necessary for contractors to get an overall understanding of the project.

Scope of work

This section of the SOW provides a detailed statement of what you expect to do during the project. This portion of the SOW lays out the full construction criteria. Take the time to imagine each phase of a project, referencing the 35 percent drawings. This section needs to present a systematic project from the time of award until the final punch list item is complete.

Period of performance

This portion of the SOW should define the period over which the project will occur. The time frame for the project can be pre-determined or based on a completion date to coincide with some external requirement (i.e., new government regulation). It is important to define the period of performance since this is usually a variable in the project's cost. Additionally, if there are delays in a project and it finish beyond its period of performance, a contract modification may be required and the costs of the project will increase as well.

Place of performance

This section of the SOW describes where the work will happen. In some cases, the vendor may perform all or some of its work onsite at the customer's location. This is usually dependent on the type of industry or work. It is important to define this in case the customer requires the vendor to work at the customer's site and to clarify any equipment and/or work space requirements.

Work requirements

This section of the SOW describes the teams performing the work and the quality expectations. This includes subjects like expectations of cleanliness around the job site, dust control, noise control, and which government representatives will have access to the project site during active phases. When describing the teams, it should include specific qualifications for different tasks. This sections helps prevent a contractor from cutting corners by having unqualified people performing tasks like welding, surveying, or electrical work. It also sets the standard for the process of construction so the job site does not become overly hazardous or sloppy.

Schedule/milestones

This part of the SOW should define the schedule of deliverables and milestones for this project. Since the SOW often accompanies the RFP for the project, it is imperative that all milestones, tasks, and schedule information are as accurate as possible since vendors will need to consider these items in their proposals.

Acceptance criteria

This section of the SOW defines how the customer will accept the deliverables resulting from this SOW. It is important that acceptance of deliverables is understood by all parties. This section should include a description of how both parties will know when work is acceptable, how it will be accepted, and who is authorized to accept the work.

Other requirements

Any special requirements, such as security requirements (personnel with security clearance and what level, badges, etc.) should be described in this section of the SOW. There should also be a description of any information technology (IT) access restrictions/requirements or system downtime/maintenance if required. This is also a good place to include any government furnished material or equipment. The Federal Acquisition Regulation (FAR) 52.245–1, *Government Property*, gives detailed descriptions and uses of government property.

Paragraph set up

Paragraphs in the SOW should follow a clear numbering format. Logically numbered paragraphs facilitate easier communication during meetings and phone calls or if disputes arise. Use the following format to number the paragraphs:

1.0 Main heading

1.1 Subject (1st level)

1.1.1 Paragraph (2nd level)

1.1.1.1 Subparagraph (3rd level)

  a. Example

    (1) Example

      (a) Example

        1. Example

410. Documenting the project

Since most projects require a lot of coordination between different organizations, there is a lot of paperwork involved. We catalog all paperwork in two sets of folders referred to as the programming and construction folders. You, as the construction inspector, are responsible for assembling the appropriate documents in the construction folder.

AF Form 332

Each facility on an Air Force base has a facility manager. Facility managers come from the using unit and are the single point of contact for any facility maintenance or repair issues. The AF Form 332 (fig. 2–3) is the Base Civil Engineer Work Request form. The customer, usually a facility manager, fills these out for any work required on a building. The form includes the requester's contact information, date the work is required, a description of the work, and justification of the work.

BASE CIVIL ENGINEER WORK REQUEST
(See Reverse for Instructions)

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average .3 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to the Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project 0704-0188, Washington DC 20503. Please DO NOT RETURN your form to either of these addresses. Send your completed form to HQ AFESC/DEMG.

SECTION I - TO BE COMPLETED BY REQUESTER

1. FROM *(Organization)* 817 GMS	2. OFFICE SYMBOL TDE	3. DATE OF REQUEST September 29, 2013	4. WORK REQUEST NO. *(For BCE Use)*
5. NAME AND PHONE NO. OF REQUESTER TSgt Walt White, 867-5309		6. REQUIRED COMPLETION DATE November 29, 2013	7. BUILDING, FACILITY OR STREET ADDRESS WHERE WORK IS TO BE ACCOMPLISHED 1703

8. DESCRIPTION OF WORK TO BE ACCOMPLISHED *(Include Sketch or Plan, when appropriate)*

Install new running track next to the fitness center.

9. BRIEF JUSTIFICATION FOR WORK TO BE ACCOMPLISHED *(Not required for maintenance and repair)*

Current running track next to the fitness center on base is paved with asphalt and in poor condition. Numerous cracks and holes create an increased hazard of trips, falls, and injuries during PT sessions and fitness exams.

10. DONATED RESOURCES

	FUNDS		LABOR		MATERIAL		CONTRACT BY REQUESTER		NONE

11. NAME OF REQUESTER Walt White	12. GRADE OF REQUESTER TSgt	13. SIGNATURE OF REQUESTER *(See Reverse of Form)* Walt White

14. COORDINATION

SECTION II - FOR BASE CIVIL ENGINEER USE

15. WORK ORDER *(Place an "X" in the appropriate box.)*

	IN-SERVICE		SELF-HELP	X	CONTRACT		SABER

16. DIRECT SCHEDULED WORK *(Place an "X" in the appropriate box.)*

	EMERGENCY		URGENT	X	ROUTINE		SELF-HELP		M/C

17. SELF-HELP *(Place an "X" in the appropriate box.)*

	BRIEFING REQUIRED		ADEQUATE COORDINATION		INSPECTION REQUIRED

SECTION III - COMPLETE ONLY IF WORK IS TO BE ACCOMPLISHED BY WORK ORDER

18. WORK CLASS	19. PRIORITY	20. ESTIMATED HOURS	21. ESTIMATED FUNDED COST	22. ESTIMATED TOTAL COST

	23. THERE IS NO NEED FOR AN ENVIRONMENTAL ASSESSMENT (AFR 19-2)		24. A WRITTEN ASSESSMENT IS BEING/HAS BEEN PROCESSED		25. APPROVED		26. DISAPPROVED

27. REMARKS

SECTION IV - APPROVING AUTHORITY

28. NAME AND GRADE *(Please Type or Print)*	29. SIGNATURE	30. DATE

AF IMT 332, 19910101, V4 PREVIOUS EDITION IS OBSOLETE. MASTER FILE COPY

Figure 2–3. AF Form 332.

DD Form 1391

Classification, scope, and cost of projects vary widely. When various projects exceed their cost or scope thresholds, as outlined in AFI 32–1032, *Planning and Programming Appropriated Fund Maintenance, Repair, and Construction Projects*, they require higher approval authorities. Approval beyond the BCE could be the group, the wing, or all the way to Congress. Projects requiring major command (MAJCOM), Air Staff, or congressional approval require a DD Form 1391, FY____ Military Construction Project Data (fig. 2–4). This includes a detailed cost estimate, requirement, justification, and impact if not approved. Also included are site plans, before and after construction or additions and space requirement calculations.

1. COMPONENT	FY 2016 MILITARY CONSTRUCTION PROJECT DATA	2. DATE *(YYYYMMDD)*	REPORT CONTROL SYMBOL
USAF		20160301	DD-A&T(A)1610

3. INSTALLATION AND LOCATION	4. PROJECT TITLE
Bowman Air Force Base, New Hampshire	Whole Dormitory Complex Renewal

5. PROGRAM ELEMENT	6. CATEGORY CODE	7. PROJECT NUMBER	8. PROJECT COST *($000)*
123654A	100	BWMN 16-0034	Auth. $20,000.00 Approp. $20,000.00

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST *($000)*
Primary Facility				15152.00
Dormitory	m2	9058	1372.00	12427576.00
Community Building	m2	1468	1161.00	1704348.00
Energy Plant Expansion	LS	0	0.00	670.00
EMCS	LS	0	0.00	32.00
Building Information systems	LS	0	0.00	322.00
Supporting Facilities				2692.00
Electric Service	LS	0	0.00	224.00
Water, Sewer, Gas	LS	0	0.00	145.00
Steam and/or chilled Water Distr	LS	0	0.00	1067.00
Paving, Walks, Curbs, and Gutters	LS	0	0.00	298.00
Storm Drainage	LS	0	0.00	88.00
Site Imp (451) Demo (287	LS	0	0.00	738.00
Information Systems	LS	0	0.00	132.00
Estimated Contract Costs				17844.00
Contingency Percent (5.00%)				892.00
Subtotal				18736.00
Supervision, Inspection & Overhead				1736.00
TOTAL REQUEST				19860.00
TOTAL REQUEST (ROUNDED)				20.000.00

10. DESCRIPTION OF PROPOSED CONSTRUCTION

Construct standard-design dormitory, Airman community building, and equipment storage. Expand central heating and cooling plant. Connect to expanded central heating and cooling plant. Connect to energy monitoring and control system (EMCS). Project includes living sleeping rooms, semi-private baths, walk-in closets, storage, dayroom, laundry facilities, and bulk storage. Supporting facilities include utilities; electric service, exterior lighting, fencing; fire protection and alarm systems; paving, walks, curb and gutters; road upgrades and parking; storm drainage; water distribution lines; outside recreation facilities (lighted basketball and volleyball courts, etc.) and bus shelters; information systems; and site improvements. Access for the disabled persons will be provided. Air conditioning: 4000 tons. Demolish three dormitory buildings (12047 SM) to include asbestos and lead base paint abatement and restore suite. Comprehensive interior and furnishings related design services are required.

PROJECT: Construct standard-design enlisted barracks complex, Airman community building and upgrade existing central energy plant. Relocate administrative space with the existing dormitory buildings to other facilities. (Current Mission).

DD FORM 1391, JUL 1999 PREVIOUS EDITION IS OBSOLETE.

Figure 2–4. DD Form 1391.

Specifications

Specifications are the guidebook for a project. When combined with the drawings for a project, they provide the technical information about each component or system. Most installations have a master specification as a guide for creating new ones. The master contains general information like expected work hours for the contractor, safety requirements, necessary security clearances, and civil engineer contact information.

Project unique information comes from a number of sources. These can include the base design guide from the comprehensive planners, Unified Facilities Codes (UFC), past projects, operations maintainability standards, or national and international codes. Even though project drawings and specifications are the governing document for a project, other authoritative documents form their basis. If there is any disagreement between the specifications and the published authoritative document, the specification will need to be modified.

Government-furnished equipment

Specifications sometimes call for government-furnished equipment (GFE). GFE is equipment that belongs to the government but is available to a contractor for performance of a contract. Typical examples include computers, facilities, test equipment, or tools uniquely fabricated for a certain mission or facility.

Material submittals

Depending on the nature of the project, the specifications may call for types, grades, or quality of material. These could range from a certain thickness and type of glass for a window, or tile for a floor, or paint for an exterior fence. Because the government is paying for these projects, it is very important that the contractors use the correct material and do not cut corners. To ensure the correct materials are used, contractors must submit samples. The specifications will designate which materials samples require submission.

AF IMT 3000

This form accompanies material submittals by the contractor. The CE project manager approves or disapproves the submittal and returns it to base contracting for final approval or disapproval. Once base contracting has given final approval or disapproval to the submittal, they forward a copy to the CE project manager to file in the project folder. Project managers track all submittals on the Record of Submittal Data, which is part of AF IMT 1477, Construction Inspection Record. When you first receive the AF IMT 3000, Material Approval Submittal, you compare the material to what is on the form and then the form to what is in the specifications (fig. 2–5). Often times contractors will attempt to use cheaper materials that may or may not meet design requirements. Determination of material feasibility is up to the project engineer and not the contractor.

Record of Submittal Data

The Record of Submittal Data is mandatory for all projects requiring submittals. This constitutes notice to the contractor of the requirements for submittals. List all submittals required in the specifications and the contract reference and the number of copies required of each submittal specified. The submittals required in division one of the specifications must be included. Four copies are required of all submittals, except for samples, which require only one set.

MATERIAL APPROVAL SUBMITTAL

(See Instructions on Reverse)

Form Approved
OMB № 9000-0062
Expires May 31, 2005

Public reporting burden for this collection of information is estimated to average 20 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to the Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project OMB № 9000-0062, Washington DC 20503. Please DO NOT RETURN your form to either of these addresses. Send your completed form to: SAF/AQCP, 1060 Air Force Pentagon, Washington DC 20330-1060.

TO: *(Contracting Officer)* **FROM:** *(Contractor)* | DATE *(YYYYMMDD)*

CONTRACT NUMBER | SUBMISSION NUMBER | SUBMITTAL ☐ NEW ☐ RESUBMITTAL

PREVIOUS SUBMISSION NUMBER | PROJECT NUMBER

TO BE COMPLETED BY CONTRACTOR | **FOR GOVERNMENT USE ONLY**

ITEM	SPECIFICATION SECTION	DESCRIPTION OF MATERIAL *(Include Type, Model Number, Catalog Number, Mfg., etc.)*	AP-PROVED	DISAP-PROVED	SEE REVERSE	INITIAL
			☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	
			☐	☐	☐	

BY COMPLETING THIS FORM, THE UNDERSIGNED CONTRACTOR CERTIFIES THAT THE MATERIAL COMPLIES WITH ALL SPECIFICATIONS OF SUBJECT CONTRACT.

DATE | TYPED OR PRINTED NAME AND TITLE | SIGNATURE

FOR GOVERNMENT USE ONLY

TO: *(Base Civil Engineering Officer)*

For Evaluation and Action

DATE | TYPED OR PRINTED NAME AND GRADE | SIGNATURE

TO: *(AF Contracting Office)*

RECOMMEND ☐ APPROVAL ☐ DISAPPROVAL AS INDICATED ABOVE AND SUBJECT TO ANY APPLICABLE COMMENTS ON THE REVERSE

DATE | TYPED OR PRINTED NAME AND GRADE | SIGNATURE

TO: *(Contractor)*

☐ APPROVED ☐ DISAPPROVED AS INDICATED ABOVE AND SUBJECT TO ANY APPLICABLE COMMENTS ON THE REVERSE SIDE. REQUEST RESUBMITTAL ON DISAPPROVED ITEMS WITHIN ____ DAYS OF DATE SHOWN BELOW.

DATE | TYPED OR PRINTED NAME AND GRADE | SIGNATURE

AF IMT 3000, 20030901, V1 PREVIOUS EDITION IS OBSOLETE.

Figure 2–5. AF IMT 3000.

Drawings

The saying “a picture is worth a thousand words,” holds true for contract drawings. They relay information and instructions to the contractors. If a drawing does not read well, it is practically useless. Drawings should be clean and concise. Detailing should be sufficient to explain the desired finished construction product.

All drawing packages should contain a location plan. All views should be clearly marked: floor plans, elevations, sections, and scale. Enter sheet title and drawing number on each sheet.

Correspondence

Pulling together all the moving parts of planning a project requires a lot of communication. It is impossible for one person to remember every e-mail or conversation about a project. Correspondence between project designers, contracting officers, contractors, inspectors, and others can be either formal or informal.

- *Formal correspondence* is memorandums for record (MFR), requests for information (RFI), amendments, and modifications to the specifications or drawings.
- *Informal correspondence* can be e-mails or even hand-written notes and sketches from meetings or from the field.

411. Review project specifications

The keystone project description documents are the preliminary design drawings, also called the 35 percent drawings, the SOW, and the specifications. When constructed properly, each document builds on the previous one. The construction industry is broad and complex. Not only are there a huge number of disciplines, and codes, but the standards and terms for these can vary from state to state and country to country. In years past, communicating construction requirements was rife with confusion. To help alleviate confusion, there is a commercial system called the Construction Specifications Institute (CSI) MasterFormat®. In the DOD, there is a system called the Unified Facilities Guide Specifications (UFGS).

CSI MasterFormat®

CSI MasterFormat® is a system to assign a number to any construction practice. Any individual component of a construction project has a number associated with it. The list of numbers and titles classified by work results or construction practices is consistent throughout the North American construction industry. The CSI MasterFormat® system helps organize project manuals, detailed cost information, and relate drawing notations to specifications. MasterFormat® splits into two groups—procurement and contracting requirements group and the specifications group. Each group is further broken into divisions. All total, there are two groups, five subgroups, and forty-nine divisions.

Procurement and contracting requirements group

This group describes the contracting aspect of a construction project. It has no subgroups and only one division. This division is numbered 00 and includes tasks involved with procurement and contracting requirements, introductory information, procurement requirements, and contracting requirements.

Specifications group

The specifications group describes the physical material, components, and equipment necessary for a construction project. The specifications group breaks into five subgroups: general requirements, facility construction, facility services, site and infrastructure, and process equipment. The divisions in these subgroups number sequentially 01 through 49. Some divisions within these subgroups have nothing assigned to them but are reserved for future expansion.

Divisions

Each division is broken into further categories, each with a numerical assignment down to an individual task. Using this method, it is simple to find a number for a specific task within a construction contract. For example, if a project required forms to pour a six-inch slab on grade concrete pad, the number for that task is 03 11 13 .65 3000. The following is an example:

03 Concrete.

03 11 Concrete forming.

03 11 13 Structural cast in place concrete forming.

03 11 13.65 Forms in place, slab on grade.

03 11 13.65 3000 Edge forms, wood, 4 use, on grade, to 6” high.

Unified Facilities Guide Specifications

The DOD has certain tasks and requirements that do not normally exist in civilian construction industries. Even though the CSI MasterFormat® is an excellent product, it does not always exactly meet government needs. To solve this problem, the Secretary of Defense founded and mandated the UFGS. This enables the Military Services to unify their specifications into one database. The UFGS Master uses the latest CSI MasterFormat® for common tasks plus similarly formatted entries for military or government specific tasks. It is a database of numbers divided into the same divisions as the MasterFormat®.

The UFGS also does not go the level of detail required for the MasterFormat. This is because the UFGS is for building government construction documents rather than construction estimates. In the UFGS under division 03 11 13.00 10, Structural, cast-in-place concrete forming does not have cost estimating information. Instead, the UFGS has all the necessary text to build a contract specification discussing how a contractor will perform a certain task in the contract. This allows project designers to copy and paste specific parts of the UFGS into their documents and tailor them for particular needs.

Numbers from the UFGS are available in two primary places. There is a public domain format (pdf) version published on a recurring basis and available through the Whole Building Design Guide (WBDG) Website. This version is more than 21,000 pages and useful for routine projects as well as in deployed locations. The data works with a software program called *SpecsIntact*. This is an automated system for preparing standardized facility construction specifications.

Unified Facilities Guide Specifications divisions

The UFGS foregoes groups and subgroups to focus on divisions. Figure 2–6 shows a list of the divisions in the UFGS. Figure 2–7 shows the categories within Division 04, Masonry. This division within the UFGS contains a very detailed description of the methods and requirements for contractors conducting masonry on a government contract. For example, within the UFGS Division 04, section 04 23 00, Glass masonry units, paragraph 1.3 delivery, storage, and handling, gives the following instructions for glass masonry units:

Deliver cement, lime, and other cementitious materials to the site in unbroken containers, labeled with the manufacturers' names and brands. Store mortar materials in a manner to prevent the inclusion of foreign materials and damage by water or dampness. Avoid chipping and breakage of masonry units. Protect glass block materials from contact with earth and exposure to the weather, and keep dry until used. Do not use materials containing frost or ice.

Division	Title	Division	Title
00	Procurement and contracting requirements	23	Heating, ventilating, and air conditioning
01	General requirements	25	Integrated automation
02	Existing conditions	26	Electrical
03	Concrete	27	Communications
04	Masonry	28	Electronic safety and security
05	Metals	31	Earthwork
06	Wood, plastics, and composits	32	Exterior improvements
07	Thermal and moisture protection	33	Utilities
08	Openings	34	Transportation
09	Finishes	35	Waterway and marine construction
10	Specialties	40	Process integration
11	Equipment	41	Material processing and handling equipment
12	Furnishings	42	Process heating, cooling, and drying equipment
13	Special construction	43	Process gas and liquid handling, purification, and storage
14	Conveying equipment	44	Polution and waste control equipment
21	Fire supression	46	Water and wastewater equipment
22	Plumbing	48	Electrical power generation

Figure 2–6. UFGS divisions.

Division 04	Masonry
Code	Task
04 01 00.91	Restoration and cleaning of masonry in historic structures
04 01 20	Rehabilitation of reinforced and unreinforced maronry walls using FRP composite structural repointing
04 01 21	Rehabilitation of reinforced and unreinforced maronry walls using surface applied FRP composites
04 20 00	Masonry
04 21 13.13	Nonbearing masonry veneer/steel stud walls
04 21 26	Glazed structural clay tile and prefaced concrete masonry units
04 23 00	Glass masonry units

Figure 2–7. UFGS Division 04, Masonry.

Prepare project specifications

Preparing project specifications involves a very thorough knowledge of a project. While the project designer is responsible for writing the specifications, engineering personnel are often involved in some or all of the process, as well as reviewing the final product.

While UFC 1–300–02, *Unified Facilities Guide Specifications (UFGS) Standard,* gives specific instructions about building specifications, there is still an art to the task. The task involves plugging the given information from the UFGS into the correct paragraph. The art involves using the correct phrasing and sequence of events for the project.

Principle guidelines

Writing specifications requires a specific skill set of qualifications. The writer needs to be able to think through the entire project clearly. They should be able to visualize the entire project from start to finish clearly enough to see details but without losing the overall intent. The writer must also be able to communicate clearly and have a good understanding of precise measurements and exact quantification.

When completed, the specifications should meet the standard of the four c’s:

- **C***lear* – No ambiguity. There should be no doubt about the intent or direction of the project. Anyone reading the specifications should know exactly what is expected and what the project entails.
- **C***oncise* – No wordiness. Flowery language in specifications only serves to confuse the reader. Also, only state something once. If a subject is in the drawings, it is best to leave it out of the specifications. Do not use colloquial terms or jargon. For example, do not use “bulkhead” for wall, “deck” for floor, or “head” for toilet.
- **C***omplete* – All required information and in the proper format. UFC 1–300–02 has very clear, detailed guidelines on formatting. Meaning what to include and what to leave out.
- **C***orrect* – Technically accurate and applies to the correct project. Specifications must call for work that complies with the appropriate codes, regulations, and design intent.

Unified Facilities Criteria 1–300–02

Since the UFGS is a very large database, it helps to have a document with guidance on how to use it. UFC 1–300–02 gives detailed instructions on how to format a SOW and contract specifications. Included within UFC 1–300–02, in Appendix A, there is a generic example of a contract specification. When you have to build a contract specification from scratch, use this arrangement to the extent applicable in the preparation of UFGS by eliminating paragraphs, which do not apply and adding additional paragraphs as necessary. It is important that UFGS authors understand that the paragraphs listed in the Appendix A are not mandatory. Use only those paragraphs that are applicable to the specified subject and add any applicable requirements not listed. It is important to follow the sequence of information provided even when adjusting the paragraph titles to fit the specified subject matter.

412. Cost estimating and review

The bill of materials (BOM) is an estimate taken from the construction drawings and specifications. It includes a list of the raw materials and assemblies and their prices and quantities required for a project.

Building the bill of material

If a contract is complex, the BOM is broken into groups. Individual bills of material can cover different tasks or phases of the project. The information on the BOM is a detailed analysis of contract requirement or comparisons with the material quantities actually required to complete similar projects.

Using drawings

The construction drawings are your main basis for defining the required activities for measuring the quantities of material. Accurate estimating requires a thorough examination of the drawings. You should carefully read all notes and references and examine all details and reference drawings. Review the orientation of section views. Use dimensions shown on drawings or computed figures shown from those drawings instead of those obtained by scaling distances.

Tally sheet

Completing a tally sheet is the first step when gathering information for complex projects. If a project is for a new facility, a tally sheet is a good place to start cataloging specific materials included in the project. If the project is for a renovation, use a tally sheet during a site visit to inventory what materials need to be demolished, or what to reuse.

Materials takeoff

The materials takeoff (MTO) is the heart of the materials estimate. Its name implies its definition: the "material" is "taken off" the drawings and used to create a spreadsheet or list. Accuracy during this phase of the estimate is critical; underestimating can cause a shortage on the job, delaying completion; and overestimating can cause a surplus, increasing the cost of the project. In addition to containing some of the information on the tally sheet, the MTO also contains the suggested vendors or sources, supply status, and the required delivery date.

Bill of material

The BOM sheet is similar in content to the MTO sheet. Here, though, the information is in a format suitable for cost estimating. Use this form for requests of supply status, issue, or location of material, and for preparing purchase documents.

Estimating

Estimating is the process of determining the amount and type of work and the quantities of material, equipment, and labor required. Lists of these quantities and types of work are estimates.

We use estimates for either contract projects, or in-house projects. Contract estimates require a formal set of documents called the *government estimate*. This is the approved construction estimate prepared and submitted to the contracting officer (CO) to support contract award. When contractors submit bids for a contract, the CO compares their bid price to the government estimate to help determine the best contract bid.

NOTE: UFC 3–740–05, *Handbook: Construction Cost Estimating,* gives very detailed instructions for properly completing a full government estimate.

Types of estimates

Project estimators need to assemble information about various conditions affecting the construction of the project. This enables estimators to prepare a detailed and accurate estimate. Drawings should be detailed and complete. Specifications should be exact and leave no doubt as to their intent.

Information should be available about local material, such as quarries, gravel pits, spoil areas, types of soil, haul roads and distances, foundation conditions, the weather expected during construction, and the time allotted for completion. You should know the number and types of construction equipment available for use. Consider all other items and conditions that might affect the production or the progress of construction.

Failure to read all the notes on a drawing or failure to examine reference drawings can cause many omissions. For example, if you overlook a note that states “symmetrical about the center line” you will compute only half the required quantity. To help with the estimating process, there are six categories to estimates:

1. Preliminary.
2. Detailed.
3. Activity.
4. Equipment.
5. Labor.
6. Material.

Preliminary estimates

Our preliminary estimates come from limited information, such as the general description of projects or preliminary plans and specifications having little or no detail. Preliminary estimates are prepared to establish costs for the budget and to program general work force requirements.

Detailed estimates

Detailed estimates are precise statements of quantities of material, equipment, and work force required to construct a given project. Underestimating quantities can cause serious delays in construction and even result in unfinished projects. A detailed estimate must be accurate to the smallest detail to quantify requirements.

Activity estimates

An activity estimate is a listing of all the steps required to construct a given project, including specific descriptions as to the limits of each clearly definable quantity of work (activity). Activity quantities provide the basis for preparing the material, equipment, and personnel estimates. They provide the basis for scheduling material deliveries, equipment, and work force. Because we use activity estimates to prepare other estimates and schedules, errors in these estimates can multiply many times. Be careful in their preparation!

Equipment estimates

Equipment estimates are listings of the various types of equipment, the amount of time, and the number of pieces of equipment required to construct a given project. Information, such as that obtained from activity estimates, drawings, specifications, and an inspection of the site, provides the basis for preparing the equipment estimates.

Labor estimates

The direct labor estimate consists of a listing of the number of direct labor days required to complete the various activities of a specific project. These estimates may show only the days for each activity, or they may be in sufficient detail to list the number of days for each rating in each activity. Day estimates determine the number of personnel and the ratings required on a deployment. They also provide the basis for scheduling personnel in relation to construction progress.

In addition to direct labor, the estimator must also consider overhead labor and indirect labor. Overhead labor, considered productive labor, does not contribute directly or indirectly to the product. It includes all labor that is required regardless of the assigned mission. Indirect labor includes labor required to support construction operations but does not produce a product such as administration and management.

Material estimates

A material estimate consists of a listing and describing the various materials and the quantities required to construct a given project. We obtain information for preparing material estimates from the activity estimates, drawings, and specifications.

Building an estimate

The following figures contain the basic information to put together a simple construction estimate. In this scenario, there is a rough sketch of a shelter with material requirements and basic dimensions. Figures 5–8 and 5–9 are drawings of a simple storage area. Figures 5–10, 5–11, 5–12, and 5–13 have cost data pulled from estimating software for different divisions of the project. Figures 5–14 and 5–15 are MTO sheets that separate concrete work from woodwork. Figure 5–16 is the BOMs.

Project description

The project is to build a simple shaded area for storage of water in a sunny climate (fig. 2–8). The floor will be 6” thick, 10’ × 12’ 3,000 pounds per square inch (psi) concrete with a textured finish. The planned shade structure is to be of wood construction. The four corner posts will be 6” × 6” and 8’ tall. Each will be reinforced with 2” × 4” cross braces cut at 45 degrees (°) where they join the roof members. Three sides will have 2” × 2” railings at 18” and 36” from the floor. Roof structural members consist of 2” × 6” lumber (fig. 2–9). Sheathing on the roof will be ¾” thick plywood and nailed with a pneumatic nail gun. Roof shingles will be organic, class C shingles.

The first step is to break the project into task groups. In this simple project, the work divides into concrete work (fig. 2–14) and carpentry work (fig. 2–15) MTO sheets. The first requirement for the concrete floor is formwork, which goes as a separate item on the MTO. After that, add the materials to the MTO needed for the floor according to the project description. The carpentry group includes each of the materials made of wood plus the shingles.

After itemizing the materials for the project, it is time to research the cost data. This project involves materials from three different divisions: 03 Concrete, 06 Wood, Plastics, and Composites, and 07 Thermal and Moisture Protection. Figures 2–10 through 2–13 contain the cost data associated with the individual tasks. From this data, find the individual line item and the unit of measure to put on the MTOs. The line item is the combination of the division number down to the individual number. For the required concrete forms, the number is 031113.653000.

Item 031113.653000 is all-inclusive in the cost data. Each column to the right (fig. 2–10) shows what is included in the final cost. The Crew column is the size of the crew and the crafts required to complete the task. Daily output is how much work that crew does in a day. This is helpful in planning the schedule for large projects. The Material and Labor columns show the cost per unit for the specific crew. The Total column shows the total cost for material and labor. The Total Incl (including) O&P (overhead and profit) column is the recommended price for one unit of measure of that item. In complex estimates, there are additional multipliers for this cost depending on the city and other factors. For this example, the basic Total Incl O&P is adequate.

After you catalogue each item on the MTO, transfer that information to the cost sheet, or BOM (fig. 2–16). There, add the cost of each item, multiplied by the quantity and the unit. Be sure to pay attention to the unit. Because most projects deal with large quantities, costs come out at one thousand board feet (MBF) or one hundred square feet (CSF). Since this project only needs 32 feet of 6” × 6” posts, the BOM shows 0.032 MBF. Once you tally these quantities, the total will be the estimate for the project.

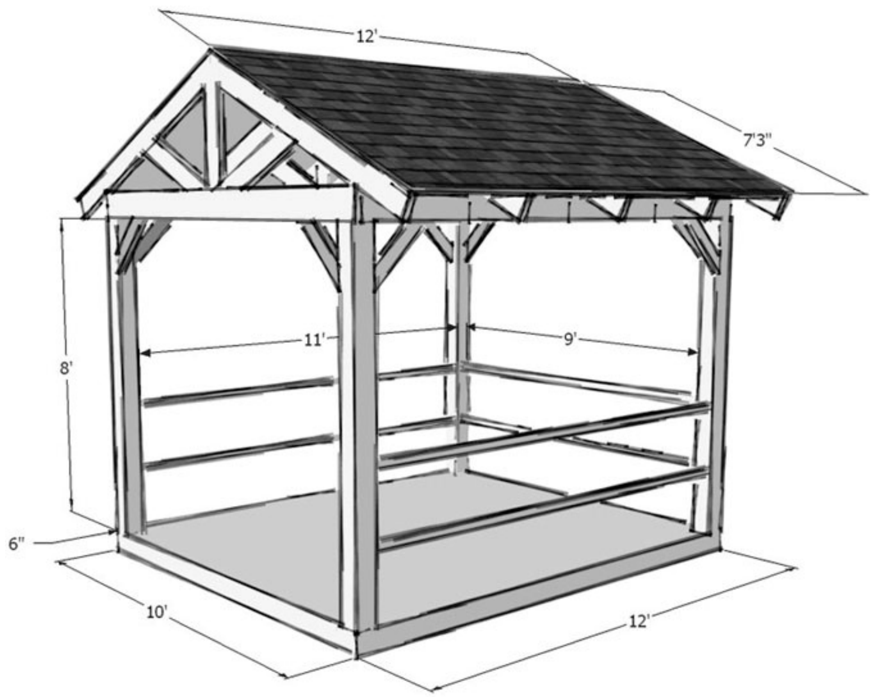


Figure 2–8. Simple storage shelter.

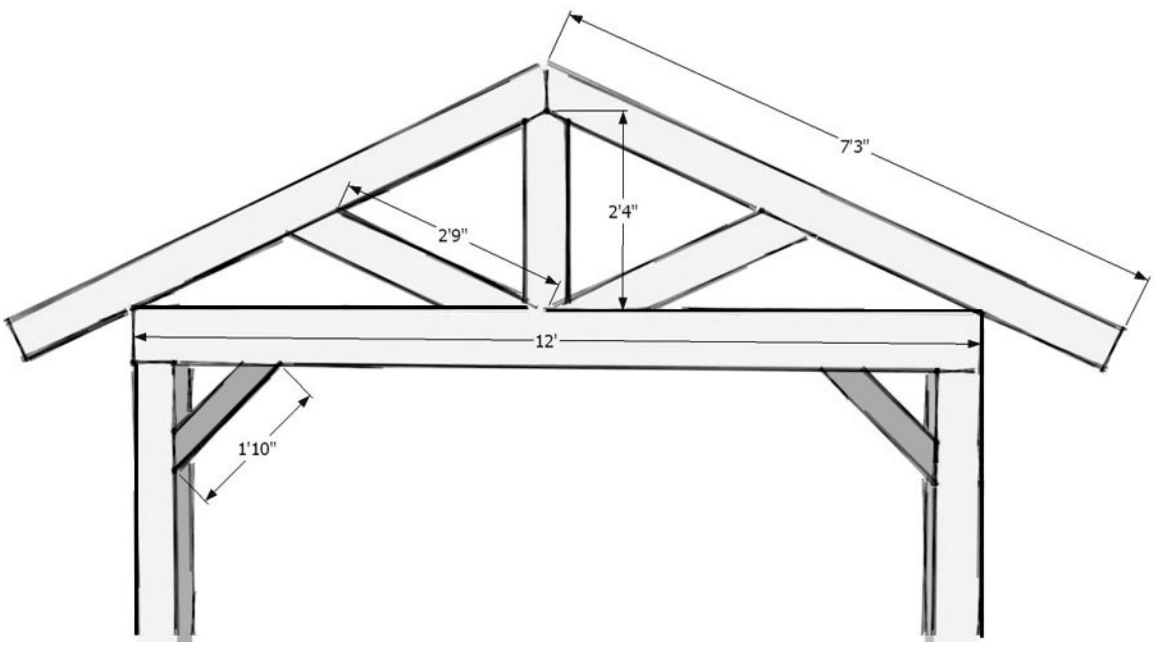


Figure 2–9. Storage shelter truss detail.

03 11 Concrete forming									
03 11 13 - Structural cast in place concrete forming									
03 11 13.65 Forms in place, slab on grade	Crew	Daily output	Labor hours	Unit	Material	Labor	Equip-ment	Total	Total Incl O&P
0010 Forms in place, slab on grade									
2000 Curb forms, wood, 6" to 12" high, on grade, 1 use	C-1	215	.149	SFCA	2.21	5.85		8.06	11.50
2050 2 use	C-1	250	.128	SFCA	1.22	5.05		6.27	9.15
2100 3 use	C-1	265	.121	SFCA	.88	4.76		5.64	8.30
2150 4 use	C-1	275	.116	SFCA	.72	4..59		5.31	7.85
3000 Edge forms, wood, 4 use, on grade, to 6" high	C-1	600	.053	L.F.	.27	2.10		2.37	3.54
3050 7" to 12" high	C-1	435	.074	SFCA	.59	2.90		3.49	5.10
3500 For depressed slabs, 4 use, to 12" high	C-1	300	.107	L.F.	.46	4.21		4.67	7

03 22 Welded wire fabric reinforcing									
03 22 05 - Uncoated welded wire fabric									
03 22 05.50 Welded wire fabric	Crew	Daily output	Labor hours	Unit	Material	Labor	Equip-ment	Total	Total Incl O&P
0010 Welded wire fabric ASTM A185									
0050 Sheets									
0100 6 x 6 W1.4 x W1.4 (10 x 10) 21 lb. per C.S.F.	2 Rodm	35	.457	C.S.F.	12	21.50		33.50	47.50
0200 6 x 6 W2.1 x W2.1 (8 x 8) 30 lb. per C.S.F.	2 Rodm	31	.516	C.S.F.	19.25	24		43.25	60
0300 6 x 6 W2.9 x W2.9 (6 x 6) 42 lb. per C.S.F.	2 Rodm	29	.552	C.S.F.	24	26		50	68
0400 6 x 6 W4 x W4 (4 x 4) 58 lb. per C.S.F.	2 Rodm	27	.593	C.S.F.	32	27.50		59.50	80
0500 4 x 4 W1.4 x W1.4 (10 x 10) 31 lb. per C.S.F.	2 Rodm	31	.516	C.S.F.	17.75	24		41.75	58.50
0600 4 x 4 W2.1 x W2.1 (8 x 8) 44 lb. per C.S.F.	2 Rodm	29	.552	C.S.F.	25	26		51	69
0650 4 x 4 W2.9 x W2.9 (6 x 6) 61 lb. per C.S.F.	2 Rodm	27	.593	C.S.F.	37	27.50		64.50	85.50
0700 4 x 4 W4 x W4 (4 x 4) 85 lb. per C.S.F.	2 Rodm	25	.640	C.S.F.	47	30		77	100

Abbreviations

C.S.F.	Hundred Square Feet
C-1	3 Carpenters, 1 Laborer
L.F.	Linear Feet
O&P	Overhead and Profit
Rodm	Rodman
SFCA	Square Foot Contact Area

Figure 2–10. Cost estimating data 1.

03 30 Cast-in-place concrete									
03 30 53 - Miscellaneous cast-in-place concrete									
03 31 53.40 Concrete in place	Crew	Daily output	Labor hours	Unit	Material	Labor	Equip-ment	Total	Total Incl O&P
4751 Slab on grade (3500 psi), incl troweled finish, not incl forms or reinforcing	C-14F								
4760 4" thick		3425	0.021	S.F.	1.29	0.79	.01	2.09	2.61
4820 6" thick		3350	0.021	S.F.	1.89	0.81	.01	2.71	3.29
4840 8" thick		3184	0.023	S.F.	2.59	0.85	.01	3.45	4.13
4900 12" thick		2734	0.026	S.F.	3.88	0.99	.01	4.88	5.75
4950 15" thick		2505	0.029	S.F.	4.88	1.09	.01	5.97	6.95
5000 Slab on grade (3000 psi), incl textured finish, not incl forms or reinforcing.	C-14G								
5001 4" thick		2873	0.019	S.F.	1.26	0.72	.01	1.99	2.48
5010 6" thick		2590	0.022	S.F.	1.97	0.80	.01	2.78	3.38
5020 8" thick		2320	0.024	S.F.	2.57	0.90	.01	3.48	4.18

06 11 Wood framing									
06 11 10 - Framing with dimensionl, engineered or composite lumber									
06 11 10.14 Posts and columns	Crew	Daily output	Labor hours	Unit	Material	Labor	Equip-ment	Total	Total Incl O&P
0010 Posts and columns									
400 4" x 4"	2 Carp	.52	30.769	M.B.F	1150	1275		2425	3250
420 4" x 6"	2 Carp	.55	29.091	M.B.F	1200	1200		2400	3200
440 4" x 8"	2 Carp	.59	27.119	M.B.F	1075	1125		2200	2925
460 6" x 6"	2 Carp	.65	24.615	M.B.F	1075	1025		2100	2750
480 6" x 8"	2 Carp	.70	22.857	M.B.F	1075	950		2025	2650

Abbreviations

Incl	Included, Including
M.B.F.	Thousand Board Feet
2 Carp	2 Carpenters
C-14F	1 Laborer Foreman 2 Laborers 6 Cement Finishers 1 Gas Engine Vibrator
C-14G	1 Laborer Foreman 2 Laborers 4 Cement Finishers 1 Gas Engine Vibrator
O&P	Overhead and Profit

Figure 2–11. Cost estimating data 2.

06 11 Wood framing									
06 11 10 - Framing with dimensionl, engineered or composite lumber									
06 11 10.24 Miscellaneous framing	Crew	Daily output	Labor hours	Unit	Material	Labor	Equip-ment	Total	Total Incl O&P
0010 Miscellaneous framing									
8500 2" x 4"	2 Carp	.51	31.373	M.B.F	375	1300		1675	2400
8505 Pneumatic nailed	2 Carp	.62	25.806	M.B.F	375	1075		1450	2050
8520 2" x 6"	2 Carp	.60	26.667	M.B.F	375	1100		1475	2125
8525 Pneumatic nailed	2 Carp	.73	21.858	M.B.F	375	910		1285	1825
8540 2" x 8"	2 Carp	.60	26.667	M.B.F	420	1100		1520	2150

06 11 Wood framing									
06 11 10 - Framing with dimensionl, engineered or composite lumber									
06 11 10.26 Porch or deck framing	Crew	Daily output	Labor hours	Unit	Material	Labor	Equip-ment	Total	Total Incl O&P
0360 Railings and trim, 1" x 4"	1 Carp	300	.027	L.F	.44	1.11		1.55	2.19
370 2" x 2"	1 Carp	300	.027	L.F	.32	1.11		1.43	2.06
380 2" x 4"	1 Carp	300	.027	L.F	.35	1.11		1.46	2.09
390 2" x 6"	1 Carp	300	.027	L.F	.56	1.11		1.67	2.32
400 Decking, 1" x 4"	1 Carp	275	.029	S.F.	1.55	1.21		2.76	3.57
410 2" x 4"	1 Carp	300	.027	S.F.	1.19	1.11		2.30	3.01
420 2" x 6"	1 Carp	320	.025	S.F.	1.21	1.04		2.25	2.94
430 5/4" x 6"	1 Carp	320	.025	S.F.	2.35	1.04		3.39	4.19
440 Balusters, square, 2" x 2"	2 Carp	660	.024	L.F	.33	1.01		1.34	1.91

Abbreviations

1 Carp	1 Carpenters
2 Carp	2 Carpenters
Incl	Included, Including
L.F.	Linear feet
M.B.F.	Thousand Board Feet
O&P	Overhead and Profit

Figure 2–12. Cost estimating data 3.

06 16 Sheathing									
06 16 36 - Wood panel product sheathing									
06 16 36.10 Sheathing	Crew	Daily output	Labor hours	Unit	Material	Labor	Equip-ment	Total	Total Incl O&P
0010 Sheathing									
0012 Plywood on roofs, CDX									
0030 5/16" thick	2 Carp	1600	.010	S.F.	.53	.42		.95	1.22
0035 Pneumatic nailed	2 Carp	1952	.008	S.F.	.53	.34		.87	1.11
0050 3/8" thick	2 Carp	1525	.010	S.F.	.36	.44		.80	1.07
0055 Pneumatic nailed	2 Carp	1860	.009	S.F.	.36	.36		.72	.95
0100 1/2" thick	2 Carp	1400	.011	S.F.	.42	.47		.89	1.19
0105 Pneumatic nailed	2 Carp	1708	.009	S.F.	.42	.39		.81	1.06
0200 5/8" thick	2 Carp	1300	.012	S.F.	.51	.51		1.02	1.35
0205 Pneumatic nailed	2 Carp	1586	0.01	S.F.	.51	.42		.93	1.21
0300 3/4" thick	2 Carp	1200	0.013	S.F.	.58	.55		1.13	1.49
0305 Pneumatic nailed	2 Carp	1464	0.011	S.F.	.58	.45		1.03	1.34

07 31 Shingles and shakes									
07 31 13 Asphalt shingles									
07 31 13.10 Asphalt roof shingles	Crew	Daily output	Labor hours	Unit	Material	Labor	Equip-ment	Total	Total Incl O&P
0010 Asphalt roof shingles									
0100 Standard strip shingles									
0150 Inorganic, class A, 210-235 lb/sq	1 Rofc	5.50	1.455	Sq	73.50	51.50		125	166
0155 Pneumatic nailed	1 Rofc	7	1.143	Sq	73.50	40.50		114	148
0200 Organic, class C, 235-240 lb/sq	1 Rofc	5	1.600	Sq	64	56.50		120.50	164
0205 Pneumatic nailed	1 Rofc	6.25	1.280	Sq	64	45.50		109.50	146
0250 Standard, laminated multi-layered shingles									
0300 Class A, 240-260 lb/sq	1 Rofc	4.50	1.778	Sq	86.50	63		149.50	201
0305 Pneumatic nailed	1 Rofc	5.63	1.422	Sq	86.50	50.50		137	179

Abbreviations

2 Carp	2 Carpenters
O&P	Overhead and Profit
O&P	Overhead and Profit
Rofc	Roofer composition
S.F.	Square Feet
Sq	Square 100 Feet

Figure 2–13. Cost estimating data 4.

QUANTITY LIST

PROJECT NUMBER: FTLW 15-0867 Date: 20150309

PROJECT TITLE: Construct Covered Storage Area @ FOB Holmes.

	SECTION	ITEM DESCRIPTION	QNTY	Unit
1.		Concrete Work		
2.	031113.653000	Edge forms, wood, 4 use, on grade, to 6" high	44	L.F.
3.	032205.500600	4 x 4 W2.1 x W2.1 (8 x 8) 44 lb. per C.S.F.	1.2	C.S.F.
4.	033053.405010	6" Slab on grade (3000 psi), incl textured finish, not incl forms or reinforcing.	120	S.F.
5.				
6.				
7.				
8.				
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34.				
35.				

Page 1 of ______ Pages

Figure 2–14. Material take off 1.

QUANTITY LIST

PROJECT NUMBER: FTLW 15-0867 Date: 20150309

PROJECT TITLE: Construct Covered Storage Area @ FOB Holmes.

	SECTION	ITEM DESCRIPTION	QUANTITY	Unit
1.		Carpentry Work		
2.	061110.140460	Posts and columns 6" x 6"	0.032	M.B.F
3.	061110.260370	Railings and Trim 2" x 2"	62	L.F.
4.	061636.100305	Plywood on Roofs, 3/4" thick, Pneumatic nailed	174	S.F.
5.	061110.248525	Miscellaneous framing 2" x 6" Pneumatic nailed	0.130	M.B.F
6.	061110.248500	Miscellaneous framing 2" x 4" Pneumatic nailed	.016	M.B.F
7.	073113.100200	Organic, class C, 235-240 lb/sq	2	Sq
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
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35.				

Page 2 of ______ Pages

Figure 2–15. Material take off 2.

Price Sheet

PROJECT NUMBER: FTLW 15-0867 Date: 20150309

PROJECT TITLE: Construct Covered Storage Area @ FOB Holmes.

	SECTION	ITEM DESCRIPTION	QUANTITY	Unit	Price	Total
1.		Carpentry Work				
2.	031113.653000	Edge forms, wood, 4 use, on grade, to 6" high	44	L.F.	$3.54	$155.76
3.	032205.500600	4 x 4 W2.1 x W2.1 (8 x 8) 44 lb. per C.S.F.	1.2	C.S.F.	$69.00	$82.80
4.	033053.405010	6" Slab on grade (3000 psi), incl textured finish, not incl forms or reinforcing.	120	S.F.	$3.38	$405.60
5.	061110.140460	Posts and columns 6" x 6"	0.032	M.B.F	$2,750.00	$88.00
6.	061110.260370	Railings and Trim 2" x 2"	62	L.F.	$2.06	$127.72
7.	061636.100305	Plywood on Roofs, 3/4" thick, Pneumatic nailed	174	S.F.	$1.34	$233.16
8.	061110.248525	Miscellaneous framing 2" x 6" Pneumatic nailed	0.130	M.B.F	$1,825.00	$237.25
9.	061110.248500	Miscellaneous framing 2" x 4" Pneumatic nailed	.016	M.B.F	$2,050.00	$32.80
10.	073113.100200	Organic, class C, 235-240 lb/sq Pneumatic nailed	2	Sq	$146.00	$292.00
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.					Total:	$1,655.09

Page 3 of _____ Pages

Figure 2–16. Basic bill of materials.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

409. Prepare preliminary contract documents

1. List all eight pieces of information common to all contract construction projects.

2. Within which part of the SOW would you find contractor security requirements?

410. Documenting the project

1. Who uses the AF Form 332, and for what purpose do they use it?

2. Describe what project specifications provide?

3. Who makes determinations regarding material feasibility?

411. Review project specifications

1. What is the code for restoration and cleaning of masonry in historic structures in the UFGS?

2. In which UFC do we find detailed instructions on how to format a statement of work?

412. Cost estimating and review

1. List the six categories of cost estimates.

2. Explain the difference between direct and indirect labor.

2–3. Contract Inspection

Understanding the drawings, specifications, and contract documentation is important, but it is only half the job. Every contract type has different requirements for frequency of onsite inspections. You must visit the construction site at regular intervals and document the progress the contractor is making in order to make recommendations for payment. Again, defense of the taxpayer's money is your task here. An honest review of what a contractor has accomplished leads to an accurate payment for work accomplished.

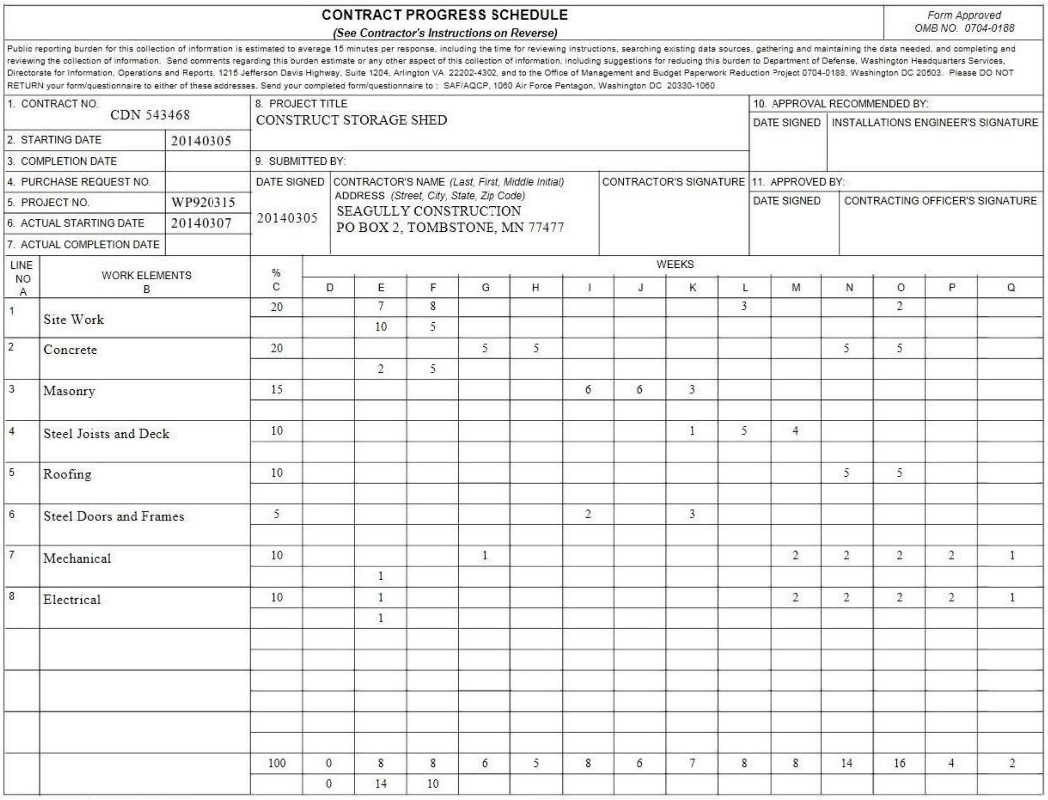
413. Perform inspection duties

Documenting the progress of a construction project is critical to project success. Since contractors are bound to the specifications, drawings, and a performance period, any deviation needs to be justified. Before starting a project, a contractor must submit a detailed schedule showing the expected progress. As it moves through the project, the contractor submits periodic reports showing what it has already completed. Records kept by the construction inspector track the daily progress. The forms required for these three functions are the contract progress schedule, contract progress report, and the AF IMT 1477. These documents are an integral part of the contract execution and surveillance process. They constitute the legal record of the government position and version of contract events. Ensure these documents are correctly maintained and completely accurate.

Reading the contract progress schedule

The contract progress schedule (fig. 2–17) allows the contractor to divide a project into work elements over a given period. Each element or category receives a percentage value of the total project. It then allows the contractor to plan how much of each type of work it will accomplish during each week of the project.

Refer to figure 2–17. Line 1 shows that site work will involve 20 percent of the project. During the second week, they plan to complete 7 percent, 8 percent on the third week, 3 percent on the tenth week, and 2 percent on the twelfth week to total 20 percent.



CONTRACT PROGRESS SCHEDULE
(See Contractor's Instructions on Reverse)

Form Approved
OMB NO. 0704-0188

Public reporting burden for this collection of information is estimated to average 15 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information, Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302, and to the Office of Management and Budget Paperwork Reduction Project 0704-0188, Washington DC 20503. Please DO NOT RETURN your form/questionnaire to either of these addresses. Send your completed form/questionnaire to : SAF/AQCP, 1060 Air Force Pentagon, Washington DC 20330-1060

1. CONTRACT NO. CDN 543468
2. STARTING DATE 20140305
3. COMPLETION DATE
4. PURCHASE REQUEST NO.
5. PROJECT NO. WP920315
6. ACTUAL STARTING DATE 20140307
7. ACTUAL COMPLETION DATE

8. PROJECT TITLE
CONSTRUCT STORAGE SHED

9. SUBMITTED BY:
DATE SIGNED 20140305
CONTRACTOR'S NAME *(Last, First, Middle Initial)*
ADDRESS *(Street, City, State, Zip Code)*
SEAGULLY CONSTRUCTION
PO BOX 2, TOMBSTONE, MN 77477
CONTRACTOR'S SIGNATURE

10. APPROVAL RECOMMENDED BY:
DATE SIGNED | INSTALLATIONS ENGINEER'S SIGNATURE

11. APPROVED BY:
DATE SIGNED | CONTRACTING OFFICER'S SIGNATURE

LINE NO A	WORK ELEMENTS B	% C	WEEKS D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Site Work	20		7	8						3			2		
				10	5											
2	Concrete	20				5	5						5	5		
				2	5											
3	Masonry	15						6	6	3						
4	Steel Joists and Deck	10								1	5	4				
5	Roofing	10											5	5		
6	Steel Doors and Frames	5						2		3						
7	Mechanical	10				1						2	2	2	2	1
				1												
8	Electrical	10		1								2	2	2	2	1
				1												
		100	0	8	8	6	5	8	6	7	8	8	14	16	4	2
			0	14	10											

Figure 2–17. Contract progress schedule.

Reading the contract progress report

The contract progress report (fig. 2–18) shows the contractor's progress according to the schedule on the contract progress schedule. The contractor submits this form through base contracting weekly for jobs with performance periods of 60 days or more. The project managers approve or disapprove the progress reports based on information gathered by the construction inspector. After the contract progress report's approval, the progress report authorizes base contracting to release payment to the contractor for that period of performance.

Contractors submit the contract progress report with a copy of contract progress schedule. Refer back to figure 2–17, Line 1, Site Work, plans 20 percent over the course of the project. However, the actual performance in the second week was 10 and in the third week five. In addition, they had not scheduled any concrete work in the second or third week but ended up doing two and five percent. Mechanical work was not scheduled, but the contractor completed one percent of the total mechanical work since construction start. In addition, one percent of the electrical work scheduled for the period finished. The bottom two rows show the scheduled and actual percentages. In the first week, the schedule shows eight and eight percent; yet 14 and 10 percent were completed.

Figure 2–18, Form 3065, has a column for the percent completed in the current period and a column for the percent completed cumulatively. The numbers in these columns should match the numbers in the columns in the respective categories on the Form 3064.

CONTRACT PROGRESS REPORT | OMB NO. 0704-0188

Public reporting burden for this collection of information is estimated to average 15 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to the Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (OMB No. 9000-0058), 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS. RETURN COMPLETED FORM TO : SAF/AQCO, 1060 Air Force Pentagon, Washington DC 20330-1060.

CONTRACTOR: SEAGULLY CONSTRUCTION
ADDRESS: P.O. BOX 2, Tombstone, MN 77477

REPORT NO.: 4
PERIOD COVERED FROM: 26 Mar 2014 TO: 1 Apr 2014
PROJECT NO.:
CONTRACT NO.: CDN 543468
COMPLETION DATE:

LINE NO.	WORK ELEMENT	% OF TOTAL JOB	% COMPLETED THIS PERIOD	% COMPLETED CUMULATIVE
1	Site Work	20.00	5	15
2	Concrete	20.00	5	7
3	Masonry	15.00		
4	Steel Joists and Deck	10.00		
5	Roofing	10.00		
6	Steel Doors and Frames	5.00		
7	Mechanical	10.00		1
8	Electrical	10.00	1	1
	TOTAL	100.00	11	24

REMARKS

At the Contracting Officer's discretion and according to the payments clause of the contract, the information provided on this form may be used for computing progress payments.

PROGRESS OR COMPLETION CERTIFICATE

I hereby certify that the contractor has satisfactorily completed the indicated percentage of the contract per contract specifications.

SUBMITTED BY OR FOR

☐ CONTRACTOR ☐ BASE CIVIL ENGINEER

TYPE OR PRINT NAME AND TITLE	SIGNATURE	DATE

REVIEWED BY OR FOR CONTRACTING OFFICER

TYPE OR PRINT NAME AND TITLE	SIGNATURE	DATE

Figure 2–18. Contract progress report.

Using the AF IMT 1477

In order for project managers to approve or disapprove the contract progress schedule and contract progress schedule, there needs to be an accurate record of work accomplished. Construction inspectors use the AF IMT 1477 to record daily progress. Figures 2–19 through 2–23 show pages one through five of the AF IMT 1477. Page one shows the general information about the contract. Page 2 has space for any areas where the contractor does not comply with the drawings, specifications, codes, or regulations. Page 3, the daily inspection record, is where you record all the daily work. Page 4 is for additional notes, sketches, or information that will not fit on page three. Page five offers a log of any submittals and any GFE used.

CONSTRUCTION INSPECTION RECORD

(TYPE OR WRITE ALL ENTRIES LEGIBLY IN INK)

INSTALLATION Beale AFB, CA	PROJECT NUMBER BAEY 13-0061
CONTRACT NUMBER 321654987	AWARD COST $523 K FINAL COST $521 K
PROJECT TITLE Renovate Bowling Alley	
PROJECT DESCRIPTION Renovate and modernize bowling alley at building 2345.	
DATE NOTICE TO PROCEED ISSUED *(YYYYMMDD)* 20160302	NUMBER OF CALENDAR DAYS IN CONTRACT 125
SCHEDULED COMPLETION DATE *(YYYYMMDD)* 20160705	ACTUAL COMPLETION DATE *(YYYYMMDD)* 20160630
PRIME CONTRACTOR Zografos Construction LLC	NAME OF AIR FORCE PROJECT ENGINEER Peter Capaldi, P.E.

SUB CONTRACTORS

Bowman Demolition	
Lafon Drywall and finishing	
Brown's Hauling	
Technicians & Renovations Development Inc, Sheboygan	

CERTIFICATION

I CERTIFY THAT I HAVE READ, UNDERSTAND, AND WILL REQUIRE COMPLIANCE WITH THE FOLLOWING ASPECTS AS PERTAIN TO THIS PROJECT: PLANS; TECHNICAL PROVISIONS; FEDERAL SPECIFICATIONS; PROGRESS SCHEDULE; AND FIELD TESTS.

I FURTHER CERTIFY THAT I UNDERSTAND THAT I HAVE NO AUTHORITY TO MAKE CHANGES IN THE PLANS OR SPECIFICATIONS AND THAT MY DUTIES CONSIST PRIMARILY OF SEEING THAT TERMS AND CONDITIONS OF THE CONTRACT ARE CARRIED OUT, TO PROVIDE A PERMANENT RECORD OF THE ACCOMPLISHMENT OF THE PROEJCT BY MEANS OF AF FORM , SUPPLEMENTED AS NECESSARY BY ANNOTATED COPIES OF PLANS AND SPECIFICATION, AND FURTHER, TO PROVIDE TIMELY RECOMMENDATIONS TO THE BASE CIVIL ENGINEER FOR CHANGES IN THE CONTRACT PLANS AND SPECIFICATIONS, IF REQUIRED.

I WILL MAINTAIN THIS RECORD ON A CURRENT BASIS, IN ACCORDANCE WITH THE REQURIEMENTS OF PERTINENT REGULATIONS AND INSTRUCTIONS GOVERNING THE PREPARATION, MAINTENANCE, AND COMPLETION OF THIS RECORD.

NAME AND GRADE OF INSPECTOR SSgt Jenna Coleman	SIGNATURE Jenna L. Coleman	DATE 20160630
AIR FORCE CONSTRUCTION MANAGER Patrick Troughton	**PERIOD COVERED *(YYYYMMDD)*** **FROM** 20160405 **TO** 20160410	
COMPLETED REPORTS 1 **THROUGH** 5	**BOOK NO.** 3 **OF** 5 **BOOKS**	

AF IMT 1477, 19800701, V1 PREVIOUS EDITION IS OBSOLETE. PAGE 1 OF PAGES

Figure 2–19. AF IMT 1477 page 1.

NON-COMPLIANCE ITEMS					
ITEM NO.	PLANS OR SPECS	DESCRIPTION	DATE IDENTIFIED	DATE COMPLETED	REMARKS
1	Drawing Sheet I-1	Contractor supplied wooden ext doors	20160406	20160408	Ctr procured correct doors
2	Drawing Sheet F-7	Fire alarm handle installed 6' from door	20160406	20160409	Relocated pull handle

-Arrived on site in time for ctr to receive delivery of extr doors. Upon inspection noted that all ext doors were made of wood. Drawings specifically call for hollow metal doors, 1 ¾" thick. Ctr refused delivery. Correct doors were delivered to site w/in two days at no additional cost since it was supplier's error.
-During inspection noted that fire alarm pull handle seemed far from door. Measured distance at 6' 2". Drawings specifically state 5' or less. Ctr noted error and recalled subcontractor to relocate handle.

AF IMT 1477, 19800701, V1 PAGE 2 OF 5 PAGES

Figure 2–20. AF IMT 1477 page 2.

DAILY INSPECTION RECORD

DATE *(YYYYMMDD)*	TIME OF INSPECTOR'S VISIT TO SITE							
	ARRIVAL	DEPARTURE	ARRIVAL	DEPARTURE	ARRIVAL	DEPARTURE	ARRIVAL	DEPARTURE
20160406	0815	0927						

WEATHER CONDITIONS SATISFACTORY FOR WORK [X] YES [ ] NO *(IF NO, DESCRIBE CONDITIONS.)*

WORK FORCE - CONTRACTOR AND SUB-CONTRACTOR

TRADE	NO.	TRADE	NO.	TRADE	NO.	TRADE	NO.
Carpenter	3	Laborer	2				
Electrician	2						
Foreman	1						

MATERIALS DELIVERED TO JOB SITE

ITEM	QUANTITY	ITEM	QUANTITY
Exterior Doors	4		

CONTRACTOR EQUIPMENT ON HAND

TYPE	NO.	TYPE	NO.	TYPE	NO.	TYPE	NO.
Demo Dumpster	2						
Forklift	1						

WORK ACCOMPLISHED OR IN PROGRESS - TESTS PERFORMED

- Electricians installed new power panel. Completed wiring to outlets and switches in new management office.

- Carpenters and laborers completed hanging drywall in new dining area. Ready for tape and mud.

- Foreman refused delivery of new exterior doors after discovering they were wood rather than metal.

CONTINUE REPORT ON PAGE 4

NOTE: WRITE ALL ENTRIES LEGIBLY IN INK. LINE OUT ALL UNUSED PORTIONS. INSPECTOR SIGNS FIRST NAME, MIDDLE INITIAL AND LAST NAME ON EACH COMPLETED DAILY INSPECTION RECORD

REPORT NO. 4

AF IMT 1477, 19800701, V1 PAGE 3 OF 5 PAGES

Figure 2–21. AF IMT 1477 page 3.

REMARKS *(Delays; safety; special instructions given or received; reasons for rejecting materials and/or work.)*

-Arrived on site in time for ctr to receive delivery of extr doors. Upon inspection noted that all ext doors were made of wood. Drawings specifically call for hollow metal doors, 1 ¾" thick. Ctr refused delivery. Correct doors were delivered to site w/in two days at no additional cost since it was supplier's error.

-During inspection noted that fire alarm pull handle seemed far from door. Measured distance at 6' 2". Drawings specifically state 5' or less. Ctr noted error and recalled subcontractor to relocate handle.

LAST ENTRY

SIGNATURE	DATE
Jenna L. Coleman	20160406

AF IMT 1477, 19800701, V1 PAGE 4 OF 5 PAGES

Figure 2–22. AF IMT 1477 page 4.

RECORD OF SUBMITTAL DATA						
SECTION.	ITEM DESCRIPTION	TYPE SUBMITTAL	DATE DUE	DATE RECEIVED	DATE APPROVED	REMARKS
08	Metal Doors	Mnfr Desc	20160215	20160220	20160223	Manufacturer's description meets spec
No more submittals submitted during this inspection period.						

GOVERNMENT FURNISHED EQUIPMENT/MATERIALS				
DESCRIPTION	DATE ORDERED	DATE RECEIVED	DATE INSPECTED	INSPECTED BY/REMARKS
Not Applicable. No GFE				

PAGE 5 OF 5 PAGES

Figure 2–23. AF IMT 1477 page 5.

Pages three and four of the AF IMT 1477 (figs. 2–21 and 2–22) are the core of the AF IMT 1477. You record each inspection of a project on pages three and four. It is very important to catalog all the information available for that day. At the end of each performance period, these records can prove or disprove a contractor's performance. When a daily inspection report is complete, line out the unused portions of the page and sign at the bottom of page four. These then can help resolve a dispute if a contractor attempts to falsely charge for percentages of work not accomplished. These pages can also be very important after project completion if there is any warranty or guarantee disputes.

Conducting inspections

Construction inspectors must be familiar with the drawings, specifications, regulations, and codes involved with a project. While this may seem time consuming, a quality construction management and inspection team can greatly improve the overall efficiency of a construction project. Inspections divide into four types: daily or routine inspections, pre-final inspections, final inspection, and post-final inspection.

Daily or routine inspections

Record observations from daily and routine inspections in the AF IMT 1477. Daily inspections ensure the contractor complies with all the necessary standards. It is very important to carefully record contractors on site, equipment on hand, weather conditions, test performed, and any discussions with contractors. During discussions with contractors, be very careful *not to imply in any way* that work can deviate from the drawings and specifications without proper approval authority.

Modifications and deviations

No plan survives contact with the enemy. In the case of construction, execution becomes that enemy. It is inevitable that changes arise, material availability will change, there will be problems with a design, and many more potential challenges. Document any significant deviation from contract specifications and drawings through a formal modification.

Execute modifications due to unforeseen site conditions as quickly as possible to prevent delays. Identify modifications due to design deficiencies and correct them as soon as possible to prevent increased cost due to removing deficient construction or expensive alterations to accommodate design. Modification requests from users should be discouraged unless the facility under construction would not be usable without the requested change. When it becomes necessary to initiate a modification, contact the team leader, contracting officer, immediately.

Pre-final inspection

Perform pre-final inspection when there are only a few items to be completed and there is time before the completion date to allow time to complete all items. The project inspector and the contractor will thoroughly inspect the job for all remaining items to be completed. Conduct this inspection at the contractor's request. Enter incomplete items of work on a standardized base developed "Report of Inspection" form, commonly referred to as a *punchlist*. Provide a copy of the pre-final inspection form to the contractor, Base Contracting, and filed in the project folder.

Operations and maintenance checks

You conduct O&M checks after the pre-final inspection. This review provides the opportunity for the users, fire protection flight, and maintenance personnel to become familiar with newly installed equipment and/or systems. Conduct a functional demonstration training class, if required by the contract, at this review. Give discrepancies identified at this review in writing to the project inspector who will validate the discrepancies.

Final inspection

The contractor requests a final inspection when all, or nearly all, punch list items are complete. The inspector is responsible for formally notifying and inviting all appropriate base agencies to attend the final inspection. At a minimum, the inspection group should include the contract manager, team leader, using agency, contracting officer, and the contractor. The inspector records all valid discrepancies identified during this walk through on an inspection report form.

Conducting contract closing actions

When all the work and inspections are complete, and the user has started using the facility, there is still work to do. This phase of a project can be one of the most challenging. Most organizations involved in a project are eager to move to the next one and can overlook finishing details. The most commonly overlooked are warranty/guarantee procedures, post-acceptance inspections, and as-built drawings.

Overseeing warranty/guarantee procedures

Place warranty information in the CE O&M work database. While there may be variations between manufacturers' warranties for new equipment, contractors are required to guarantee their work for 1 year from the date of final acceptance of the work. The warranty for work accepted prior to final acceptance extends from the time of acceptance of that portion of the project.

Contractors are responsible for remedying, at their own expense, any flaws or failures in a project due to workmanship or materials. The contractor is also responsible for any work done by subcontractors and holding them accountable to the warranty. If the contractor does not remedy a warranty item in a timely manner, the government reserves the right to replace, repair, or otherwise remedy the failure, defect, or damage at the contractor's expense. Facility maintainers are required to perform all maintenance on new equipment, even if it is under warranty. Failure to do so could void the warranty.

Post-acceptance

The purpose of the post-acceptance inspection is to discover latent design or functional deficiencies not apparent before or during acceptance of facility inspection. It should be scheduled by the project inspector between 9 and 12 months after physical completion of the project. Delaying the post-acceptance inspection too long leads to finding discrepancies after the contractor's warranty period is already expired.

DD Form 1354

The CE project DD Form 1354, Transfer and Acceptance of DOD Real Property, is a very important document but sometimes easy to forget. Since construction projects often include more than one facility or system, the real property office needs an accurate accounting of the changes to each system. Give one copy of the DD Form 1354 to real property and one copy filed in the project folder. If a project included new exterior light, sanitary sewer, sidewalks, parking lots, or any other form of real property, we list those items separately. Work closely with the real property office to determine the necessary information they need documented.

Final actions

Once the government has taken full acceptance of a facility, there are four last items to manage keys, operations and maintenance manuals, as-built drawings, and backstock. Catalog copies of any keys with the lock shop within civil engineering. O&M manuals are the publications regarding upkeep and operation of any new equipment or systems installed. The shops need to have copies of these books in order to properly service and repair the equipment. As-built drawings, once complete, need to be stored either in the flat file vault or electronically with the appropriate naming conventions. Backstock includes extra carpet, tile, paint samples, or unique items, used for minor facility repair or for color and material matching.

414. Standards of conduct

People of great integrity and maturity are integral when developing and executing contracts. We need these kinds of people for two reasons. First, they must ensure the contractors deliver the products and services according to specifications and drawings. They must also ensure that contractors have necessary access to job sites, that they comply with safety standards, and that work happens in a timely manner.

Some contractors may try to cut corners to increase profits. Government employees may try to manipulate contracts for their own benefit. The Air Force core values of integrity, service, and excellence are important to ensure fairness and identify fraud, waste, and abuse. To guide government employees, the FAR defines limitations and areas of responsibility for all parties involved in a contract. Aside from the FAR personnel involved in contracts, need to be familiar with certain labor laws, such as the McNamara-O-Hara Service Contract Act (SCA) and the Davis-Bacon Act (DBA).

Federal acquisition regulation

The FAR is a document, which sums up the guidance in the Federal Acquisition Regulation System (FARS). The system provides strict guidance on how the federal government acquires assets, builds contracts, and administers contract execution. By following the FAR, government employees can avoid illegal or unethical behavior. The essential components to understand are the general provisions, and guidance on gratuities, relationships, and ratification.

General

Since all government projects receive funding by way of taxes, government business requires the highest degree of public trust and an impeccable standard of conduct. The general rule is to avoid any conflict of interest or even the appearance of a conflict of interest in government-contractor relationships. While many federal laws and regulations place restrictions on the actions of government personnel, their official conduct must be such that they would have no reluctance to make a full public disclosure of their actions. Meaning that if someone feels the need to hide an action, it is probably the wrong one.

Gratuities

No government employee may solicit or accept—directly or indirectly—any gratuity, gift, favor, entertainment, loan, or anything of monetary value from anyone who

(a) has or is seeking to obtain government business with the employee's agency;

(b) conducts activities that are regulated by the employee's agency; or

(c) has interests affected by the performance or nonperformance of the employee's official duties.

There are certain limited exceptions. For example, we can exchange small items of little or no value with contractors. These can include soft drinks or coffee—as long as they are not part of a meal—plaques, certificates, and trophies. Government employees may accept gifts up to $20 in value, per contractor, *not to exceed* $50 per year per contractor.

Relationships

In some instances, a contractor and government employee are friends. There is no restriction in friendship. However, make certain that there is no question of a conflict of interest. If a government employee assigned to a contract finds that a friend is conducting work under the contract, it is wise to ask for reassignment. This can help avoid undue scrutiny or compromising the friendship.

Ratification

The term *ratification* is uncommon, but all military and government civilian personnel should become familiar with it because of personal and financial consequences.

The FAR defines *ratification* as the act of approving unauthorized commitments by one without authority to do so. Unauthorized commitments are agreements made by government personnel to purchase items with federal funds. According to the FAR, these agreements are not binding to the government because the government representative who made them lacked the authority to enter into such agreements on behalf of the government. When dealing with contract situations, only authorized contracting personnel can obligate government funds for contractor reimbursement.

If a construction inspector or manager attempts to obligate the government to pay for any work not already specified in the existing contract, that person is liable for the additional incurred expense and possible additional disciplinary action.

McNamara-O-Hara Service Contract Act

The McNamara-O'Hara SCA requires contractors and subcontractors performing services on prime contracts in excess of $2,500 to pay service employees in various classes no less than the wage rates and fringe benefits found prevailing in the locality, or the rates (including prospective increases) contained in a predecessor contractor's collective bargaining agreement. The Department of Labor issues wage determinations on a contract-by-contract basis in response to specific requests from contracting agencies.

For contracts equal to or less than $2,500, contractors are required to pay at least the federal minimum wage as provided in Section 6(a)(1) of the Fair Labor Standards Act.

Davis-Bacon and related acts

The DBA and related acts apply to contractors and subcontractors performing on federally funded or assisted contracts in excess of $2,000 for the construction, alteration, or repair (including painting and decorating) of public buildings or public works. DBA and related acts contractors and subcontractors must pay their laborers and mechanics employed under the contract no less than the locally prevailing wages and fringe benefits for corresponding work on similar projects in the area. The DBA directs the Department of Labor to determine such locally prevailing wage rates. The DBA applies to contractors and subcontractors performing work on federal or District of Columbia contracts. The DBA prevailing wage provisions apply to the "related acts," under which federal agencies assist construction projects through grants, loans, loan guarantees, and insurance.

For prime contracts in excess of $100,000, contractors and subcontractors must also, under the provisions of the Contract Work Hours and Safety Standards Act, pay laborers and mechanics, including security guards, at least one and one-half times their regular rate of pay for all hours worked over 40 in a workweek. The overtime provisions of the Fair Labor Standards Act may also apply to DBA-covered contracts.

Occupational safety and health administration

One thing that all contractors working in the United States or for the United States abroad have to follow is regulations established by the Occupational Safety and Health Administration (OSHA). OSHA is an agency of the United States Department of Labor and works to assure the safe and healthy working conditions for workers by setting and enforcing standards. It also provides training, outreach, and education and assistance. Pursuing a formal course by OSHA professionals is a high priority for a new construction inspector. Generally, if something looks unsafe, go to the OSHA Website and look up the rules for the work performed. If you identify an infraction, notify the contractor supervision immediately and send notification to the contracting officer through the contract administrator. This includes making the infraction a part of your daily log entries.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

413. Perform inspection duties

1. What two forms are compared before you make a recommendation for payment to base contracting?

2. As the construction inspector, on which form do you record daily contractor progress?

3. What are the five sections on page three of the inspection record?

4. During a pre-final inspection, what goes on the "Report of Inspection" form?

5. Whom do you invite to the O&M checks when there is newly installed equipment?

6. How many copies of the DD Form 1354 are needed during project close out and where are they filed?

414. Standards of conduct

1. Aside from the FAR, what labor laws should you be familiar with?

2. What four components of the FAR are essential for you to understand?

3. Define the term “ratification” within the context of the FAR.

2–4. Materials and Test Reports

A major part of most construction is soil. Soil is the composition of the earth below and around a facilities footprint. We also engineer soil as part of a structure. For example, engineers design the soil that supports asphalt roads in such way as to disperse loads over a wider area. Facilities are heavy and need strong support to hold them up. Therefore, knowing the composition of the soil in an area allows us to decide if we need to engineer the soil or change the location of a future facility. As a member of construction management, your knowledge of soils provides an understanding of the basics of material test reports. Reading test reports and informing the project engineer whether the material meets project specifications is a big part of the job.

415. Soil properties and classification

The fundamental component of assessing material stability is soil classification. The word soil has numerous meanings and connotations to different groups of professionals who deal with this material. Simply defined, soil is the entire unconsolidated earthen material that overlies and excludes bedrock. It is composed of loosely bound mineral grains of various sizes and shapes. Loosely bound grains contain many voids of varying sizes. These voids are most likely to contain air, but also water, organic matter, or different combination of these materials. Engineers must be concerned not only with the sizes of the particles but also with the voids between them and particularly with what these voids enclose.

Physical properties

The properties of soil are very important when evaluating potential locations for construction of a new structure. As an engineering craftsman, you must be able to identify and classify soils to determine their engineering characteristics. The characteristics we are concerned with are the grain size and the particle shape.

Grain sizes

We divide soils into groups based on the size of individual particles as established by the Unified Soils Classification System (USCS).

The following four soil groups designate the size ranges of individual soil particles:

- Cobbles.
- Gravels.
- Sands.
- Fines.

Soil grain sizes are determined by using sieves. A sieve is a screen attached across one end of a shallow circular container. The screen lets particles smaller than the openings fall through and keeps larger particles on the sieve. By using sieves with screen openings of different sizes (the largest on the top and the smallest at the bottom), we separate soil into particle groups. We base particle groups on grain sizes to determine the percentage of different size ranges in a sample. If a particle does not pass through the screen with a particular size opening, we describe the soil as *retained on* that sieve. We describe particles that pass through a sieve opening as *passing* that sieve size. By passing a soil mixture through several different size sieves (fig. 2–24), you can break it into components and classify it by the quantities retained on the sieves. American Society for Testing and Materials (ASTM) C136, section 10, dictates the minimum required information on a sieve analysis report.

Sieve sizes are either by inches or by a number. Inches refer to the actual linear dimension of the openings between the wires of the screen. The number designation indicates the number of openings per linear inch of screen. Figure 2–25 shows you the 1/4-inch sieve and No. 4 sieve.

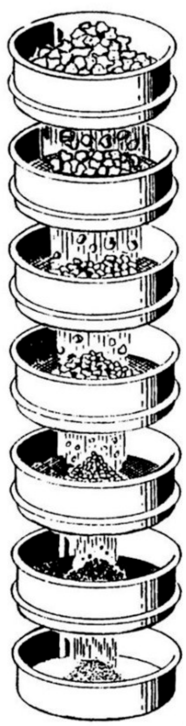


Figure 2–24. Typical sieve set.

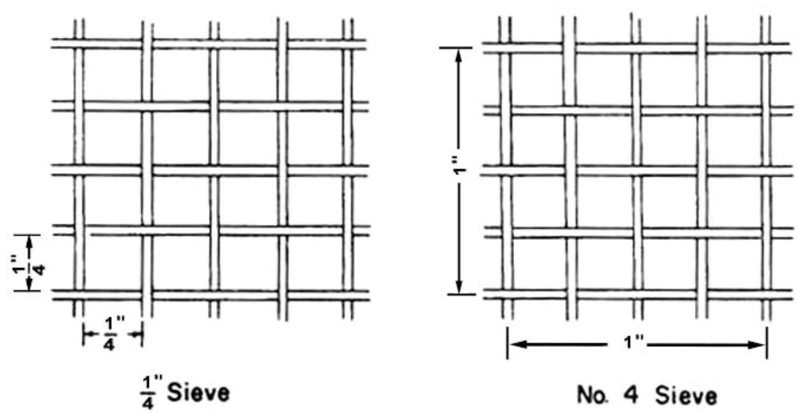


Figure 2–25. Sieve size designations.

By measurement, the opening in the No. 4 sieve is 0.187 inches, while the opening in the 1/4-inch sieve is 0.25 inches. Sieves with openings 1/4-inch or larger are referenced according to the size of the opening, and those with openings smaller than 1/4-inch are identified by the number of openings per linear inch.

Figure 2–26 shows the names of the size groups and their associated sizes.

Size Group	Sieve Size	
	Passing	Retained
Cobbles	No maximum size	3 inch
Gravels	3 inch	No. 4
Coarse	3 inch	¾ inch
Fine	¾ inch	No. 4
Sands	No. 4	No. 200
Coarse	No. 4	No. 10
Medium	No. 10	No. 40
Fine	No. 40	No. 200
Fines (silt and clay)	No. 200	No minimum

Figure 2–26. Soil size groups and ranges.

Particle shapes

The shape of the particles in a soil mass is an important influence on the strength and stability of a soil material. The two general shapes normally recognized are bulky and platy.

Bulky shapes

Gravel, sand, and silt particles, although covering a large range of sizes, are all of bulky shape. This means they are particles relatively equal in all three of the dimensions, as contrasted to platy grains, in which one of the dimensions is small as compared to the other two. You might think of a very thick book as a bulky object. All of the dimensions are roughly the same size, with the length not more than a few times larger than the thickness. A page of that book, by contrast, represents a platy object, where one of the dimensions is much smaller than the other two. You can distinguish four subdivisions of the bulky shape depending on the amount of weathering on the particles (fig. 2–27). See the subdivisions listed below in order of desirability for construction.

BULKY SHAPES IN SOIL	
Subdivision	**Description**
Angular	Angular particles have jagged projections, sharp ridges, and flat surfaces. Angular gravels and sands are generally the best materials for construction because of their interlocking characteristics. Most commonly, we artificially produce angular materials by crushing the gravel.
Subangular	Subangular particles have had their sharper points and ridges worn down, but the particles are still very irregular in shape, with some flat surfaces.
Subrounded	They are still somewhat irregular, but they have no sharp corners and few flat areas. Often you can find hard and durable subrounded particles in streambeds that are adequate for most construction needs.
Rounded	Rounded particles are those that lack projections and have few irregularities. You can find rounded particles in or near streambeds or beaches.

Platy shapes

The platy shapes have one dimension that is relatively small compared to the other two. They have the general shape of a flake of mica or a sheet of paper. Particles of clay soil exhibit this shape, although they are too small to see with the naked eye but are visible under a microscope. Coarse-grained soil particles are individually discernible to the naked eye; fine-grained particles with platy or bulky shapes are not.

Gradation

Gradation describes the distribution of the different size groups within a soil sample. The soil may be well-graded or poorly graded (fig. 2–28).

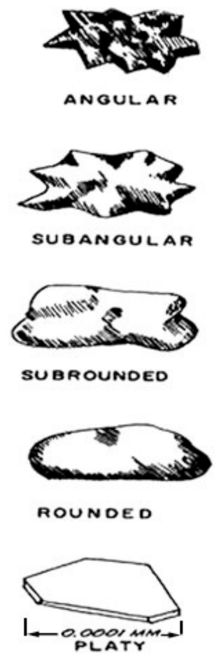


Figure 2–27. Soil grain shapes.

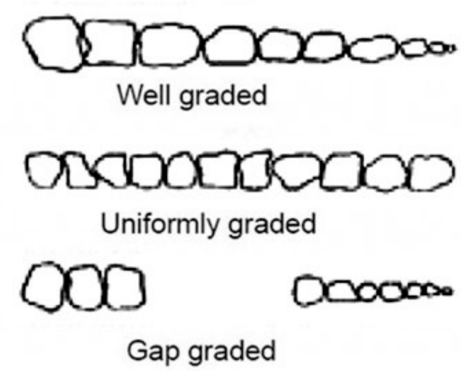


Figure 2–28. Soil gradation.

Well-graded soils

Well-graded soils have a good range of all representative particle sizes between the largest and the smallest for that sample.

Poorly-graded soils

We classify poorly graded soils as either uniformly graded or gap graded. A uniformly graded soil consists primarily of particles of nearly the same size. A gap-graded soil contains both large and small particles but lacks gradual size change because of the absence of some particle sizes.

Soil behavior

Different types of soil behave in different ways whether they are dry or wet. Soils made of mostly fines with a high clay content can be dust when there is no moisture and sticky much where there is a lot of moisture. When combined with different shapes, moisture can have varying effects on the plasticity and cohesion of soil.

The term *moisture* content defines the amount of water present in a soil sample. It is the proportion of the weight of water to the weight of the solid mineral grains (weight of dry soil) expressed as a percentage. Moisture comes to soil in several ways as described in the table below.

TYPES OF MOISTURE IN SOIL	
Moisture Type	**Description**
Surface water	Surface water from precipitation or runoff enters the soil through the openings between the particles. This moisture may adhere to the different particles or it may penetrate the soil to some layer below.
Subsurface water	The term subsurface water refers to that water collected or held in pools or layers beneath the surface by a restricting layer of soil or rock.
Gravitational pull	Water controlled by gravity seeks a lower layer and moves through the voids until it reaches some restriction. This restriction may be bedrock or an impervious soil layer.
Capillary action	Voids in soil may form continuous tunnels or tubes and cause the water to rise in the tubes by capillary action. Since the smaller the tube, the stronger the capillary action,

TYPES OF MOISTURE IN SOIL	
Moisture Type	**Description**
	the water rises higher in the finer soils that have smaller interconnected voids. This area of moisture above the free water layer or pool we refer to as the *capillary fringe*.
Adsorbed water (hygroscopic moisture)	In general, adsorbed water is water that may be present in thin film surrounding separate soil particles. When soil is in an air-dried condition, the adsorbed water present we refer to as *hygroscopic moisture*. Adsorbed water is present because soil particles carry a negative electrical charge. We call water attracted to the surface of a particle and bound to it, *dipolar water*.

Plasticity and cohesion

Plasticity is a soil's ability to deform without cracking or breaking. Soils in which adsorbed films are relatively thick compared to particle size (such as clays) are plastic over a wide range of moisture contents. Coarse soils are non-plastic. A plasticity index (PI) describes a soil's cohesiveness. To calculate the PI, we first need the liquid limit (LL) and the plastic limit (PL).

A soil sample is generally going to be in one of three states: solid, plastic, or liquid. Each state allows a specific amount of moisture before the sample moves from one state to the other. The PL is the moisture content where a soil sample stops being rigid or friable and becomes plastic or moldable. The LL is the moisture content where a soil moves from a plastic to a liquid and flows freely under its own weight. We express the moisture content of the PL and LL as a percentage of moisture in a soil sample. Between the LL and the PL is the plastic range or PI. The PI is the numerical difference in percentage of moisture contents between the two limits (PI = LL – PL).

Organic soil has a high content of decaying organic material. It is usually very compressible and has poor load-maintaining properties. Organic soil normally has a dark color and an odor.

Symbols

A letter symbol denotes each soil characteristic. A sample of soil, when run through the sieve and tested for LL and gradation, has a combination of three symbols. The USCS divides soils into three major categories and six minor categories. The major categories are course-grained, fine-grained, and highly organic. The minor categories are gravel, sand, silt, clay, organic (silts and clays), and organic (peat).

A coarse-grained soil sample is one having 50 percent or less material passing the number 200 sieve. Fine-grained soils or fines are those having more than 50 percent passing the number 200 sieve. Identification of highly organic soils usually occurs by visual examination. They typically have a rich, dark color and distinct odor. This system recognizes that 15 soil groups and uses names and letter symbols to distinguish between these groups. The letter symbols used are relatively easy to remember. They are derived either from the terms descriptive of the soil fractions, the relative value of the LL (high or low), or the relative gradation (well graded or poorly graded). See figure 2–29 for soil groups and characteristics. Note that these categories exclude cobbles—material retained on a 3" sieve.

Figure 2–30 shows the possible combination of soils and conditions according to the USCS.

Soil Groups	Symbol
Gravel	G
Sand	S
Silt	M
Clay	C
Organic (silts and clays)	O
Organic (peat)	Pt
Soil Characteristics	**Symbol**
Well graded	W
Poorly graded	P
Low LL (less than 50)	L
High LL (50 or greater)	H

Figure 2–29. Soil classification symbols.

Major divisions			Group symbol	Group name
Coarse grained soils more than 50% retained on or above No. 200 sieve	**gravel** >50% of coarse fraction retained on No. 4 sieve	clean gravel <5% smaller than #200 Sieve	GW	well-graded gravel, fine to coarse gravel
			GP	poorly graded gravel
		gravel with >12% fines	GM	silty gravel
			GC	clayey gravel
	sand ≥50% of coarse fraction passes No. 4 sieve	clean sand	SW	well-graded sand, fine to coarse sand
			SP	poorly graded sand
		sand with >12% fines	SM	silty sand
			SC	clayey sand
Fine grained soils 50% or more passing the No. 200 sieve	silt and clay liquid limit <50	inorganic	ML	silt
			CL	clay of low plasticity, lean clay
		organic	OL	organic silt, organic clay
	silt and clay liquid limit ≥50	inorganic	MH	silt of high plasticity, elastic silt
			CH	clay of high plasticity, fat clay
		organic	OH	organic clay, organic silt
Highly organic soils			Pt	peat

Figure 2–30. Soil identification.

416. Identifying soils in the field

Laboratories are usually difficult to come by for conducting proper soil classification. The material is expensive, heavy, and sometimes delicate. However, there will be times when tests and soil classification are necessary. These are times when engineering personnel can determine the category of a soil using simple tests with little or no equipment.

Odor test

Organic soils usually have a distinctive, musty, slightly offensive odor. This odor is especially apparent from fresh samples but becomes less pronounced as the sample dries. Warming a wet sample makes the odor stronger.

Sedimentation test

It is easy to approximate the proportions of sand and gravel in a soil by spreading the dry sample out on a flat surface and separating the gravel particles by hand. Separating the fines from the sand particles is much more difficult. Smaller particles settle through water at a slower rate than large particles.

To perform this test, place about 1 inch of the fine fraction of soil (passing the No. 4 sieve) in a transparent cup or jar. Mark the height of the sample with a grease pencil. Place about 5 inches of water into the jar ensuring that at least 1 inch remains above the water line to the top of the jar. Cover and shake the water and soil mixture for 3 to 4 minutes. Place the jar on a flat surface. After 30 seconds, compare the level of material that settled to the bottom with the height of the original sample (grease pencil line). This comparison should indicate the proportion of sand within the mixture. For example, if the level of the settled material comes halfway from the bottom of the jar to the grease-pencil line after 30 seconds, then is can be estimated the amount of sand in this fraction of the soil is about 50 percent. See figure 2–31 for an approximation of materials based on settling time.

Approximate Time of Settlement Through 5 Inches of Water	Grain Diameter (mm)	Differentiates
2 seconds	0.400	Coarse sand, fine sand
30 seconds	0.072	Sand, fines
10 minutes	0.030	Coarse silt, fine sand
1 hour	0.010	Silt, clay

Figure 2–31. Sedimentation test.

Bite or grit test

The bite or grit test is a quick and useful test to identify sand, silt, or clay. Simply grind a small pinch of soil between the teeth.

CAUTION: First be sure there are very little or no organics present.

The results of this test indicate the following:

- Sandy soils – The sharp, hard particles of sand grate very harshly between the teeth and are highly objectionable.
- Silty soils – Silt grains are so much smaller than sand grains that they do not feel nearly as harsh between the teeth. They are not particularly gritty, although their presence is still quite unpleasant and easily detected.
- Clayey soils – Clay gains are not gritty, but feel smooth and powdery-like flour between the teeth. Dry lumps of clayey soil stick with lightly touched with the tongue.

Feel test

This is a general-purpose test requiring considerable experience and practice before you can expect reliable results. Its use will increase with growing familiarity with soils. Consistency and texture are two characteristics that can be determined. Consistency means whether a soil is hard, stiff, brittle, friable, sticky, plastic, or soft. Texture means whether a soil is floury, smooth, gritty, or sharp. To check either property, rub a dry soil sample against a sensitive, exposed skin area such as the inner wrist or elbow.

Roll or thread test

Mix a representative sample with water until it stops sticking to your fingers. We refer to this moisture content as just below the “sticky limit.”

Prepare a non-absorbent rolling surface by placing a sheet of glass or heavy waxed paper on a flat or level support. Shape the sample into an elongated cylinder, and roll the prepared soil cylinder on the surface rapidly into a thread about 1/8 inch in diameter (fig. 2–32).

Figure 2–32. Roll or thread test.

The number of times the thread rolls without crumbling is a measure of the soil’s plasticity. Materials that break before reaching 1/8-inch are not plastic or have low plasticity.

- If soil molded into a ball or cylinder, under firm finger pressure, does not crumble or crack, it is of high plasticity (CH).
- If we mold a soil sample but it cracks or crumbles without breaking up, it is of low plasticity (CL, ML, or MH).
- If the soil forms a soft, spongy ball or thread when molded, it is organic material (OL or OH), also peat.
- If the soil does not stick together or thread at any moisture content, it is non-plastic soil (ML or MH).

Wet shaking test

Perform the wet shaking test on material passing the No. 40 sieve. Moisten enough material to form a ball of material about ¾ inch in diameter. The sample should be just wet enough to form a ball but not be sticky (fig. 2–33).

Smooth the soil pat in the palm of the hand with a knife blade or a small spatula. Shake it vertically and strike the back of the hand vigorously against the other hand. The soil reacts to this test when, on shaking, water comes to the surface of the sample, producing a smooth, shiny appearance. Squeeze the sample between the thumb and forefinger of the other hand and the surface water will quickly disappear. The surface becomes dull and the material becomes firm, resisting deformation. Cracks occur as pressure is continued, with the sample finally crumbling like a brittle material. If the water content is adequate, shaking the broken pieces will cause them to liquefy again and flow together; then we can repeat the cycle. The results of this test indicate the following:

- A rapid reaction to the shaking test is typical of non-plastic, fine sands and silts.
- A sluggish reaction indicates slight plasticity or silts containing small amount of clay.
- No reaction at all to this test does not indicate a complete absence of silt or fine sand.

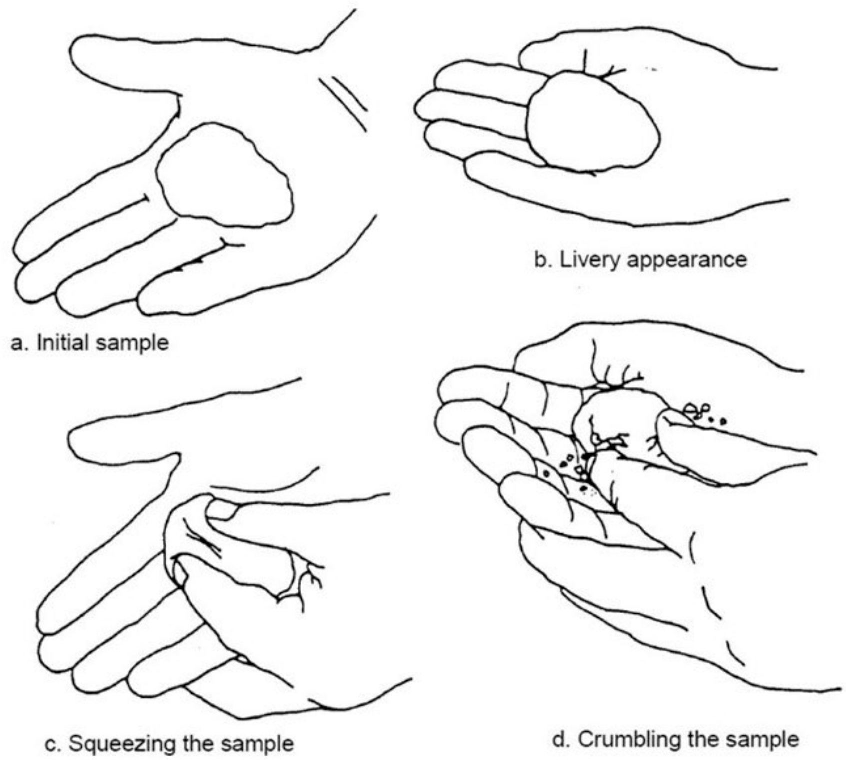


Figure 2–33. Wet shaking test.

Breaking or dry-strength test

This test is for materials passing the No. 40 sieve and helps determine between clayey (C) and silty (M) soils (fig. 2–34). Moisten a sample so it is pliable but not sticky. Form a pat 2 inches in diameter and ½ inch thick. Natural samples can give an approximation because of variations in the compaction and drying process but need verification. Allow the sample to dry completely. Try to break it using only hand strength then crumble it to a powder using only finger strength. The results of this test indicate the following:

- If the pat cannot be broken nor powdered by finger pressure, it is very highly plastic soil (CH).
- If the pat can be broken with great effort, but do not powder, it is highly plastic soil (CH).
- If the pat can be broken and powdered with some effort, it is medium-plastic soil (CL).
- If the pat breaks easily and powders readily, it is slightly plastic soil (ML, MH, or CL).
- If the pat has little or no dry strength and crumbles or powders when picked up, it is non-plastic soil (ML or MH) or (OL or OH).

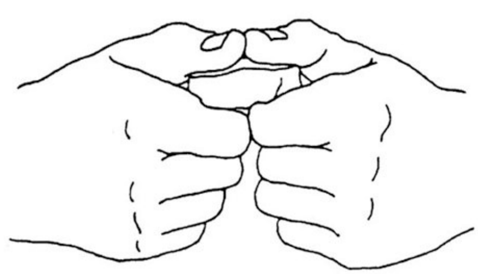


Figure 2–34. Breaking or dry-strength test.

Ribbon test

The ribbon test only works in material passing the No. 40 sieve. Moistening the sample to the point where it sticks together but is not sticky, then trying to form a ribbon, can determine several properties (fig. 2–35):

- If the sample holds together for a length of 8 to 10 inches without breaking, it is considered to be plastic having a high LL (CH).
- If the soil can be ribboned with difficulty to only 3 to 8 inches, it is low plasticity (CL).
- If the coil does not ribbon, it is non-plastic (ML or MH).

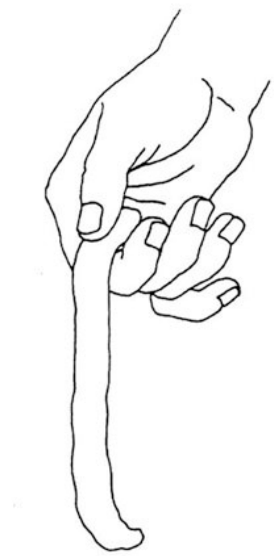


Figure 2–35. Ribbon test.

Shine test

The shine test measures a soil's plasticity. A slightly moist or dry piece of highly plastic clay (CH) produces a definite shine when rubbed with a fingernail or a smooth, metal surface like a knife. Lean clay remains dull after the treatment (CL).

Hasty assessment

The following test procedures produce observations that pertain to the USCS and permit field identification as well as classification (figs. 2–36 and 2–37). The purpose of these tests is to get the best possible identification in the field. If a simple visual examination will define the soil type, only one or two of the other tests will verify the identification.

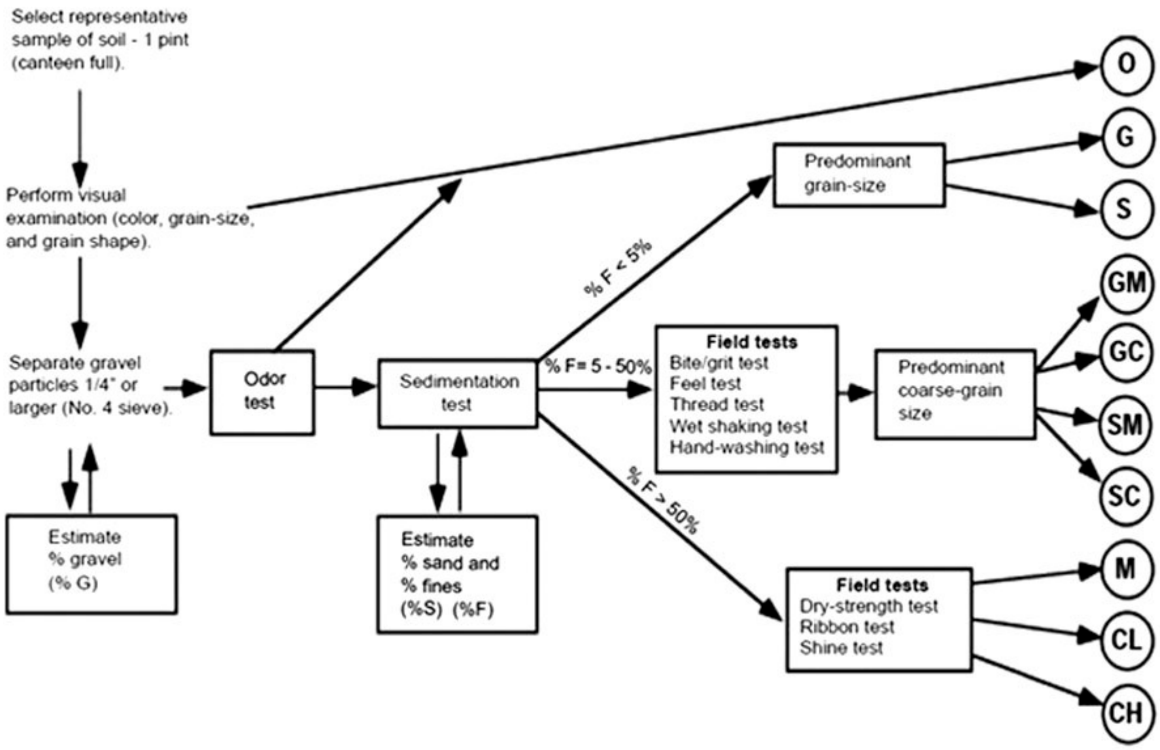


Figure 2–36. Hasty field identification chart.

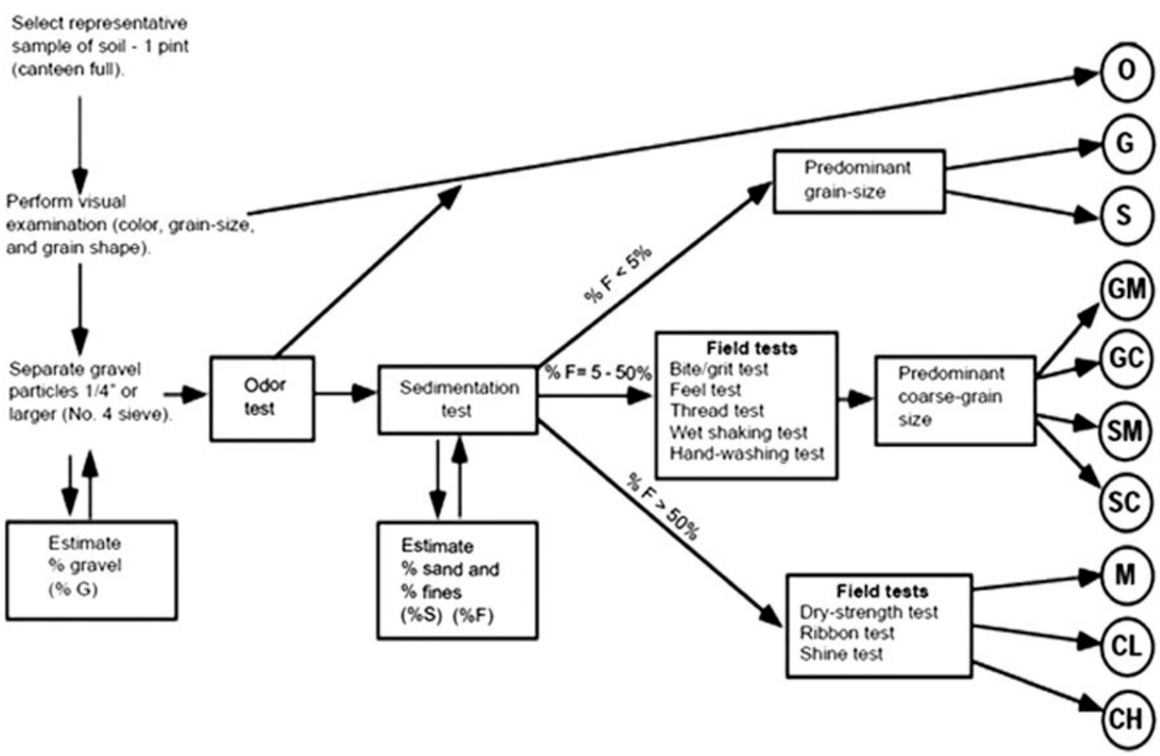


Figure 2–37. Hasty field identification procedures.

417. Interpreting material test reports

We divide the skills in our Air Force specialty code (AFSC) into drafting, surveying, geographic information system (GIS), and project management. Let us further divide project management between construction and material tests. Most of the elements you will inspect during the course of a contract will be construction, such as framing, electrical installation, plumbing, HVAC, and so forth. No less important, and at times more so, are materials tests. The majority of materials testing involves three types of material—soil, asphalt, and concrete. You do not need to be an expert in the performance of testing; however, you do need to know how to reference test procedures and read the test reports. Through this lesson keep in mind that the range of acceptable results is located in the specifications of the project or explained by the project engineer.

Laboratory soil analysis

When planning a major construction project where the load bearing capacity of the soil needs to be exact, there is no substitute for laboratory analysis. Other times, when a native soil is inadequate to support a desired load, we engineer subbase and base course soils for a specific purpose. While few EAs perform laboratory analysis, many review reports, collaborate on engineering requirements, and provide detailed analysis of existing or engineered materials. The primary tests conducted are moisture content, laboratory California Bearing Ratio (CBR), Atterberg limit test, proctor tests, density, and hydrometer tests.

Moisture content

In engineered soils, it is important to know what percentage of water can be present before a soil fails. The term moisture content defines the amount of water present in a soil sample. It is the proportion of the weight of water to the weight of the soil expressed as a percentage. With many soils, close control of moisture content during compaction by rolling is necessary to develop required density and soil strength.

In the laboratory, there are several ways of determining the moisture content of soils. These include the oven-dry method, the microwave-oven method, calcium-carbide-gas pressure method, and the nuclear-moisture-and-density-gauge method. Each of these is increasingly complex and efficient methods of removing moisture from a sample. The most common of these is the oven-dry method. ASTM D2216, a manual purchased through your unit, governs the procedures for the oven-dry method. Generally, the following is the formula that determines the percentage of moisture content:

$$w = (W_W / W_S) \times 100$$

Where:

w = the amount of water in a sample expressed as a percentage.

W_W = the mass of the water (the original sample (W1) minus the solid materials and its container (W2)).

W_S = the mass of original sample, without the weight of the container, after the sample is dried.

To do this test, we weight the sample before and after drying. The difference between the two is the weight of the water (*Ww*). Dividing the weight of the water by the weight of the solids (*Ws*) and multiplying by 100 gives you the percent of moisture in the original sample.

For example, if a soil sample with an original weight (*W1*) of 52 grams (without the weight of the container) and a dry weight (*W2*) of 36.2 grams (without the weight of the container), you determine the moisture content by calculating the weight of water in the soil sample (W_W) as follows:

$W_W = (W1 - W2) = (52 - 36.2) = 15.8$

$W_S = (W2) = 36.2$

Now, you have all the information to use in the percentage of moisture content formula shown above. For this example, you calculate the moisture content of the soil sample as follows:

$$w = (15.8 / 36.2) \times 100$$

$$w = 43.7\%$$

Laboratory CBR

The CBR measures the soil's shearing resistance (fig. 2–38). A field CBR reading with a Dynamic Cone Penetrometer (DCP) gives accurate information. A laboratory test measures the soil's shearing resistance under controlled moisture and density conditions. The CBR for soils is the ratio obtained by dividing the penetration stress required to cause a 3-inch piston to penetrate 0.10 inch into the soil with known compaction and moisture by a standard penetration stress of 1,000 psi. ASTM D1883 explains the required procedure and articulation of test results. Explanation of AF procedures and uses during contingency operations are in another volume of career development courses (CDC).

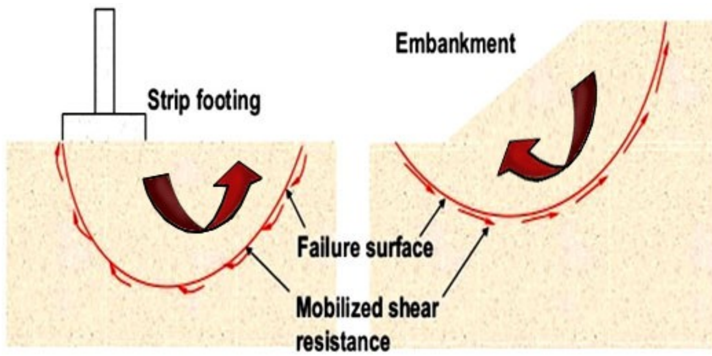


Figure 2–38. Soil shear failure surfaces.

Atterberg limit test

Atterberg was a Swedish scientist who defined plasticity and liquid limits within soil samples. The Atterberg limit test is a measure of the critical water contents of fine-grained soil. The critical water content affects the LL and PL. Laboratory testing for the LL and PL are essentially the same as the roll test and wet shaking test in the field but in controlled conditions. ASTM D4318 provides detailed information on procedures and report requirements.

The PL is the moisture content where the thread breaks apart at a diameter of 1/8 inch. Once the sample breaks at that diameter, we weigh, dry, and weigh again to determine the moisture content at which it broke.

A laboratory technician can determine the LL of a sample by using a device called the Casagrande cup (fig. 2–39). This cup allows a tester to use a special tool and create a gap of known distance (13.5 millimeters (mm)) between two halves of a material sample. Then, we lift the cup and drop it a known distance (10 mm), at a known rate (120 blows per minute) by turning the handle. Using this test, we find LL as the moisture content at which the gap closes at 25 drops of the cup.

Figure 2–39. Casagrande cup for the liquid limit test.

Proctor/modified proctor tests

The proctor compaction test is a method to determine the optimal moisture content at which a given soil type will achieve its maximum dry density. The test consists of compacting soil at known moisture content into a cylindrical mold of standard dimensions using a compactive effort of controlled magnitude. The soil is compacted into the mold to a certain amount of equal layers, each receiving a number of blows from a standard weighted hammer at a specified height. We repeat the process for various moisture contents and the dry densities are determined for each. We, then, plot the dry density to moisture content to establish the compaction curve. Finally, we obtain the maximum dry density from the peak point of the compaction curve, or the best compaction, and its corresponding moisture content, also known as the *optimal* moisture content. See figure 2–40 for an example of a proctor mold, hammer, and test. ASTM D1557 contains details on execution and reporting of the test under modified effort and ASTM D698 contains test procedures using standard effort.

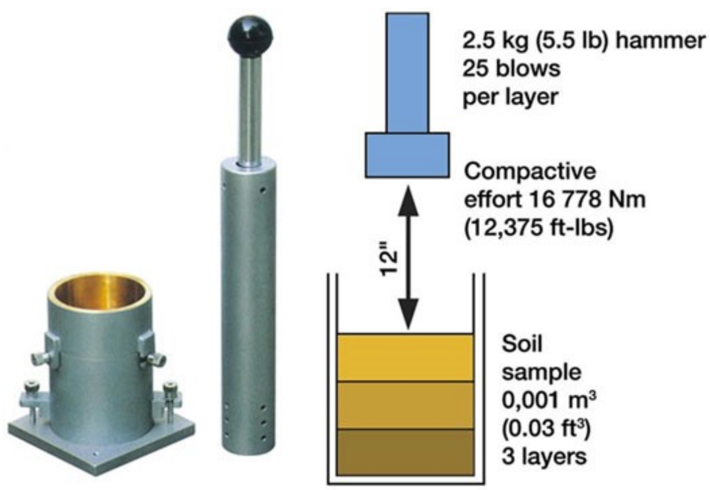


Figure 2–40. Proctor test, mold and hammer.

Density and unit weight by sand cone method

Testing professionals utilize the sand cone test to determine the water content and the in-place soil density of compacted soils. This is important when, for example, constructing an asphalt road. The compacted soil underneath the asphalt transfers the weight of vehicles to the soils below it. In construction inspection, the basis of acceptance is usually the sand cone test. The specifications will dictate the specifics of the results of the test. Testing contractors and project engineers depend on ASTM D1556 for testing instructions.

To start the sand cone test a hole is hand excavated in the soil to be tested and the tester places all the material from the hole in a container. The tester then fills the hole with free flowing sand of a known density, and the volume to calculate the volume (fig. 2–41). The in-place wet density of the soil is determined by dividing the wet mass of the removed material by the volume of the hole. The water content of the material from the hole is determined and the dry mass of the material and the tester calculates in-place dry density using the wet mass of the soil, the water content, and the volume of the hole.

Figure 2–41. Sand cone apparatus and container.

Pavement types

When driving a car on a road, it is easy to think that the pavement holds the load of the car. However, this is not the whole truth. While the pavement does bear some of the load, the material underneath it is far more important. Engineers design roads using a system of materials that distribute loads over larger areas. Distributing a load prevents any one point from holding the entire weight of a vehicle. In some cases, the subsurface material could be adequate to support a load—military aircraft frequently land on unpaved surfaces. Pavement, in addition to some load bearing capacity, adds durability, sustainability, traction, and debris reduction. Pavement types are broken into two categories—flexible and rigid.

Flexible pavement

Asphalt concrete (AC), sometimes referred to as Asphalt Cement Concrete (ACC) or simply asphalt, is referred to as flexible because it can respond to minor changes in the subsurface material. These materials may expand or contract based on their water content or ambient temperature or several other factors. Loads applied to AC distribute out in a triangle shape to supporting materials (fig. 2–42).

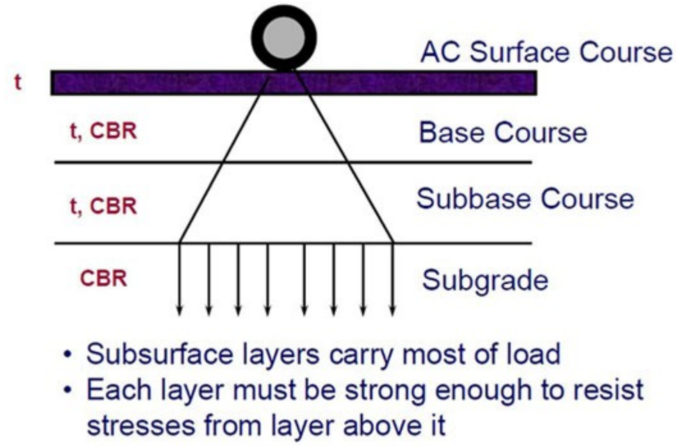


Figure 2–42. AC load distribution.

Rigid pavement

Portland cement concrete (PCC), usually referred to simply as concrete, is a rigid pavement (fig. 2–43). Even though rigid pavements offer very little flexural ability, subsurface materials can move based on moisture content and weather variations. Rigid pavements also expand and contract based on weather variations. This is why we design concrete in squares, or slabs. Slabs allow the overall paved surface to flex and the PCC to expand and contract according to temperature changes. Regardless of the behavior of the subsurface materials, unless there is damage to a concrete slap, it maintains its shape. Sealing gaps is critical. Runoff from precipitation can damage the subsurface material and cause the slabs to crack prematurely. Adding reinforcement to concrete makes it stronger. We design networks of steel rebar or rods to reinforce it. Because of its rigidity, loads applied to concrete slab distributed evenly over the entire subsurface layers.

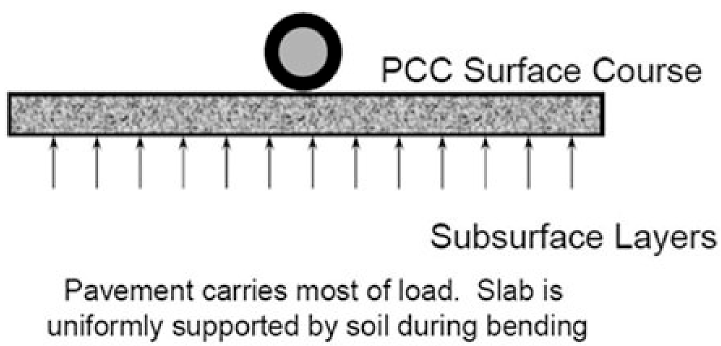


Figure 2–43. Rigid pavement.

Asphalt material testing

Asphalt concrete, also called blacktop, asphalt, or simply pavement, is a combination of two or more materials. The first is the aggregate or rocks and fines that make up the bulk of the material. The other part is the asphalt binder or bitumen. Bitumen is a sticky, black, and highly viscous liquid produced as a byproduct of the oil refinement.

At high temperatures, between 270°F and 325°F, the bitumen is highly viscous and completely coats the aggregate. When laid on the prepared surface and compacted, bitumen cools and hardens, binding together the aggregate and maintaining its compaction.

Marshall Stability mix design

AC is an engineered material and used in many environments for many purposes. An asphalt mix designed for a sidewalk in Miami, Florida, will be different from a mix designed for a runway in Minot, North Dakota. The differences will be the amount of bitumen, the size of aggregate, the required compaction, and other variables. Getting the amount of binder or bitumen correct requires careful attention. Too much binder in Miami will make a sticky, soupy sidewalk. Not enough binder in Minot will produce a runway that crumbles to pieces in sub-freezing temperatures. To determine the optimum binder content (OBC), engineers use the Marshall Stability mix design. Marshall Test specific procedures and intended results are contained within ASTM D6926

Paving projects routinely use The Marshall Test. The stability of an AC mix is determined by evaluating the maximum load carried by a compacted specimen at a standard test temperature of 60°C. This temperature allows the bitumen to flow. Flow is the deformation in units of 0.25mm between no load and maximum load carried. The test attempts to determine the OBC for the aggregate mix type and the intended traffic intensity.

Figure 2–44 shows the standard equipment needed to conduct the test. First, the tester mixes a sample of the AC mix design (aggregate and bitumen), and heats it to 60°C. The mixed material then goes into a mold for compaction. A slide hammer, similar to the one used in the DCP, dropped a set distance and a set number of blows, achieves optimum compaction. The compacted sample then cools for a few hours and, then, put into a press. The press slowly applies the design load to the sample. The amount of deformation of the sample determines whether the design can support the intended traffic load, as well as its flow.

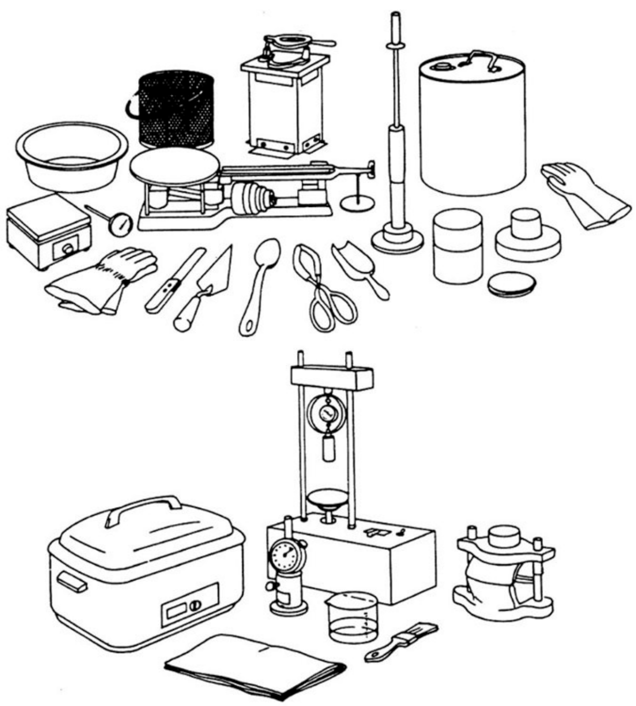


Figure 2–44. Marshall Stability test equipment.

Asphalt determination

It is sometimes necessary to determine the amount of asphalt in an AC mix design, sometimes called hot mix asphalt (HMA). The reasons could include quality control, specification acceptance, or forensic evaluations. While engineering will likely not accomplish these tests directly, it is important to understand the process.

There are several methods used to determine HMA binder content. The two most common are the *ignition method* and the *solvent extraction method*. The before and after masses are then compared to determine asphalt binder content. These methods also produce aggregate on which a sufficient for gradation tests.

Ignition method

The ignition method of determining asphalt binder content allows for the asphalt binder in an HMA sample to burn off in an oven at temperatures above the flame point of the binder.

Solvent extraction method

Solvent extraction methods (described in AASHTO T 164 and ASTM D 2172) use a solvent to remove asphalt binder from aggregate in an HMA mixture.

Specific gravity

The surface of the aggregate used in HMA is porous. Pores allow the aggregate to absorb both water and asphalt. Although asphalt plants make every effort to be sure aggregate is dry before mixing it with binder, some moisture remains. The ratio of water to asphalt absorption varies with each aggregate.

After compaction, HMA still has voids, or empty spaces between pieces of aggregate. These voids in the mineral aggregate (VMA) may be filled with voids in asphalt (VFA) or voids with air (V_a) (fig. 2–45). The combination of VFA and V_a determine the effective asphalt content (permeable void [P_{be}]). The effective asphalt content provides a good indication of the mixtures probable pavement service performance.

With so many variables—air voids, water absorption, effective asphalt content—the actual volume of a sample of HMA can vary depending on temperature. Specific gravity tests are useful in making volume corrections based on temperature. The two types of specific gravity tests are bulk and theoretical. More information on determining specific gravity is located in ASTM D2726.

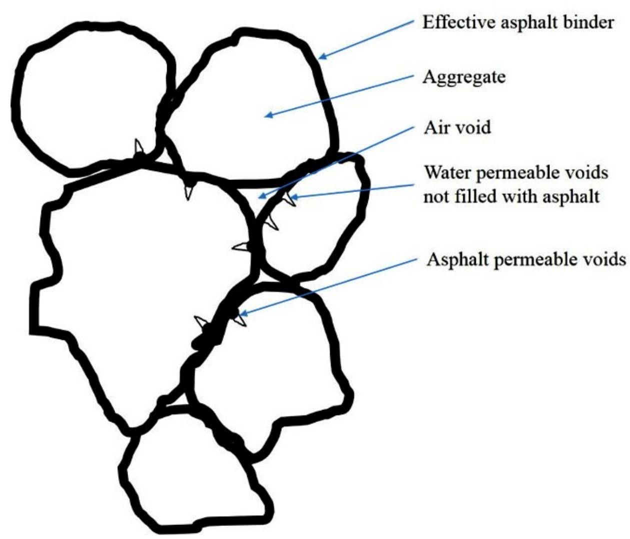


Figure 2–45. Spaces between compacted aggregate.

Bulk

The bulk specific gravity test is part of calculating the specific gravity of a compacted HMA sample by determining the ratio of its weight to the weight of an equal volume of water. The bulk specific gravity test measures a HMA sample's weight under three different conditions:

1. Dry (no water in the sample).
2. Saturated surface dry (SSD) where water fills the HMA air voids.
3. Submerged in water or underwater.

Using these three weights and their relationships testers calculate, a sample's apparent specific gravity, bulk specific gravity, bulk SSD specific gravity, and absorption.

Theoretical

The theoretical maximum specific gravity of a HMA mixture is the specific gravity excluding air voids. Theoretically, if we eliminate all the air voids from and HMA sample, the combined specific gravity of the remaining aggregate and asphalt binder would the theoretical maximum specific gravity. Theoretical maximum specific gravity multiplied by the density of water gives the value for theoretical maximum density.

Theoretical maximum specific gravity is a critical HMA characteristic because it is part of the calculation for percent air voids in compacted HMA. Calculate the percentage of air voids by taking a sample of loose HMA (not compacted), weighing it, and then determining its volume by calculating the volume of water it displaces. Theoretical maximum specific gravity is then the sample weight divided by its volume.

Concrete assessment

Portland cement concrete is a mixture of fine and coarse aggregates, Portland cement, and water. Portland cement gets its name because from the limestone in an area of England called Portland. For this reason, we sometimes refer to it as Portland cement concrete, concrete, PCC, or PC. The cement and water chemically react to form microscopic crystals that hold aggregates in a strong, rock-like mass. We call this process hydration, which gives PCC its strength. Manufacture of concrete happens in mixing plants, field mixtures, or truck mixers near or at the construction site. The quality of the concrete produced depends on the proper mix design to achieve the desired workability of the fresh concrete and the strength of the hardened material.

There are a few basic tests to ensure the proper quality of concrete for the project. These tests check the temperature, slump, air content, and air compressive.

Temperature

The process of concrete curing, or drying, is hydration. Hydration is different from evaporation. While some evaporation does happen, the chemical process provides the strength. In the first few hours of hydration, the strength of the concrete increases dramatically. Within 24 hours, most concrete has cured enough for use. The hydration process can continue for several years. The ideal temperature range for hydration is between 68° and 86°F with 73.4° the most favorable. If the temperature drops below 40°F, hydration virtually stops. Temperatures above 86°F cause hydration and evaporation to happen too quickly and the finished concrete will not achieve full strength. The governing ASTM for this procedure is ASTM C1064.

Slump test

Moisture content in concrete may vary depending on the purpose of the project. Some mixes require more moisture for better workability. Some require less so they can cure more quickly. Regardless of the use, hydration takes place best within a certain range. The slump test gives a very good indication of how much moisture is in a concrete sample.

Figure 2–46 shows the equipment required for a slump test: a tray, a funnel, a rod, and the slump cone. With the slump cone on the tray, large side down, a random sample of concrete is put in through the smaller opening; use the funnel to retain as much of the sample as possible. Use the rod after each scoop of concrete to remove any entrapped air bubbles. Once the cone is full, remove it and set it aside. The slump is the difference between the top of the slump cone and the top of the freestanding concrete sample (fig. 2–47). A true slump indicates the ideal moisture content. Specifications for a certain project will tell the desired slump which is generally in the range of two to four inches. Zero slump indicates too little moisture. A collapsed slump indicates too much moisture. A shear slump indicates poor mixing or material continuity within the sample (fig. 2–48). ASTM C143 contains complete procedures and requirements for completion of slump tests.

Figure 2–46. Slump test equipment.

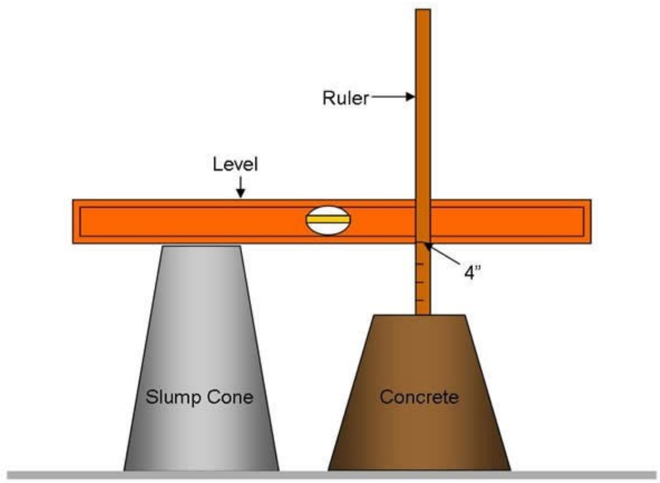


Figure 2–47. Slump test measurement.

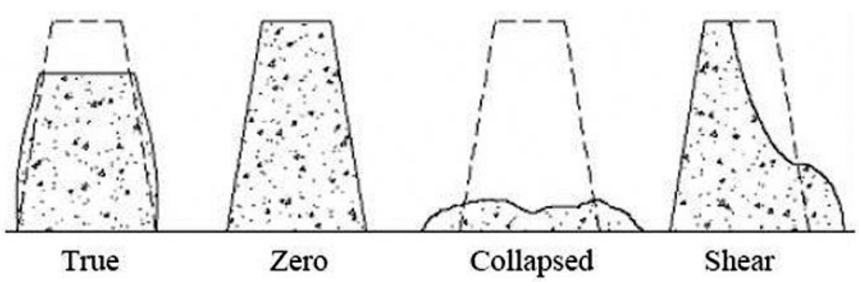


Figure 2–48. Slump test results.

Air content by pressure method

Entrained air is different from entrapped air. Entrapped air is large pockets of air introduced during the placement process. Entrapped air makes the concrete weaker and prevented by vibrating the in-place concrete. Entrained air in concrete is small bubbles, perhaps billions of air cells per cubic foot. These air pockets relieve internal pressure on the concrete by providing tiny chambers for water to expand into when it freezes. Air-entrained concrete is produced using air-entraining Portland cement, or by the introduction of air-entraining agents, under careful engineering supervision. The amount of air is usually between four and seven percent of the volume of the concrete. Entrained air improves a mixture's workability, durability, water tightness, and freeze-thaw resistance.

The concrete air pressure meter (fig. 2–49) measures the amount of air in a sample. It does this by compressing the concrete sample under air pressure. Since the entrained air within the sample is the only compressible ingredient of the concrete mix, this gives a good indication of the amount of entrained air.

To perform the test, fill the bucket with concrete to the top and tap the side with a rubber mallet to remove any entrapped air. With the lid secured in place, pressurize the upper chamber using the pump handle. This creates a known volume of air at a known pressure. The pressure release lever passes the air into the concrete bucket. The pressure gauge is set so the reading is the percent of entrained air. ASTM C231 describes details on air content by pressure procedures.

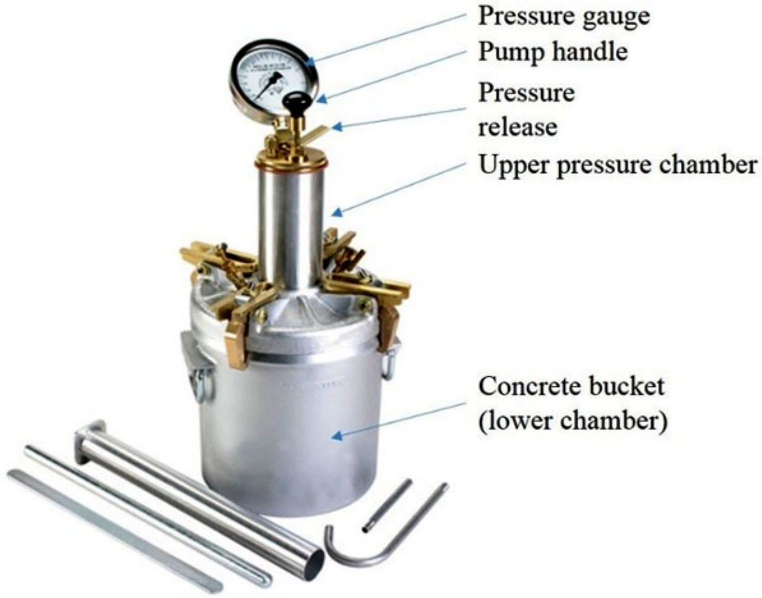


Figure 2–49. Concrete air pressure meter.

Compressive and flexural strength tests

We also need cured concrete to be tested. Since concrete may be subject to different kinds of loads, it has to be tested for flexural (fig. 2–50) as well as compressive (fig. 2–51) strength. It is not practical to test concrete's strength once placed and cured so samples must be prepared for lab tests.

Concrete beam molds, for flexural strength, have dimension of 6 × 6 × 21 inches. Molds for concrete cylinders most commonly are 6 inches in diameter and 12 inches long. These samples cure at the construction site to provide the most accurate comparison with the constructed concrete for the project. Procedures for obtaining samples of concrete on site are located in ASTM C31. It is useful from time to time to test concrete under ideal environmental conditions. Procedures for accomplishing this are found in ASTM C192.

Testers perform compressive strength tests at seven and 28 days cure time. Testers perform flexural strength tests at 14 and 28 days cure time. The test results represent the average strength so testers take two samples of each type. ASTMs C39 and C78 contain instructions for completing these tests.

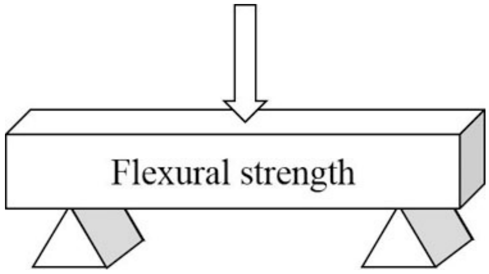


Figure 2–50. Concrete flexural strength.

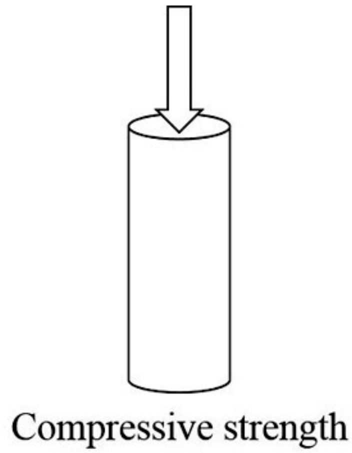


Figure 2–51. Concrete compressive strength.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

415. Soil properties and classification

1. List the soil groups defined by grain size.

2. What document dictates the minimum required information to be on a sieve analysis report?

3. What soil size group pass through the three-inch sieve but retained on the 3/4 inch sieve?

4. What are the five soil grain shapes?

5. Explain the difference between uniformly graded particles and gap-graded particles.

6. Define “plasticity.”

7. What formula do we use to calculate the plasticity index (PI)?

8. What do the soil identification symbols SW, MH, and ML stand for?

416. Identifying soils in the field

1. How do we make the odor test more effective or stronger?

2. When performing the grit test, what do clayey soils feel like?

3. What does it mean if a sample breaks before reaching 1/8-inch thread size during the roll test?

4. How do we tell a sample is slightly plastic when performing the dry-strength test?

5. What characteristic does the shine test measure?

417. Interpreting material test reports

1. Define the variables of the moisture content formula: $w = (Ww / Ws) \times 100$.

2. What two field tests measure essentially the same thing as the Atterberg limit test?

3. What are the two ASTM guides that govern the proctor test?

4. For what test does ASTM D1556 provide instructions?

5. What are the two primary components that make up asphalt?

6. Name the two types of specific gravity tests.

7. List the basic elements in concrete mixture.

8. Which ASTMs are associated with temperature, workability, and air content of concrete?

Answers to Self-Test Questions

407

1. After technical reviews and negotiations between the contractor and the contracting officer are complete.
2. Any construction, development, conversion, or extension of any kind carried out with respect to a military installation.
3. O&M.

408

1. (1) The unit of measure.
   (2) Its cost per unit.
2. A document from the government to the contractor ordering the completion of work under an existing IDIQ contract.
3. WORB.
4. SABER contracts have one contractor while MACCs have three or more.

409

1. (1) Introduction.
   (2) Scope of work.
   (3) Period of performance.
   (4) Place of performance.
   (5) Work requirements.
   (6) Schedule/milestones.
   (7) Acceptance criteria.
   (8) Other requirements.
2. Other requirements.

410

1. Facility managers (or other customers), for construction work required on a building.
2. Specifications contain all the technical information about each component or system in a project.
3. Project engineer.

411

1. 04 01 00.91
2. UFC 1–300–02, *Unified Facilities Guide Specifications (UFGS) Standard*.

412

1. (1) Preliminary.
   (2) Detailed.
   (3) Activity.
   (4) Equipment.
   (5) Labor.
   (6) Material.
2. Direct labor constructs the facility while indirect labor is administration and management.

413

1. (1) Contract Progress Report.
   (2) Contract Progress Schedule.
2. AF IMT 1477, Construction Inspection Record.
3. (1) Time of inspector's visit to site.
   (2) Work force – contractor and sub-contractor.

   (3) Materials delivered to job site.
   (4) Contractor equipment on hand.
   (5) Work accomplished or in progress – tests performed.
4. Incomplete items of work.
5. Users, fire protection flight, and maintenance personnel.
6. Two copies; one to the real property office and the other filed in the project folder.

414

1. McNamara-O-Hara SCA and the DBA.
2. (1) General provisions.
   (2) Gratuities.
   (3) Relationships.
   (4) Ratification.
3. The act of approving unauthorized commitments by one without the authority to do so.

415

1. (1) Cobbles.
   (2) Gravels.
   (3) Sands.
   (4) Fines.
2. ASTM C136, section 10.
3. Coarse gravels.
4. (1) Angular.
   (2) Subangular.
   (3) Subrounded.
   (4) Rounded.
   (5) Platy.
5. Uniformly graded particles all have the same size, while gap-graded particles are missing sizes.
6. A soil’s ability to deform without cracking and breaking.
7. PI = LL - PL
8. SW: Well-graded sand, fine to coarse sand, MH: silt of high plasticity, fat clay, ML: silt.

416

1. By warming a wet sample to make the odor stronger.
2. Smooth and powdery between the teeth.
3. The sample has low plasticity.
4. The pat breaks easily and powders readily.
5. Plasticity.

417

1. w = the amount of water in a sample expressed as a percentage, Ww = the mass of the water minus the solid materials and its container, Ws = the mass of original sample, without the weight of the container, after the sample is dried.
2. The roll and wet shaking tests.
3. ASTM D1557 and ASTM D698.
4. Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.
5. Aggregate and bitumen.
6. Bulk and theoretical.
7. Fine and coarse aggregates, Portland cement, and water.

8. ASTMs C1064, C143, and C231.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

13. (407) When does a construction inspector begin recording construction progress data?
    a. During design review.
    b. As soon as project awards.
    c. At request of using agency.
    d. Before pre-construction meeting.

14. (407) Which document contains the start date and duration/performance period of the contract?
    a. Air Force Form 103.
    b. Construction permit.
    c. Notice to proceed.
    d. Build authority.

15. (407) What document does the base civil engineer (BCE) use to clear execution of work on an Air Force base?
    a. Air Force Form 103.
    b. Construction permit.
    c. Notice to proceed.
    d. Build authority.

16. (408) Which contract type allows the base civil engineer (BCE) to have a construction contractor already under contract?
    a. Indefinite delivery indefinite quantity (IDIQ).
    b. Operations and maintenance (O&M).
    c. Simplified Acquisition of Base Engineer Requirements (SABER).
    d. Military construction (MILCON).

17. (408) What does the Army call their Simplified Acquisition of Base Engineer Requirements (SABER) style system?
    a. SABER.
    b. Job order contracts (JOC).
    c. Military construction (MILCON).
    d. Operations and maintenance (O&M).

18. (408) Who decides if a project goes competitive bid, indefinite delivery indefinite quantity (IDIQ), or Simplified Acquisition of Base Engineer Requirements (SABER)?
    a. Contracting officer.
    b. Base civil engineer.
    c. Engineering flight chief.
    d. United States Army Corps of Engineers.

19. (409) Which part of the Statement of Work provides a detailed statement of what we expect to be done during the project?
    a. Scope of work.
    b. Work requirements.
    c. Schedule/milestones.
    d. Period of performance.

20. (409) Where in the statement of work are the quality expectations and team descriptions?
    a. Scope of work.
    b. Work requirements.
    c. Schedule/milestones.
    d. Period of performance.

21. (410) Who usually fills out and submits the Air Force Form 332?
    a. Facility manager.
    b. Unit commander.
    c. Engineering flight chief.
    d. Installation commander.

22. (410) Who approves the Department of Defense (DD) Form 1391?
    a. Unit commander.
    b. Group commander.
    c. Installation commander.
    d. Major command (MAJCOM) commander.

23. (410) When receiving an Air Force (AF) Form 3000 from a contractor, which of these do you *NOT* do?
    a. Compare material on form to what is on site.
    b. Compare what is on site to specifications.
    c. Submit it to contracting for review.
    d. Record submittal on AF Form 66.

24. (411) Which specifications format does the Department of Defense (DOD) use instead of the Construction Specifications Institute (CSI) MasterFormat?
    a. Federal Construction Guide (FCG).
    b. Military Construction Specifications (MCS).
    c. Defense Master Specifications Guide (DMSG).
    d. Unified Facilities Guide Specifications (UFGS).

25. (411) In which Unified Facilities Guide Specifications (UFGS) division would you find fire suppression categories?
    a. 16.
    b. 21.
    c. 28.
    d. 34.

26. (412) What is your main source of information when creating a bill of materials (BOM)?
    a. Contractor.
    b. Specifications.
    c. Project engineer.
    d. Construction drawings.

27. (412) Which government handbook gives detailed instructions for properly completing government estimates?
    a. United Facilities Criteria (UFC) 3–744–01, *Guide: Construction Estimates*.
    b. Air Force Instruction (AFI) 32–3401, *Air Force Construction Cost Estimating*.
    c. UFC 3–740–05, *Handbook: Construction Cost Estimating*.
    d. Air Force Handbook (AFH) 36–2201, *Estimating Air Force Construction Projects*.

28. (413) Which tool allows contractors to divide a project into work elements over a given period?
    a. Munitions authorization record.
    b. Contractor reliability waiver.
    c. Contract progress schedule.
    d. Construction inspection report.

29. (413) What tool does base contracting use to authorize release of payment to the contractor for a period of performance?
    a. Munitions authorization record.
    b. Contract progress report.
    c. Contractor reliability waiver.
    d. Construction inspection report.

30. (413) What Air Force Information Management Tool (AF IMT), completed by the construction inspector, is used to prove or disprove contractor performance?
    a. AF IMT 68.
    b. AF IMT 600.
    c. AF IMT 601.
    d. AF IMT 1477.

31. (413) Which form provides an accurate accounting of the changes made to each system after construction completion?
    a. Air Force Information Management Tool (AF IMT) 3065.
    b. Department of Defense (DD) Form 1354.
    c. Standard Form (SF) 30.
    d. AF Form 3000.

32. (414) What guides government employees and defines limitations and areas of responsibility for all parties involved in a contract?
    a. Code of Conduct.
    b. Davis-Bacon Act (DBA).
    c. National Ethics Code (NEC).
    d. Federal Acquisition Regulation (FAR).

33. (414) Which component of the Federal Acquisition Regulation (FAR) provides guidance on the solicitation or acceptance of gifts or favors from contractors?
    a. Gratuities.
    b. Ratification.
    c. Relationships.
    d. General provisions.

34. (415) What system is used to classify soils based on the size of individual particles?
    a. Soil Classifications Library (SCL).
    b. Joint Engineering Soils Directory (JESD).
    c. Unified Soils Classification System (USCS).
    d. Combined Soils Categorization System (CSCS).

35. (415) When sieve sizes have openings smaller than 1/4 inch, how are they identified?
    a. Gauge of wire.
    b. Size of opening in inches.
    c. Total size of sieves in stack.
    d. Number of openings per inch.

36. (415) What is the name of the bulky soil subdivision most often found near streambeds or beaches?
    a. Angular.
    b. Rounded.
    c. Subangular.
    d. Subrounded.

37. (415) What quality of gradation is a soil with a good range of all particle sizes between the largest and smallest for that sample?
    a. Gap.
    b. Well.
    c. Open.
    d. Poorly.

38. (415) What factor has varying effects on the cohesion of soil?
    a. Gradation.
    b. Moisture.
    c. Sands.
    d. Heat.

39. (415) What do we call the moisture content at which a soil stops being rigid and becomes moldable?
    a. Liquid Limit.
    b. Organic Tier.
    c. Plastic Limit.
    d. Plastic Index.

40. (415) Which name do we refer to soils passing the number 200 sieve?
    a. Fines.
    b. Clays.
    c. Sands.
    d. Gravels.

41. (416) Which test compares the level of material settled at the bottom of a water-filled jar?
    a. Feel.
    b. Odor.
    c. Wet shaking.
    d. Sedimentation.

42. (416) What does the soil sample roll test measure?
    a. Plasticity.
    b. Gradation.
    c. Liquid limit.
    d. Moisture content.

43. (416) Performed on materials passing the number 40 sieve, which test helps determine whether a soil is clayey (C) or silty (M)?
    a. Odor.
    b. Ribbon.
    c. Bite-grit.
    d. Dry-strength.

44. (416) When conducting the shine test, a definite shine indicates what type of clay?
    a. Lean.
    b. Organic.
    c. Low plasticity.
    d. Highly plastic.

45. (417) The equation, w = (Ww / Ws) x 100, used in conjunction with the oven-dry method, determines which soil characteristic?
    a. Gradation.
    b. Liquid limit.
    c. Plasticity index.
    d. Moisture content.

46. (417) What soil characteristic does the Dynamic Cone Penetrometer measure?
    a. Load bearing capacity.
    b. Compaction resistance.
    c. Soil shearing resistance.
    d. Maximum flexural strength.

47. (417) Which of these is *NOT* an element of an asphalt mix?
    a. Fines.
    b. Water.
    c. Rocks.
    d. Binder.

48. (417) Upon what factor is the volume of a given sample of asphalt most dependent?
    a. Fines.
    b. Rocks.
    c. Moisture.
    d. Temperature.

49. (417) Which of these is *NOT* a concrete test method?
    a. Slump.
    b. Marshall.
    c. Air content.
    d. Compressive.

Please read the unit menu for unit 3 and continue ➔

Unit 3. Introduction to Building Information Modeling

CONSTRUCTING NEW FACILITIES to meet mission needs is a core capability of civil engineering. Government agencies also have a responsibility to taxpayers to find the most efficient and cost-effective methods available. In this CDC, you will learn the future of civil engineering design and construction. In the civilian sector, and more often in government agencies, building information modeling (BIM) has become the industry standard. BIM is the next generation of capabilities to make civil engineering more efficient and cost effective as we move further into the 21st century.

3–1. Introduction to Building Information Modeling

According to the National BIM Standard, a BIM is a digital representation of physical and functional characteristics of a facility. It serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions from design to demolition. The BIM is a shared digital representation founded on open standards for interoperability. The digital representation shows, in detail, the physical and functional characteristics of the facility.

418. Building information modeling definition

BIM is an innovative approach to building design, construction, and management. It is essentially the intersection of two ideas:

- Keeping design information in digital form makes it easier to update and share, and more valuable to designers creating and using it.
- Creating real-time, consistent relationships between digital design data and parametric modeling can save significant amounts of time and money, and increase project productivity and quality.

Construction industry standards

Construction projects require coordination with several different types of organizations. Even a small project can involve five or more organizations and dozens of people. These include the user, contractors, engineers, construction management teams, and other outside organizations (fig. 3–1).

During the course of a project, all of these variables can create a lot of room for error. In every project, there will be miscommunication, misunderstood intentions, and design problems. These inefficiencies inevitably lead to longer and more costly construction time. In the worst case, these oversights can lead to costly and time-consuming lawsuits.

Many of the problems stem from the two-dimensional (2D)-based communication used during the design phase. By 2D-based communication, we are referring to the design drawings and associated documents that support them. Even though this has been the standard for construction, fully expressing design ideas of a three-dimensional (3D) object is very difficult when we use two dimensions (computer-aided drafting [CAD] drawings, prints, paperwork, etc.). It can be even more difficult to build accurate cost estimates, workloads, and bills of material.

As CAD technology developed, many companies tried using 3D CAD models to depict buildings. This helped by giving a better picture of the final building. Another benefit of constructing a building in 3D is that it shows places where phases of construction may conflict. For example, if the structural engineer and the mechanical engineer do not work closely together, a HVAC duct may end up where a support beam needs to be. In 2D models, this sort of discrepancy is often not found until well in to the building's construction, causing costly changes and lengthened timelines. Although 3D CAD models can alleviate these issues, they cannot solve all the problems caused by 2D models.

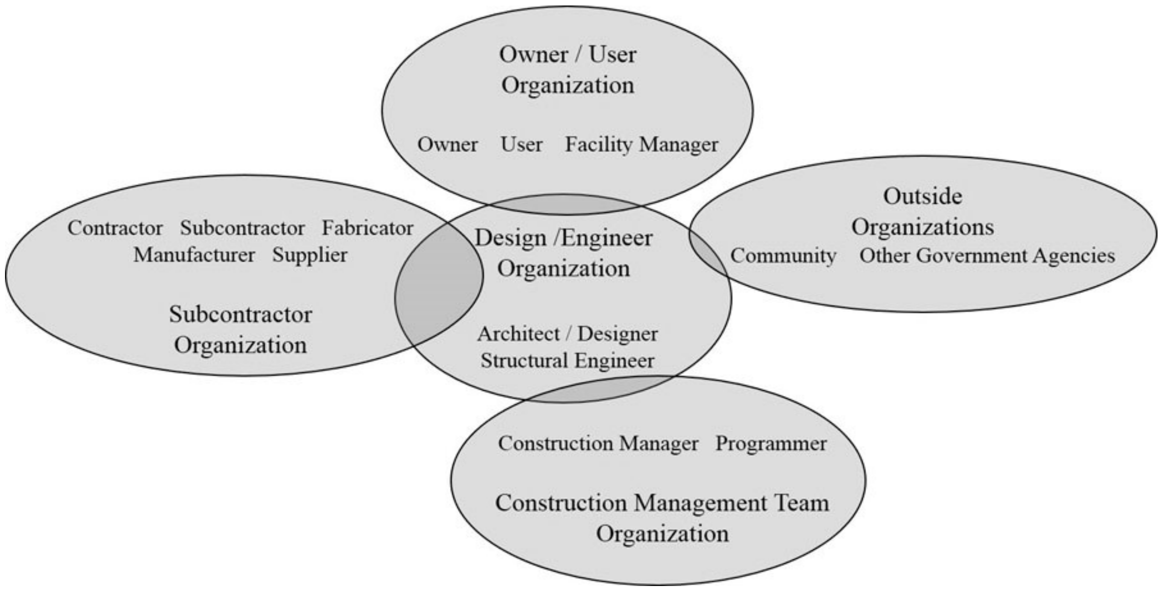


Figure 3–1. Current, loosely organized facility design process.

While a 3D model more accurately depicts a facility, there is no data associated with the facility's individual features. The 3D CAD model still requires a lot of 2D-based communication with all the parties involved to describe materials, dimensions, standards, and schedules.

Benefits of building information modeling

Ideas for BIM started to develop as early as the 1970s. However, the concept did not gain popularity until the early 2000s. Since then, as GIS and 3D CAD technologies have matured, BIM has moved from a cost-saving tool to an industry standard.

BIM combines the best features of GIS with the best of 2D and 3D CAD modeling. It does this by associating data within each feature of a facility. In GIS, if you select a water line, you can learn the material used, the year it was installed, how much water flows through it, where it connects, and much more. In BIM, each aspect of a building also has associated information. This way a user can select a window and know the dimensions, the manufacturer, the number of windows like it in the facility, and more.

As we will discuss later, BIM even introduces time, or four-dimensional (4D), by allowing designers to build a facility virtually according to the actual construction phases of the project. This simulation helps in the areas of preconstruction, design, construction, and post construction. If you have an Internet connection available, click (or copy and paste in a browser) the link below to see an animation of a 4D BIM under construction.

https://www.youtube.com/watch?v=d639sCo9kLw

In addition to data about the physical structure, many other aspects can be included (fig. 3–2). Within a BIM model, there can be legal, financial, geospatial, designer, occupier, and environmental data. As the facility progresses through its design and life cycle, all this data can be amended to reflect the most accurate and current conditions.

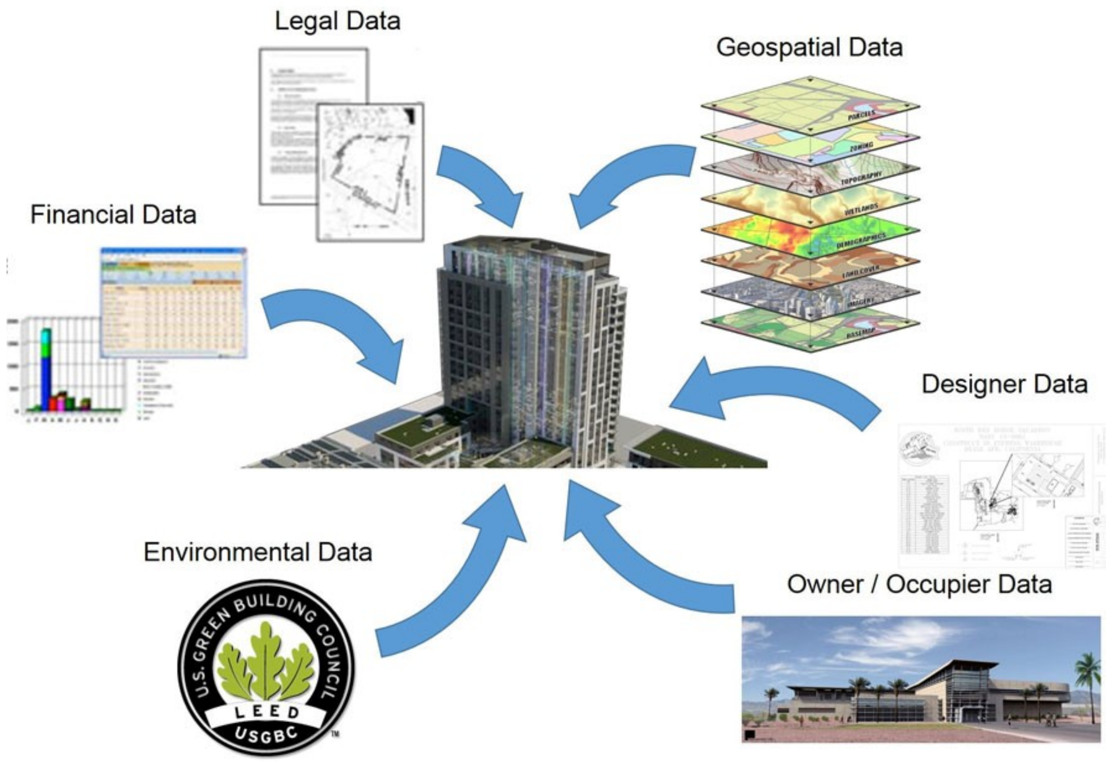


Figure 3–2. BIM and data management.

Preconstruction benefits

When a customer first submits a request for a facility, engineers consider several factors:

1. What are the budget constraints?
2. What is the facility's purpose?
3. How many people will use it?
4. Is there enough time and money?

BIM provides answers for these questions with relative certainty by creating an approximate, virtual building linked to a cost database. The cost database also helps develop cost estimates as the project develops rather than after the design is complete, and it takes almost all the guesswork out of the process.

A virtual building can also improve a building's performance and quality. This is because of an improved ability to evaluate the design's functionality and sustainability. Doing this early in the project allows ample time to consider design alternatives to maximize effectiveness and efficiency.

While the preconstruction phases are ongoing, different organizations can collaborate. As the virtual model is developing, the designer can get feedback from engineers, users, contractors, and manufacturers. Each organization can access the virtual model, see the costs as they develop, give input to the schedule, and have a much better understanding of the final project.

Design benefits

While a 3D model of a building is helpful, there are times when a 2D model is better. This is true when you need to work with simple floor plans, reflected ceiling plans, and other standard sheets in a drawing set. BIM software packages allow designers to construct the model in 3D and automatically produce traditional 2D floor plans and schedules. Developing these simultaneously significantly reduces the design time.

As the design develops, you can tie feature (window, door, railing, duct, etc.) data to a database. This way, changes apply instantly across the entire facility. For example, consider a building with four floors using a specific type of door in several places on different floors. In older design systems, each door on each drawing would need to be updated or annotated. Using BIM, only one door needs to be updated to change similar doors throughout the facility.

Since sustainability is paramount today, energy analysis in design is critical. When we link a building's design to an energy analysis tool, designers can understand and improve energy efficiency throughout the design process. If you have an Internet connection available, click the link below to see an animation of a BIM energy analysis.

Construction and fabrication benefits

Virtually building a building enhances the ability to prefabricate components off site. This can save a great deal of time and improve quality by assembling or specially manufacturing components in a controlled location. Structural steel, sheet metal, glasswork, and windows link to the virtual model allowing fabricators and manufacturers to more closely follow the design. The BIM model eliminates or reduces the need for onsite changes or reworking dimensions for specialty pieces and materials.

Fabricating materials off site can be time consuming. With BIM, you can incorporate construction phases into the model, which allows better planning for fabrication times. Using this capability allows better synchronization for delivery of raw materials, custom materials, and common materials to the work site.

Post-construction benefits

Obtaining as-built drawings from contractors has long been a major source of difficulty for the government. Once a project is paid for, there is often little incentive for a contractor to follow through with the delivery of the as-built drawings. For this reason, the drawing records for many government facilities are incomplete. In cases where the contractor has delivered as-built drawings, they were usually hard copies, on disks, or in whatever form the technology at the time called for. There are many government facilities with drawings available on old 3½-inch floppy disks! Now that information sharing technology has stabilized, a BIM model can remain as both a legacy and an active file. Future planners, maintainers, and facility managers easily access an active BIM file from multiple locations.

Other agencies

Agencies throughout the government are moving toward BIM. The United States Army Corps of Engineers (USACE) uses BIM to develop its entire centers of standardization (CoS) adapt-build program for over 40 facility types. USACE published a BIM Roadmap in October 2006 detailing their implementation plan.

The General Services Administration (GSA), through its Public Building Service (PBS) Office of Chief Architect (OCA), established the National 3D-4D-BIM Program. OCA has led dozens of projects in its capital program and is assessing and supporting 3D, 4D, and BIM applications in dozens of on-going projects across the nation.

Other federal entities require, or will soon require, BIM. This includes the Veterans Affairs (VA), Federal Aviation Administration (FAA), State Department, National Oceanic and Atmospheric

Administration (NOAA), United States Coast Guard, and many others as part of an ever-growing list. Several states also require BIM for future capital improvements.

419. Modeling concepts

CAD drafting is a fundamental skillset in the 3E5 career field. A lot of time is devoted to drafting various projects or working in GIS applications. What is not common is 3-D drafting, also called modeling. Since a key aspect of a BIM project is the virtual building, it is important to understand some principles of 3D modeling. Every time you sit down to work on a modeling project, these are the principles to keep in mind (fig. 3–3).

Figure 3–3. Realistic modeling of facilities within a believable environment.

Realism

A 3D model must consider realism. While there are limitations on the level of realism based on computer processing speed, time, and budget constraints, a model should be as realistic as possible. Part of the purpose of BIM is to create a model of a facility so that all parties involved have a meaningful representation for the finished product. Realism requires a modeler to consider botanical, geographical, structural, and mechanical relationships and references. Take some time to brainstorm these ideas and do a little research. Sketching ideas can help visualize how a facility would fit into existing surroundings.

Scale and proportion

When architects talk about scale and proportion, they are usually talking about how the individual parts of the project relate to each other, how the project relates to the size of the human body, and how the project relates to its contextual scale. A perceptually successful project is one that considers these three factors.

To ensure consistency, individual project components such as rooms, wall finishes, ceiling shapes and finishes, windows, doors, and so forth should have a compatible scale. This is especially true when working on a renovation or addition to an existing house. So often, we see renovations and additions that do not respect the scale of the original house. This results in a structure that is inconsistent and, as a result, uncomfortable. This does not mean that each room in your house should have the same ceiling height, size, and so forth. Variations in these elements are essential in creating a whole that is greater than the sum of its parts.

Architects understand that the starting point for our perception of something is the size of our own bodies. Whether or not a room is large or small or somewhere in between has a direct correlation to how we understand that room in relation to our size. Therefore, a room that is overly large, overly small, or oddly shaped can make us uncomfortable. A very tall, high-ceilinged, room that is small in area can make us feel as if we are in a pit.

There are proportional systems that can help an architect develop a design that to which the human figure is receptive. The most often used is the golden ratio. This proportional system is found in nature (most famously the Nautilus shell), and we are exposed to it every day when we turn on a light (the dimensions of the typical wall switch cover plate correspond to the golden ratio).

Volume

Any object in a 3D model can be broken down in to basic 3D shapes, or volumes. In 2D, these basic shapes are circles, rectangles, and triangles. In 3D modeling these, become spheres, boxes, cylinders, cones, and pyramids. Within a model, each shape has implied values described below.

Shape	Value
Sphere	Soft, round, friendly, global, sweeping, unbounded, non-directional.
Cube	Rigid, sturdy, objective, conservative, conventional, straight
Equilateral Pyramid	Angular, pointy, sharp, fast, aggressive, directional

Exaggeration

Exaggeration, within any CAD environment, is the ability to highlight or subdue aspects of a drawing. Even though a 2D drawing of a facility may have all the layers included in model space, each paper space view will have certain layers turned on or off to emphasize an aspect of the building. In modeling a facility or construction project, it may be important to exaggerate a certain aspect of a facility to emphasize a point or system (fig. 3–4).

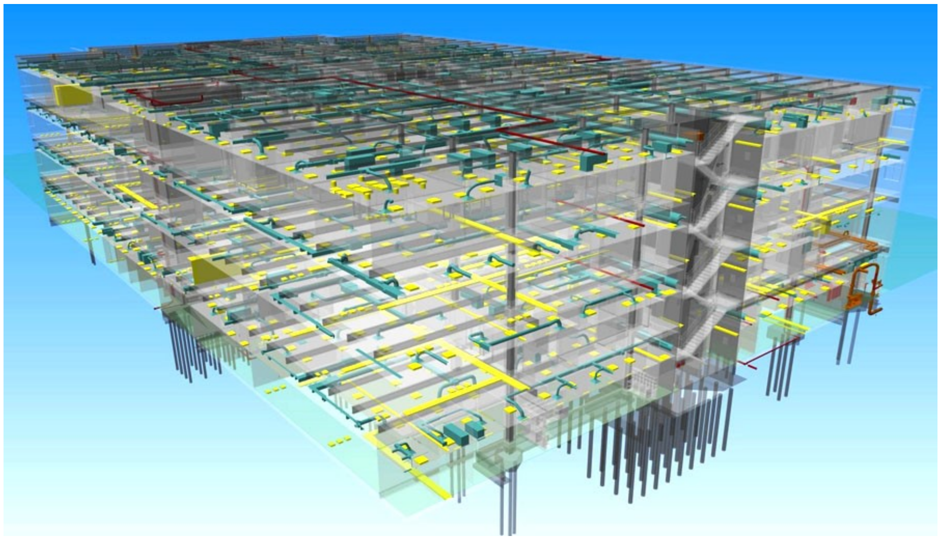


Figure 3–4. Facility with exaggerated HVAC system.

Detail

Details in a 3D model can be both helpful and harmful depending on the application. Early in the design phase, it can be important to use as much detail as possible in order to convey the idea to all parties involved. A fully rendered elevation of facility can help customers and commanders understand the final project and make better design and budget decisions (fig. 3–5). Too much detail during the construction phase will be prohibitive and take away from the basic information crews need to construct the facility.

Figure 3–5. Rendered fitness center at Nellis Air Force Base, Nevada.

3D commands and tools

By now, you are probably used to using 2D CAD drafting tools. You are probably very proficient at creating polylines, polygons, features, points, and more. You are probably also very familiar with zoom tools to change the scale of the viewing plane of your project. 3D modeling has all the same toolsets, with additional ones to aid in viewing 3D models.

Depending on where you are located and the nature of your project, you might be using one of several software platforms from any of a number of manufacturers. Describing all of the tools would be impossible in one CDC. However, there are several common 3D tools available in all software packages. Understanding these can give you more confidence in using any BIM software. The following table highlights these common 3D tools.

Unique Three-Dimensional Modeling Tools	
Tool	**Function**
Camera Tools	
3D Orbit	3D orbit allows you to select an object or the overall model and rotate it 360° through the X, Y, and Z-axis. Allows users to view the model as if they were holding it in hand and viewing it from all sides.
3D Axis	3D axis allows you to select an axis around which to view an object or model. After selecting either the X, Y, or Z-axis of rotation, the other two-axes lock.
Pan Tool	The pan tool is similar to that used in 2D but has two different features. Panning can be done while maintaining perspective or view. • *Perspective panning* locks the vanishing point of the projection as the point of rotation. • *View panning* locks the current view of the model and allows the user to pan as if it is a 2D model.
Elevation/Projection Presets	When working with multiple angles, and detailed models, it can be easy to forget where you are within the model. Preset elevations and projections allow users to snap immediately to the left, right, front, back, or azimuthal view. In addition, there are usually isometric presets, as well as customizable preset projections.

Unique Three-Dimensional Modeling Tools	
Tool	**Function**
Camera Tools	
Walkthrough	As a model begins to take shape, it can be helpful to view the model as if walking through it. This feature allows the user to determine a path along which the camera will move during the walkthrough. Can be very helpful when the project nears completion to show other collaborators the view inside a facility. Some software packages also allow you to set the size of the virtual viewer to detect any places that may be too narrow or short for a person to pass.
Modeling Tools	
Extrusion	Extruding an object means taking a 2D shape and giving a value on the third axis. You might start with a 1-inch by 1-inch square on the X-, Y-axis, then extrude it 1-inch to make it a cubic inch shape. We use most of these tools either by entering specific dimensions, or by selecting the edge of a shape or existing object and dragging the desired distance. Extrusion can also happen along a predetermined path that is either a straight line or creating a complex path.
Subtract/Void/Split/Combine	In 3D modeling, it can be difficult to model complex shapes. We assemble most complex shapes from a series of less complex basic shapes. For example, to model a nut and bolt set, the nut needs to be an extruded hexagon with a cylinder subtracted from it, while the bolt needs to be a cylinder with an extruded hexagon combined with it.
Rotate/Twist	Once you extrude an object, the faces on either end of the extrusion become mutually exclusive. If the faces are any shape other than a circle, it may be necessary to twist one or the other. In modeling, an entire object can be rotated or only one face of it, creating a twisted effect on the sides.
Loft/Splice	Some 3D shapes, particularly in HVAC systems within a facility, start as one type of shape then become another. For example, an air duct may be rectangular throughout the ceiling but need to be a circle where it meets the vent. A loft, or splice tool allows connecting dissimilar shapes in the same way as extruded shapes.

420. Dimensions of modeling

Modeling is different from 2D drafting. Besides the obvious extra dimension, there are a number of additional factors to consider. By definition, 3D modeling is the process of developing a mathematical representation of the 3D surfaces of an object using specialized software. Most people are familiar with 3D modeling through movies or video games. BIM moves these principles into the realm of construction. In construction, there are more than just 2D and 3D models (fig. 3–6). There are also 4D, five-dimensional (5D), and six-dimensional (6D) models.

Three-dimensional building information modeling

The first thing to consider when working in 3D is the location of the object or facility. In BIM, this is particularly important. Two-dimensional drafting allows more room for interpretation and placement of buildings within model space. Generally, we develop drawing along the X and Y-axes. In addition, there is no real need to locate a drawing at its actual geographic coordinate since we can easily move it later.

3D projects consider the Z-axis. From the initial stages of model development, it is critical to know which way is up and which is down. However, beginning with the correct geographic coordinates is equally important. While it is still possible to move a model once it is complete, or at any stage of development, be aware that there will be collaborators on the project. The first step is to communicate the scope of the project, building it from the correct location.

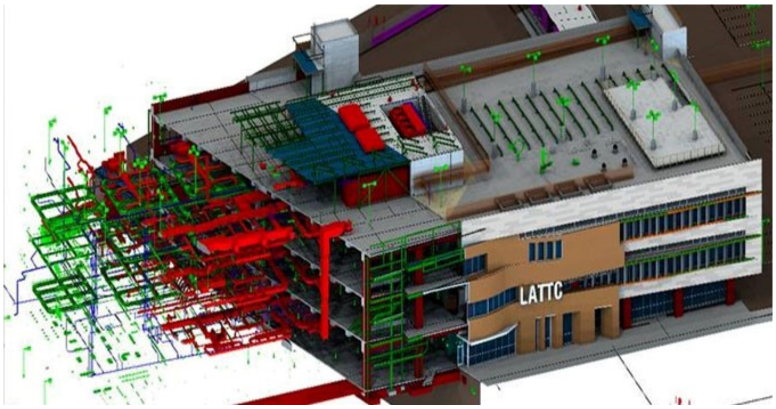


Figure 3–6. 3D BIM model.

Four-dimensional building information modeling

Most objects we think of in the world are 3D; we have length, width, and depth. Adding a fourth dimension incorporates time or duration. In the world of BIM, the fourth dimension is the schedule (time) of a project. By constructing a 4D model, various participants (architects, designers, engineers, contractors) in the project can visualize the duration of the project. This means they can virtually construct the building using an actual sequence of events. Some software packages even offer animation showing the construction of a facility.

4D BIM schedules derive from the 3D BIM geometry. Schedulers and engineers work together to optimize the resources. Based on the geometry of the model, several variables apply to the 4D model. These include sequencing logic, crew sizes, productivity rates, and local pricing. Planning all this in the 4D model allows planners to optimize the project and eliminate stops and starts, reduce project risk, and keep the project flowing smoothly (fig. 3–7).

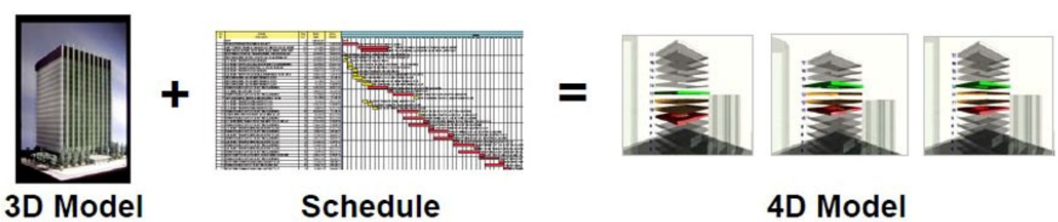


Figure 3–7. Creating a BIM 4D model.

Five-dimensional building information modeling

If 4D BIM incorporates the 2D drawing and the 3D model to produce the schedule, then the 5D BIM creates cost estimates. As each aspect of a facility, down to the smallest detail, develops in the 2D and 3D model, key product information is associated with the facility.

While building the 3D model of a facility, much of the work uses pre-constructed components. These components can be a window, a wall, a room, an air handler, or any of several other variations (fig.

3–8). Each component, or object, has cost estimating data associated with it. A planner and the software can determine the cost of the item, the cost of the crew, the tools and materials needed, and the quantities per location.

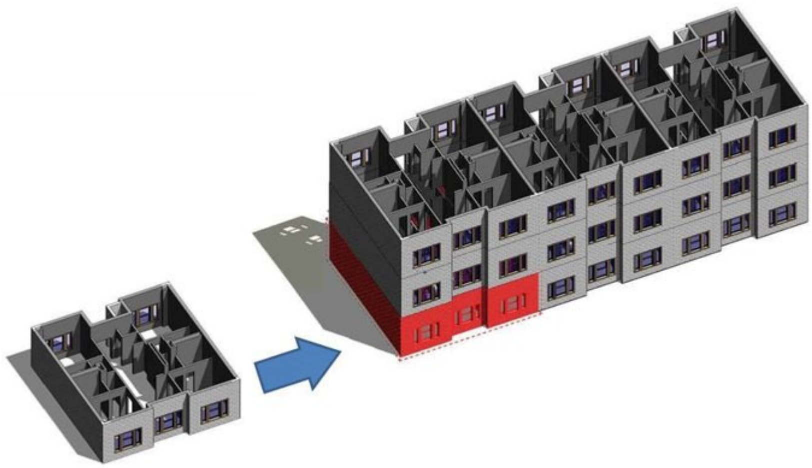


Figure 3–8. Constructing a model using components and objects.

Six-dimensional building information modeling

The previous dimensions of BIM plan for the construction of the facility. 3D shows how the facility will look and fit together. 4D shows the physical process of how we build the facility. 5D incorporates cost information for highly accurate construction estimating. 6D BIM moves into the future taking a building from concept or project to an asset. If the first five BIM dimensions focus on design and construction, then the 6D focuses on facility, or asset, management and maintenance.

Every building has a lifecycle. From conception, construction, use, then to repurposing or demolition. Each phase of a lifecycle has costs associated with it. The cost period during a building's years of use can be the highest. By applying 6D BIM during the planning phase of the facility, all the stakeholders can determine and adjust the lifecycle costs (fig. 3–9).

Figure 3–9. Lifecycle of a building.

While the 6D BIM process begins during the initial planning phases, it fully goes in to effect when the model becomes the responsibility of the user and facility management team. By this point, the model contains room elements like names, numbers, and space type (bedroom, office, cafeteria, mechanical, etc.). Embedded information like manufacturers, model numbers, serial numbers, and any operations and maintenance requirements for each asset within the facility is also included. In previous generations, all this information was in stacks of three-ring binders, heavy books, and stacks of drawings turned in for use in facility operations and maintenance. If a facility had a system failure or needed an upgrade, it could take days to dig through the stacks of legacy data. Properly managed, 6-D BIM eliminates the immense paper burden and streamlines facility management.

421. Parametric modeling

By now, you should understand the idea that BIM is much more than just drawing 3D buildings. A 3D building without any data associated with it does little good when it comes to planning schedules, determining budgets, or forecasting maintenance. Many of these benefits of BIM are possible because of parameters set within the components or objects of the building. We refer to setting and using parameters within a model as parametric modeling.

Parametric modeling does not simply use fixed geometry and properties to represent objects. Instead, it represents objects using parameters and rules that determine the geometry. These rules can include non-geometric, or functional, properties and features. Parameters and rules can be expressions that relate to other objects, and allow automatic updates of the objects according to user control or changing contexts.

Parametric objects

Object-based parametric modeling is different from object modeling. Since 3D modeling began in the 1960s, there have been two primary forms of solid modeling. One was a boundary representation (B-rep) that represented shapes with a closed, oriented set of bounded surfaces. This way a shape could satisfy a defined set of volume-enclosing criteria. Alternatively, Constructive Solid Geometry (CSG) represents a shape as a set of mathematic functions. CSG relied on different methods to determine the final shape, but it did not generate a set of bounded surfaces.

These methods competed for prominence, but eventually the industry opted to combine them. The B-rep, referred to as the evaluated shape, and the CSG, or unevaluated shape. This allowed the B-rep to be the shape displayed on a monitor for interaction, but the underlying CSG actually linked to the data associated with the object. Through this combination, we assign parameters to graphic representations of objects.

As an object is developed, certain parameters and features can be associated with it. Once they are associated, we lock them in place. Locking them in place is called *placing constraints*. This means that once we create an object, we can use it repeatedly without having to redefine its parameters or properties. We also lock it to prevent alteration during the design process. Based on these principles, if we place a parametrically defined object next to similarly defined objects, we can link the two. For example, placing a floor with a dimension of 10 feet adjacent to a wall with a 10-foot dimension, the two link and interact with one another.

This BIM aspect enables a designer to update one window and have the same update made to all the associated windows. It also enables designers to associate different objects within a model. For example, a floor can be associated with a wall and a wall with a ceiling. With parametric modeling, a change to the area of the floor automatically adjusts the dimensions of the associated walls along with their associated ceilings. In this way, parametric modeling provides a powerful way to create and edit geometry. Without it, model generation and design would be extremely cumbersome and error-prone. Designing a building containing a hundred thousand or more objects would be impractical without a system that allows for effective low-level automatic design editing.

Parametric modeling for construction

A BIM design application allows developers to divide walls into component parts. We assign each component type a layer, similar to 2D drafting. The component parts can be nested together to form larger components. This means that in a typical wall there will be studs, electrical conduit, outlets, drywall, paint, molding, and hardware. A floor will have joists, beams, decking, carpet pads, carpets, glue, and all the necessary hardware. The wall components join into a wall object, while the floor components join into a floor object. Then, wall and floor objects join, along with HVAC, electrical, and all other disciplines, to create room objects. We call these *dynamic prototypes*, which are discussed later. If the individual components within walls, floors, and other systems have associated data, then when nested to form the wall, floor, or room, the same data applies.

This makes constructing a framing plan very easy. Estimators also have an easy time determining how much lumber, carpeting, tile, paint, and all other materials they need. Associated data allows them to conduct a simple query to determine how many linear feet of lumber or square feet of drywall are in a wall, and quickly determine the cost for materials and labor. Construction teams can also cut materials to length at the factory before delivery, thus saving considerable assembly time. These principles apply on both large- and small-scale structures—a shed in a back yard, or a 200 Airman dormitory.

Answers to Self-Test Questions

418. Building information modeling definition

1. What are the two benefits to 3D modeling?

2. As far as limitations, what is not associated with a 3D model's individual features?

3. How does BIM combine the best features of a GIS with those of 2D and 3D CAD modeling?

4. Other than physical structure, what other aspects can be included in a BIM model?

419. Modeling concepts

1. What limits the level of realism of a model?

2. To ensure consistency, what should all rooms, wall finishes, ceiling shapes, windows, doors, etc. all share?

3. Describe the difference between the 3D Orbit and 3D Axis tools.

4. What does it mean to extrude an object?

420. Dimensions of modeling

1. In the world of BIM, what do we mean by the fourth dimension of a project?

2. List the variables that apply to a 4D model.

421. Parametric modeling

1. What are the other names for evaluated and the unevaluated shapes?

2. What do we mean when we talk about placing constraints?

3–2. Application of Building Information Modeling in Civil Engineering

BIM may seem like a new, fancy way of drawing a building for a construction project, and it is. However, it is also much more than that. BIM is a verb. It is a process of modeling a building from inception through its lifecycle. As the practice gains traction in the industry, expect to see more facilities built using solely BIM. In the engineering flight, this means more BIM models turned in along with or instead of as-built drawings. As this aspect develops in CE, leaders expect engineering to be familiar with BIM models, just as they are familiar with flat files and electronic drawing vaults. To do this, you must first know what a BIM model is.

422. Building information modeling design applications

BIM quickly develops into a complex model, particularly with various user inputs and parametric features. The greatest benefit of parametric modeling is intelligent object design. Each type of object has its own behavior and associations. This means that BIM design applications—the software packages developed by different firms—are inherently complex. Each type of building system is composed of objects created and edited differently, though with a similar user interface. It usually takes months to become proficient at using even one BIM design application.

As BIM design practices develop, software companies continue developing new, more efficient and specialized approaches. This causes greater diversity in how software packages operate. BIM applications do not always communicate easily. In the drafting software world, there are two major companies—Autodesk and Bentley—each makes very good BIM products, but with different methods and purposes that do not always interact well. The lack of interaction is because different BIM design applications rely on different definitions of their base objects and their behaviors. A wall designed with Bentley software, for example, behaves differently than an Autodesk wall. This problem *applies only to parametric objects*, not those with fixed geometry. Shapes accepted as fixed objects with behavioral rules dropped, an Autodesk objects and Bentley objects become interchangeable.

Behavior exchange happens most often when organizations agree on a standard for common building object definitions that includes not only geometry but also behavior. DOD developers must use the A/E/C CAD-BIM Technology Center Website to ensure all department objects are interchangeable.

To understand how to overcome communication difficulties, and BIM functions, we approach BIM in three different ways. BIM as a tool, a platform, and an environment.

BIM tools

Different computing tasks require different computer programs. Word processing requires one, while creating presentations requires another. BIM functions in much the same way. There are several different tasks to perform when developing a BIM model. Each task has a specialized software or tool. There are tools for model generation, drawing production, specification writing, cost estimation, clash and error detection, energy analysis, rendering, scheduling, and visualization. Tools generate products that are standalone, such as reports, drawings, and so forth. Sometimes tools output products to other tool applications, such as quantity takeoffs or cost estimation. If you are generating a BIM model from scratch, for example, you will start with a modeling tool. If creating estimates, you would use an estimating tool.

BIM platform

BIM platforms are the suite or group of software applications produced by vendors, or groups of vendors, that interact to create the model. One platform will have a wide range of applications designed to interact seamlessly. These applications include the functions of structural analysis, energy efficiency analysis, visualization, and facility management. A single BIM model provides a primary data model that hosts the information on the platform, accessed by the various applications. Most BIM platforms also internally incorporate tool functionality such as drawing production and clash detection. They typically incorporate interfaces to multiple other tools with varied levels of integration. Some platforms share the user interface and style of interaction.

BIM environment

If BIM as a tool is the method to create the model, and the BIM platform is the suite of software applications that create capabilities, then the BIM environment is the software and hardware that enables user interaction. The environment supports policies and practices of information within an organization. Automatic generation and management of multiple BIM tool datasets is their obvious use. In addition, when multiple platforms are used—and multiple data models—another level of data management and coordination is required. These address tracking and coordinating communication between people as well as multiple platforms. BIM environments provide the opportunity to carry much wider forms of information than model data alone, such as video, images, audio records, emails, and many other forms of information used in managing a project. BIM platforms are not set to manage such diverse information. BIM servers are the new products targeted to support BIM environments. In addition, the BIM environment includes objects and assembly libraries for reuse, interfaces to the applications the organization supports, and links to corporate management and accounting systems.

423. Organizational impact

The craft of creating buildings has not changed much in thousands of years, but the technology has and continues to change. Air Force civil engineers have always done an excellent job of staying abreast with technology, sometimes even on the leading edge.

Past advancements in technology required small modifications to existing practices. When CAD programs first became the industry standard, it was a challenging but not overly difficult adaptation. GIS, in its early years, required some adaptation but was essentially a 2D map with associated databases. In both cases, the work environments were still 2D, as was the finished, printed product. In addition, even though the tools became available to speed up the surveying, drafting, and mapping processes, the core skills and workflow were the same. BIM, because it incorporates several different technologies across several disciplines, will be a much larger change than previous technological advances. The primary challenges to fully integrating BIM to the civil engineering process will be software training, and improving communication between civil engineering, USACE, contractors, and the shops.

3E5X1 career field

The first question you probably have is how will this influence you? Currently, 3E5s are the primary source for construction document creation, storage, and maintenance at the installation level. We take engineering information and design from the local civilian and military engineering staff, and then create and maintain the construction documents of local O&M projects. Additionally, we are responsible for the maintenance of all MILCON project drawings once accepted by the installation. Currently, the USACE and their contractors use BIM to produce MILCON projects.

We work with the other crafts within the civil engineering squadron to ensure accurate updates to as-builts in the facility construction document set. When the squadron creates a work order to perform facility maintenance, we provide the drawing set to the craftsperson to assist with maintenance tasks. When the tasks finish, the craftsperson marks up the drawing set and returns it to us for updating as-builts. Currently, performing updates to as-builts occurs through a combination of standard CAD practices and hard copy updates.

With a BIM-based workflow, facility management tasks and documents generate as a by-product from the model. A properly maintained BIM environment will enable engineering to access as-built data, construction documentation, O&M data, and make updates to the facility documentation all from the BIM environment. For facilities that have a complete BIM model, this will greatly streamline the facility management practices for EAs. As the technology progresses and integrates into the civil engineering squadrons, engineering will take a larger role in maintaining BIM environments.

Simplified Acquisition of Base Engineering Requirements

The SABER contract's main purpose is to expedite contract award of civil engineer requirements through the issuance of individual delivery orders. The contract contains a collection of detailed task specifications that include most types of real property maintenance, repair, and construction work. Typically, a SABER contractor has a pre-set list of agreed-upon pricing for typical work.

Once the project is completed, the SABER contractor provides the rest of the design and returns markups to the installation. Once returned, the 3E5 staff incorporates the markups into the as-builts of the facility.

If the local design staff provides the SABER contractor with a scope of work with construction documentation, we can use a BIM based workflow. We then use the existing BIM model to determine the scope and cost of renovations, or new models for smaller projects.

Military construction

Effective with the start of fiscal year (FY) 2011—1 October 2010—all new vertical construction adopted BIM as part of all architectural and engineering services according to Design Instruction (DI) #1. Attachment F, within that document, spells out specific requirements and standards for developing and delivering BIM for Air Force MILCON.

In addition, dormitory projects in the FY11 program and beyond employ Air Force Center for Engineering and the Environment (AFCEE)-developed, BIM-based dormitory dynamic prototypes. To capitalize on this capability, Air Force design instruction now mandates a BIM approach during acquisition.

Dynamic prototypes

In BIM, dynamic prototypes are flexible, adaptable models of buildings, or building parts already modeled and ready for use. Figure 3–10 shows some prototypes for Air Force dormitories, which are now the standard for dormitory construction. These prototypes are similar to using building blocks arranged in any configuration necessary to meet individual installation needs. Figure 3–11 shows a dormitory being assembled using Unit B.

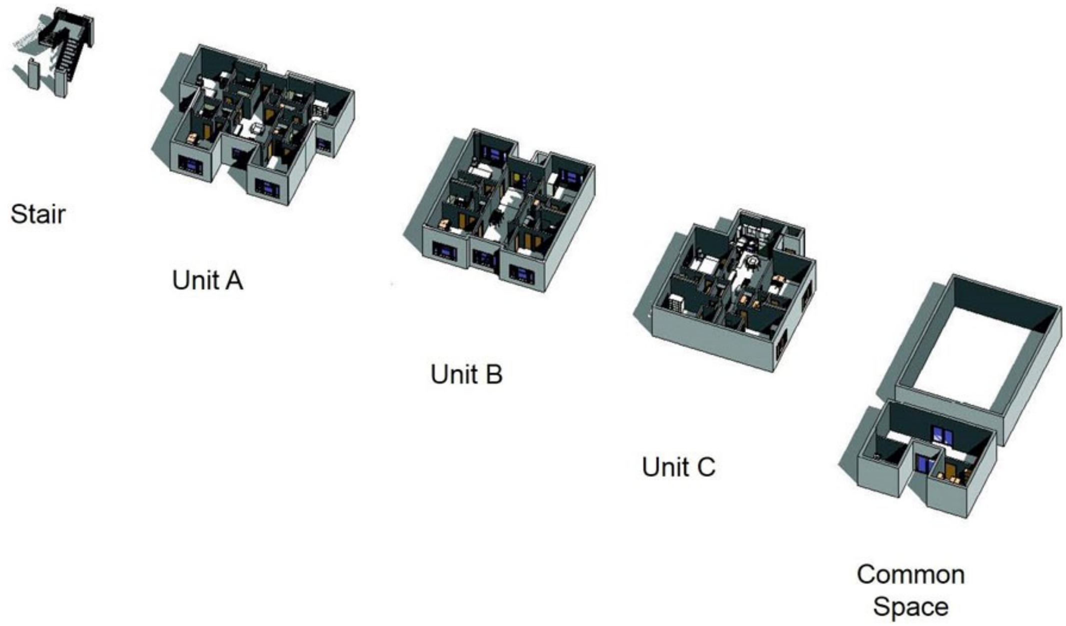


Figure 3–10. Dynamic prototypes for Airmen dormitories.

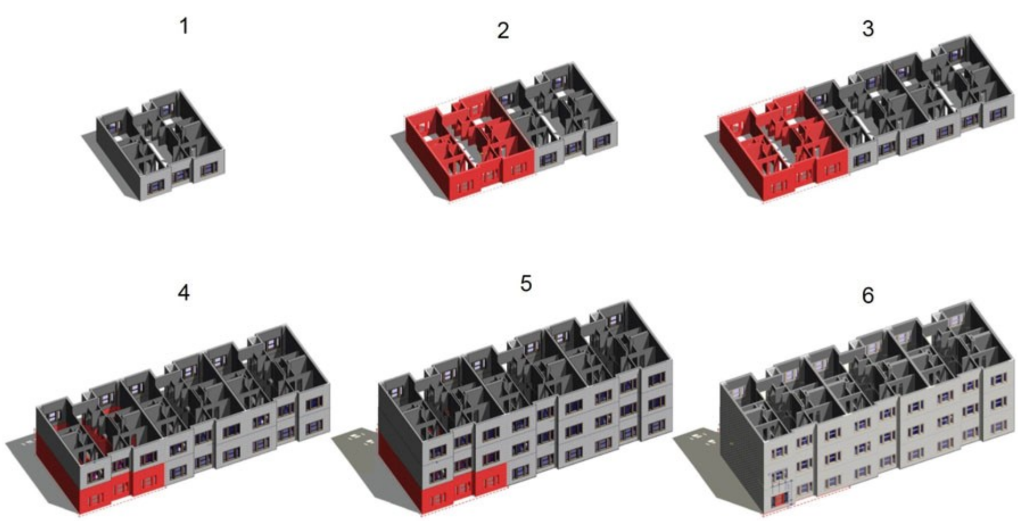


Figure 3–11. Assembled dynamic prototypes.

Each prototype is like a kit of parts. It includes each of the discipline models needed for the BIM model: architectural, structural, mechanical, electric, plumbing, and fire. Each prototype contains the data for all the materials needed for each unit (fig. 3–12). This way, after assembling the model, construction scheduling, estimating, and coordination become a simplified task. Because they are BIM models, it is also easy to produce 2D drawings of each prototype individually, or after assembly as shown in figures 3–13 and 3–14.

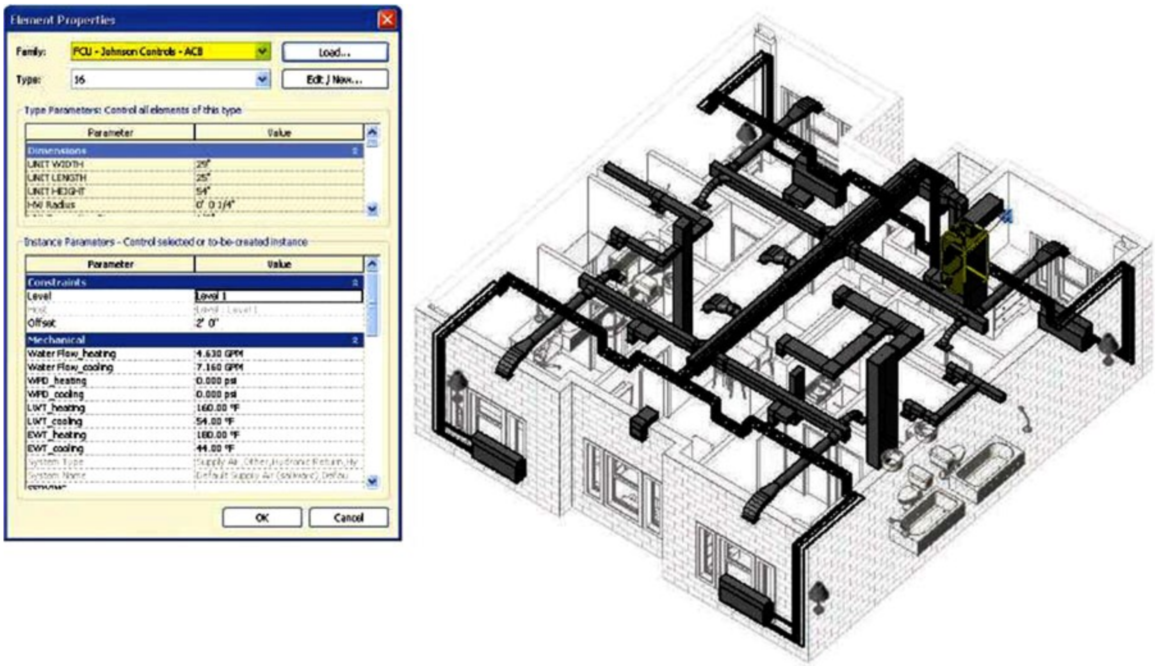


Figure 3–12. Prototype HVAC system showing associated data.

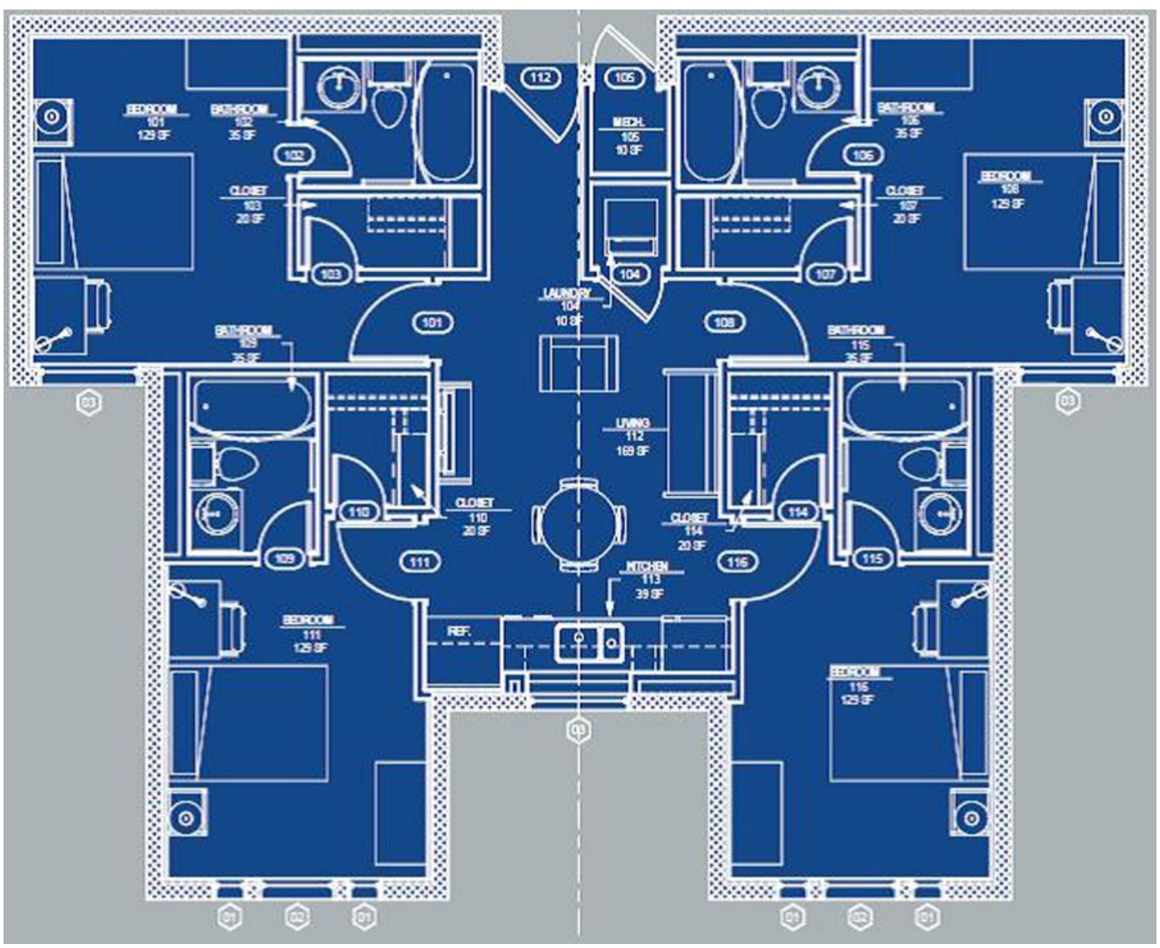


Figure 3–13. 2D floorplan of Unit A dynamic prototype.

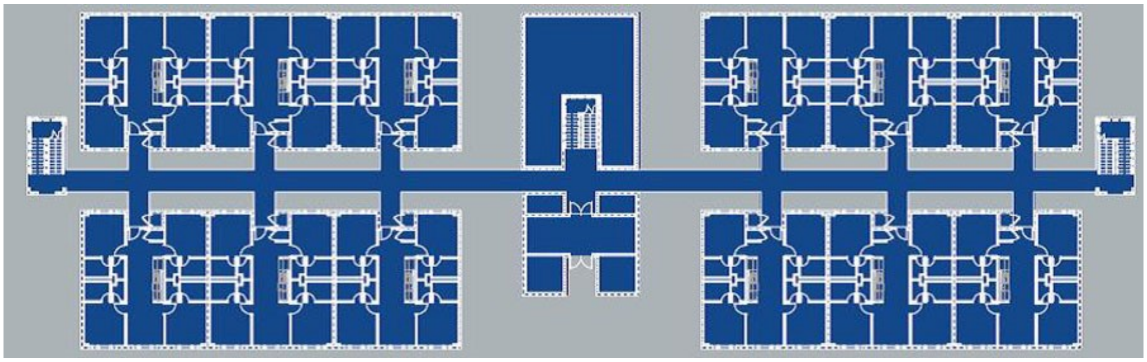


Figure 3–14. 2D floorplan of Unit B dynamic prototypes assembled.

Since these prototypes are modular, it is easier to assemble them in different configurations. Moreover, once assembled the BIM model can be fitted with different exterior finishes to determine which will best meet the intended use and the design standards (fig. 3–15).

Figure 3–15. Dynamic prototype dorm assembled with exterior finish options.

Dynamic prototypes already exist for several types of Air Force facilities. The Air Force BIM site on the WBDG has links to all the building types and their associated prototypes (http://www.wbdg.org/references/afbim_tools.php). Prototypes on the site include confinement facilities, enlisted dorms, entry control, fighter hangars, fitness centers, indoor firing ranges, legal facilities, military working dog kennels, security forces operations, and visiting quarters.

For each type of facility, there is a BIM manual. Each manual includes information about site design, building design, specifications, Leadership in Energy and Environmental Design (LEED) checklists, and software requirements.

424. Building information modeling implementation

Each year, BIM usage for MILCON projects increases. People and programs at all levels of the construction process have already started—and will continue—integrating BIM into their thinking and workflows. Based on what you have learned so far about how BIM works, you should be able understand the benefits throughout the planning, programming, construction, and O&M processes.

Facility planning and programming

BIM can assist in ensuring that the design meets the spatial requirements of the client (fig. 3–16). We quickly manipulate BIM to determine the ideal space area and layout. The owner is able to visualize the arrangement of spaces and can determine if the design meets requirements very early in the planning stage. In the Air Force, we program projects to the DD Form 1390 and 1391 requirements. The purpose of the DD Form 1391 is to submit requirements and justification to Congress to support funding request for military construction. The use of BIM can help create spatial validation reports that are useful for initial project phases and can include block, and stack, bubble, and schematic diagrams. Space Naming follows the Open Standards Consortium for Real Estate (OSCRE) standards and DOD's Real Property Categorization System (RPCS).

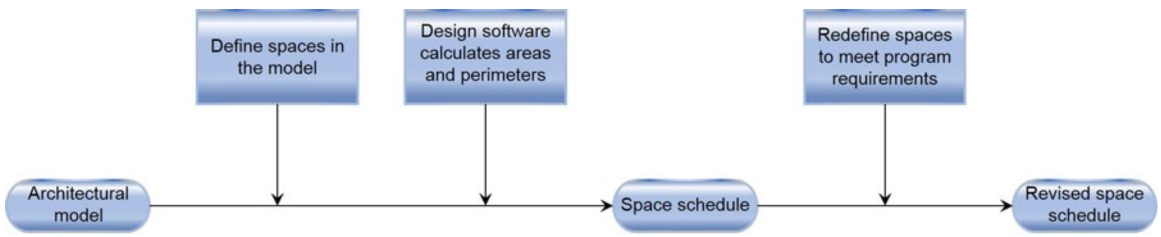


Figure 3–16. Planning process map.

Early cost modeling

The basis of most 1391s is the parametric cost estimate. Approved 1391s are the binding document MILCON project managers use to establish budgetary constraints and scope for their projects, both drive cost. BIM offers the promise of model-based quantity takeoff and cost estimating throughout the facility lifecycle, yielding more confident cost and scope control throughout the project lifecycle. Early conceptual modeling for costs ties into programmatic BIM data where we assign major systems cost data. In many instances, the early square footage requirements and costs will align directly with the 1391's line items (fig. 3–17).

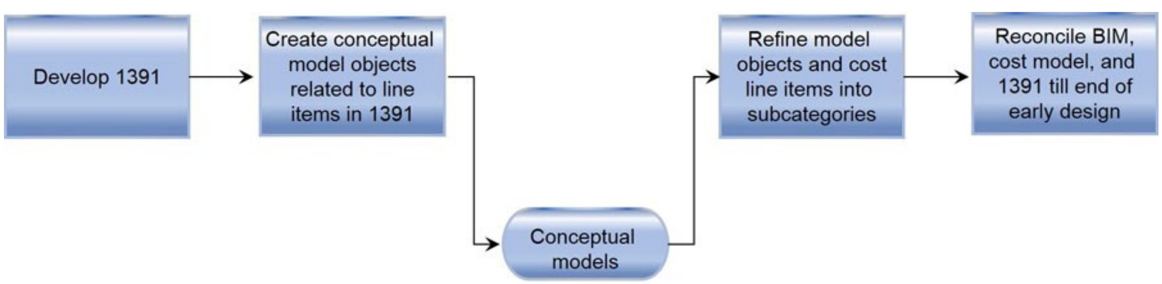


Figure 3–17. Estimating process map.

Project schedule

At a high level, BIM monitors and/or creates project schedules. A BIM tracks the project schedule or even creates the project schedule. Each BIM object links to a scheduled activity to provide a check and balance that adequately depicts activities and model elements. If a 4D model is output, various scenarios can describe construction conditions or options. Additional time may be required to link model elements to line items, but if completed in an interactive process the model develops the project schedule or uses the project schedule to indicate what elements need to be included in the model (fig. 3–18).

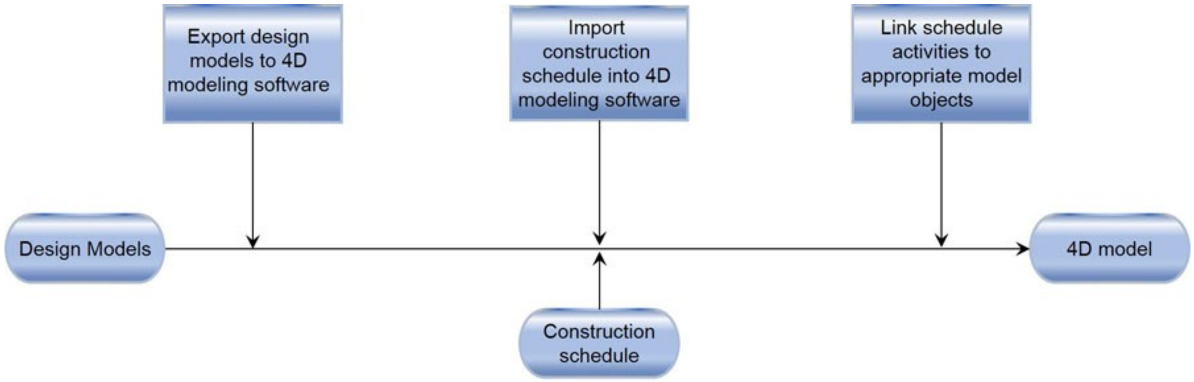


Figure 3–18. Scheduling process map.

GIS (locating the project)

GeoBase offers the Air Force superior geospatial awareness. Installations have made strides toward achieving the most accurate, robust, data-rich base maps in the history of the Air Force. Implementing BIM comes with the goal of achieving the same success inside the facility that GeoBase accomplished outside the facility.

Currently, there is a divide between geospatial map data and building data. While there are varying levels of success, the Air Force has the challenge and obligation to manage its BIM implementation in a way that maximizes connectivity with its substantial mapping information.

As a project model develops, the project origin should be accurately determined and included in the model file. The origin point is determined using the topographical, elevation model, and site layout. As the model develops further, we bring it into GIS based software to display its location and orientation with respect to the existing environment and layout around the site. This allows the owner to visualize the future site development and its impact (fig. 3–19).

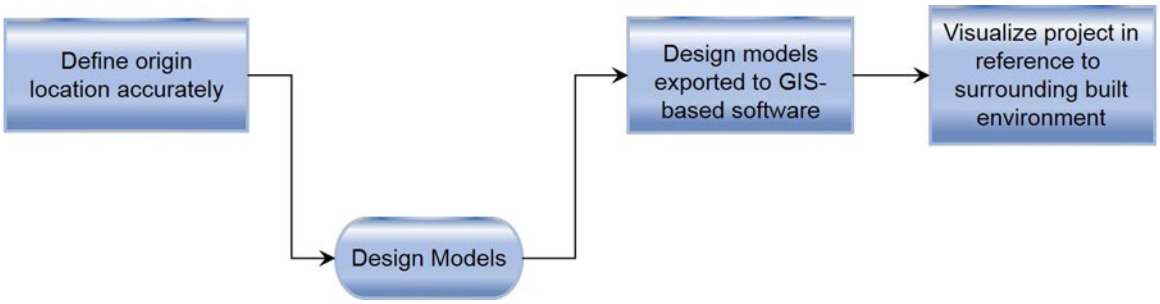


Figure 3–19. GIS inclusion process map.

Contractor

The designer and constructor of record use the original Dynamic Prototype to the fullest extent possible and make the owner aware of any required modifications. The owner will keep track of any modifications and may communicate the modifications back to the original Dynamic Prototype designer.

Dynamic Prototype is a flexible design model that leverages the advantages of BIM to standardize components of a building type through a schematic 3D model. Design models can vary from performance criteria to prescriptive criteria depending on the number of variables (fig. 3–20).

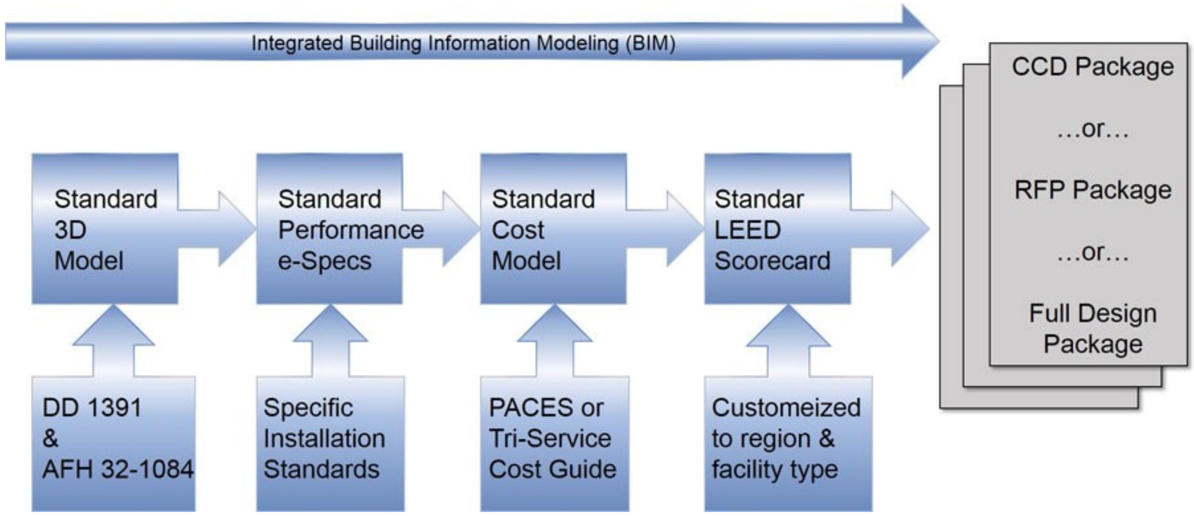


Figure 3–20. Contracting process map.

Project specifications

Specification software can take information directly from the design model to populate the specification documentation with as much information as is contained in the BIM model. By establishing the direct link in the specification document, the model elements continue to remain in sync through the design process. If a model element changes then the corresponding change in the specifications happens automatically. This occurs by adjusting the assembly code, which every model component contains, allowing the specification information within the specification software to talk to and interact with the information within the design software (fig. 3–21).

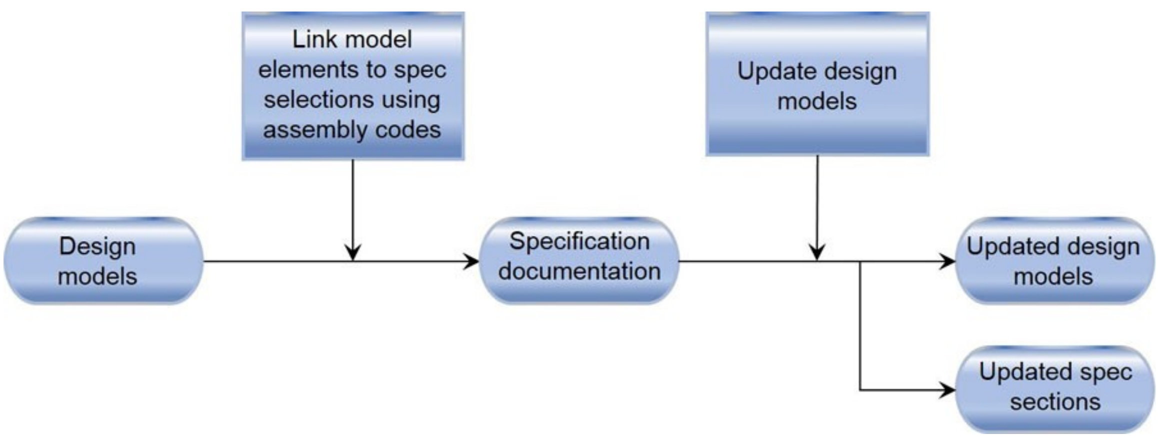


Figure 3–21. Specifications process map.

Clash detection

Clash detection software allows teams to run automated clash detection algorithms and reliably identify and address clashes between elements of the different trades. We can then hold meetings to discuss clashes and constructability issues identified in the consolidated BIM. We then capture the solutions to resolve the coordination and constructability issues that the team develops in a digital format during the meeting. After the meeting, all disciplines should have a good understanding how they need to modify their specific models in order to resolve the clashes (fig. 3–22, 3–23).

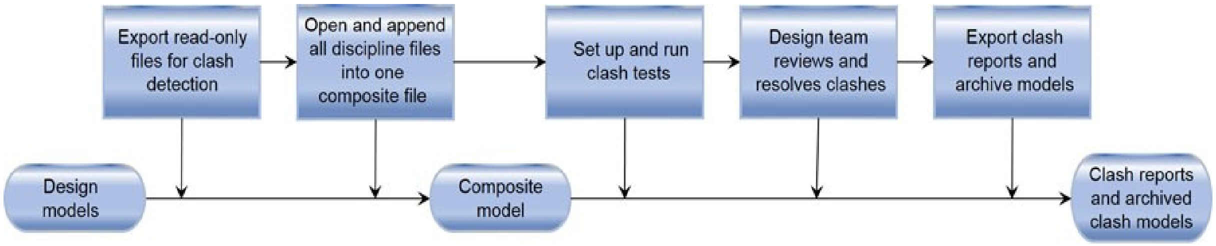


Figure 3–22. Clash detection process map.

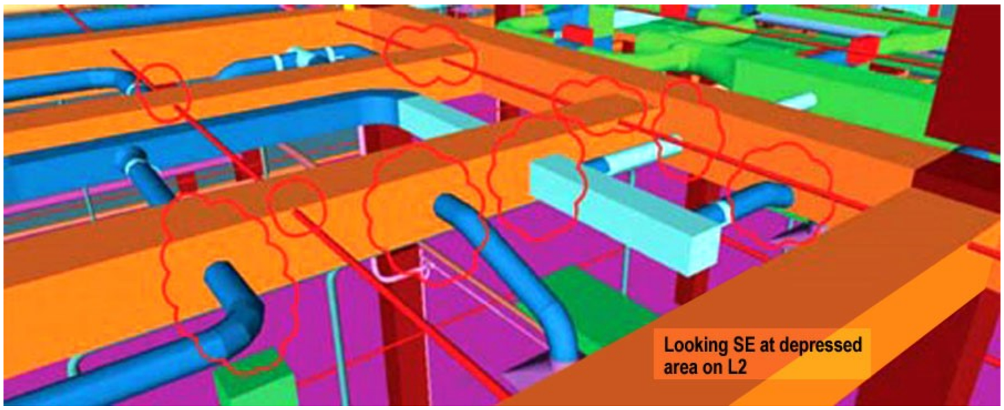


Figure 3–23. Clash detection within the model.

Shop drawings

BIM can export and import subcontractor shop drawings. File format and object enablers are important when it comes to ensuring all objects will be visible in the native viewing software. When it becomes necessary to incorporate shop drawings back into the record design model, we use the BIM-authoring software. In other cases where visualization and validation are required, we use a model aggregation and viewing tool. Incorporating shop drawings is an important step to ensure we depict the most accurate construction conditions in the BIM (fig. 3–24).

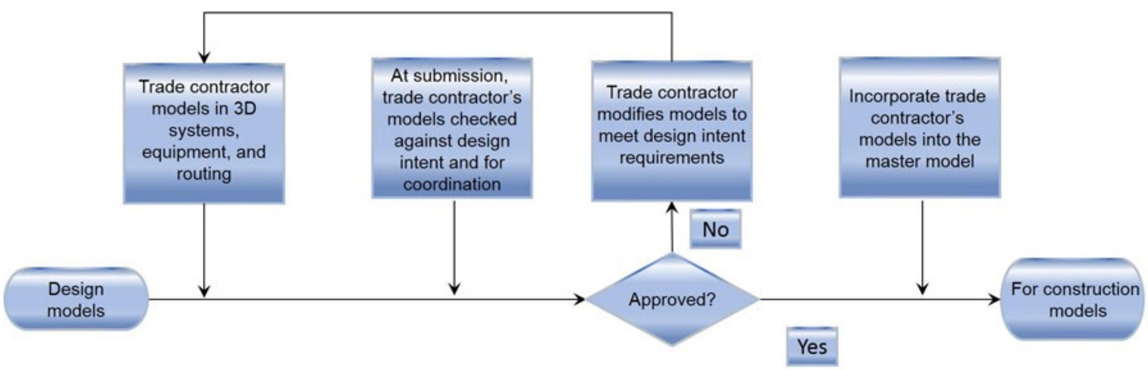


Figure 3–24. Shop drawings process model.

As-built model creation and delivery

Accurate as-built drawings can be available immediately at the close of construction with the use of BIM and a 3D model. The 3D model, updated throughout the project, accurately represents the physical design and construction of the project throughout all trades. It is helpful for the owner in maintaining and revising its structure or facility when inheriting a 3D model as its as-builts. This also leads to more accurate facility and asset management (fig. 3–25).

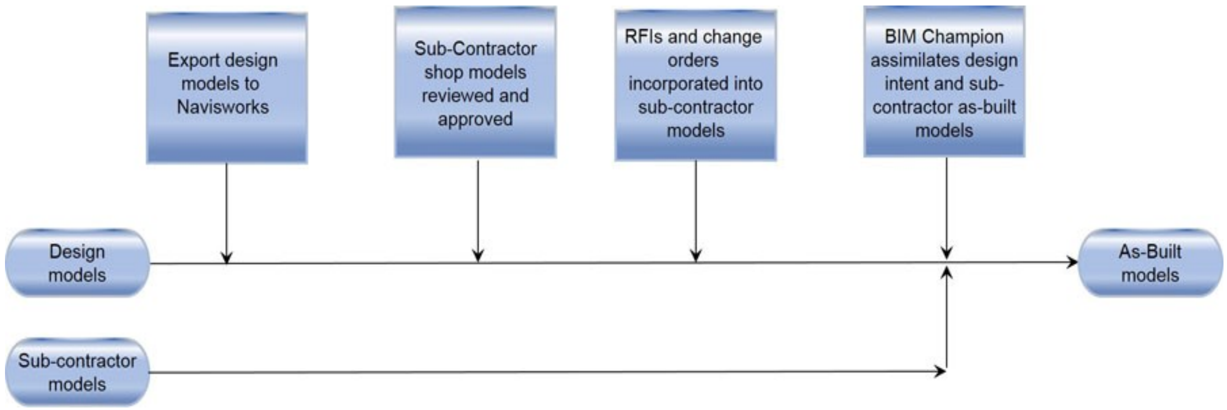


Figure 3–25. As-built process model.

Final documentation

We also use BIM during the commissioning and handover process. 3D models and the associated information allow for incorporating additional documentation to the models. Warranties, test logs, calibration certificates, equipment manual, and so forth, can be attached or hyperlinked to the specific model elements and can be brought up by querying those elements. This makes it faster and easier to manage documentation and to look up the information.

Maintaining as-built models

Models created during the acquire phase must be maintained during the sustain phase. 3E5s are the most capable party for keeping these models up to date during the facility's operation. At the conclusion of the Acquire phase, we check models for accuracy and compliance with system requirements. Once ensured, these models include the data needed for day-today and ongoing facility maintenance, they can be archived and reviewed on an as-needed basis. Either the native file format, BIM-authoring software file format, or a model aggregator format will be required. As maintenance requests occur, systems changed, or areas of the facility change, it is important to incorporate these changes into the BIM. The 3E5s are responsible for documenting changes in the as-built model (fig. 3–26).

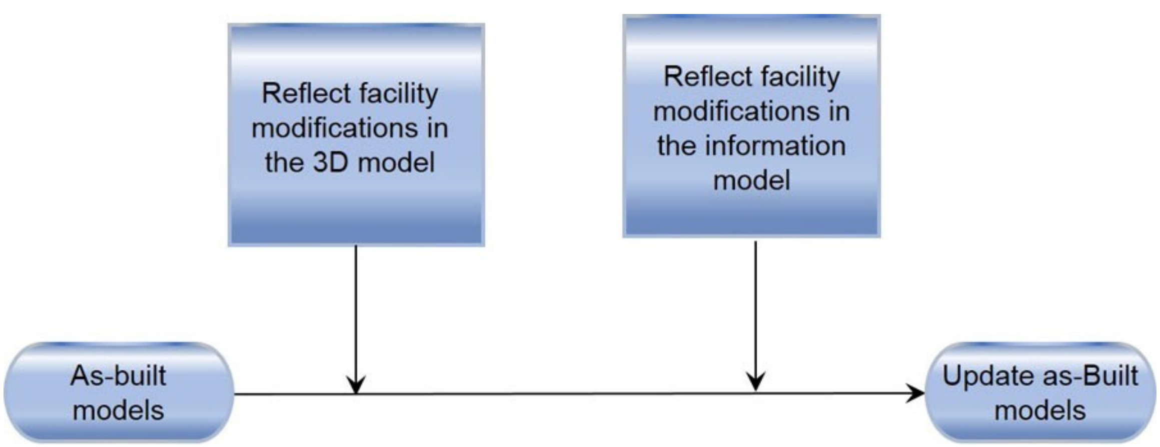


Figure 3–26. Maintain as-built process model.

425. Building information modeling in operation

Until this point, you have learned a lot about the process and theory of BIM. There are also practical matters. Purchasing the software, acquiring the hardware, and providing training remain a challenge in moving Air Force civil engineering into a BIM friendly environment. Since BIM models are rapidly becoming the primary repository for the construction documents used daily on an installation, it is important to know the fundamental aspects of creating, accepting, and using a BIM model.

BIM development

The Air Force owns a vast number of assets spread around the world. Determining asset location and condition at any given time is crucial to provide the accurate, real-time data necessary to make important strategic decisions and better manage Air Force infrastructure. The real property inventory (RPI) is the Air Force's authoritative infrastructure data source. The RPI identifies the real property assets (buildings, structures, linear structures, and land) the Air Force owns or occupies. The RPI is a key data source that underpins installation facility investment planning and programming. Within the area of facilities, key facility management information centers on the use of space, and the assets within the space and facilities. Utilization of space includes net, usable, rentable, interior gross, and exterior gross. Information about individual assets tied to installations and facilities is also used and tracked to help provide overall situational awareness.

GeoBase

GeoBase supports civil engineering and the Air Force by providing current, accurate, and timely satellite and aerial imagery and map data representing real-world features and conditions for installations, ranges, and property. When linked with other mission business data, the program's geospatial information provides location-based geospatial context.

GeoBase develops its core services through collection, creation, maintenance, management, exposure, analysis, and visualization of current, accurate, and authoritative installation geospatial data. It is also facilitates the linking of civil engineering business data to corresponding geospatial attributes as an essential element of the NexGen IT data structure; this capability permits the geospatial organization, visualization, and analysis of civil engineering business data for real-world situations.

NexGen IT

To support Space Management and other high-value Asset Management (AM) transformation needs, Air Force Civil Engineer (AF/A7C) will be deploying a new IT system known as NexGen IT that will replace the current automated civil engineering system (ACES) and add needed capability. The next evolution of these systems is NexGen IT. Founded on commercial software solutions, including a class of products referred to as the Integrated Workplace Management Systems (IWMS), NexGen IT also aligns with industry data standards such as OSCRE.

NexGen IT Program Management Plan combines the latest commercial technology with proven civil engineering experience to help engineers more effectively manage Air Force assets, prioritize projects, and maximize buying power. It will also enable ongoing efforts to standardize core business processes and risk/cost-based investment. NexGen IT will consolidate information management and integrate legacy systems.

Implementation of NexGen IT occurs in a series of six spirals, with initial efforts focused on providing an integrated work management capability that will include real property management, work management, supply management, energy management, and project management.

This new data "transparency" will mean no more time-consuming data calls or redundant data entry. The Air Force leverages the space utilization and activity management plan data to provide easy access to total occupancy costs and other critical information.

Building information modeling and S-file

Until NexGen IT is available to the entire civil engineering community, AF/A7C has identified an interim solution—known as S-File—for managing space data. S-File data is composed of assets (graphic and non-graphic features) and data tables that manage information about the assets. The graphical or geospatial components of facility space data include architectural floor plans and "asset layers." We first develop the data in BIM and then migrate it into an S-File GeoDatabase.

The S-File, an interim tool, is a GIS-based data management and reporting tool for space management. We consider it interim because the data must be gathered and cataloged in Geobase until BIM is fully functional within the Air Force. The data model follows Spatial Data Standards for Facility, Infrastructure & Environment (SDSFIE) 2.6 amended with fields supporting M–6 (A7CA commissioned project for space and occupancy) recommendations and other attributes. S-File data are typically managed as a GeoDatabase and provides reporting and visualization of space information in a GIS environment.

Implementing industry-proven AM practices represents a significant departure from the traditional Air Force way of doing business. Leaders consider it a key enabler in civil engineering transformation. Space and occupancy management is an AM practice area identified by AF/A7C that will achieve near-term cost savings across the enterprise.

Architectural floor plans representing the "base map" and the asset layers (such as rooms, floor perimeters, equipment, etc.), are linked to data tables creating "intelligent" drawing. We develop data in BIM-authoring software and migrate it to an S-File GeoDatabase (fig. 3–27).

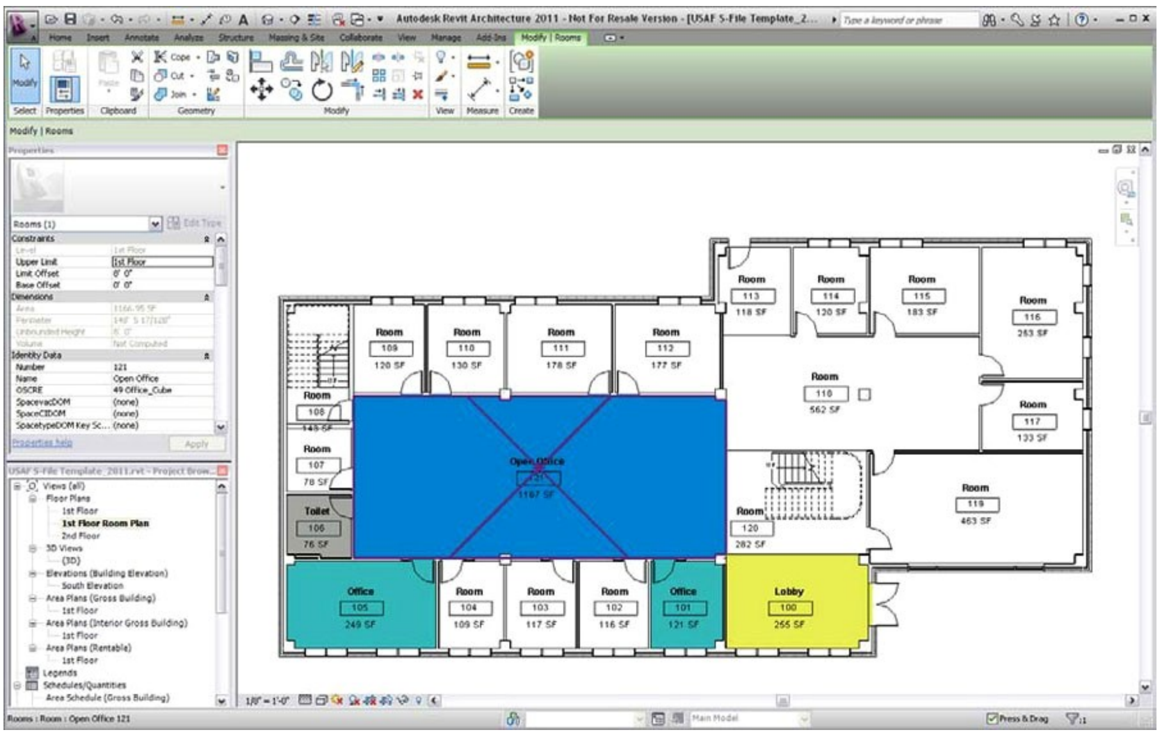


Figure 3–27. S-File data associated with a smart floorplan.

As BIM becomes more prevalent at the installation level, it is crucial that we eliminate the duplication of data, because information is stored within the model and other locations, such as GIS databases. The goal is to ensure that the system that owns the data becomes the primary proprietor of the data, and informs other systems accordingly.

Knowing which data and how much data to add to S-File can seem daunting. Currently, the Air Force provides an S-File BIM template, which allows you to enter the exact information necessary, and then incorporate it into a GeoDatabase. Instructions for using the template are in a document called, "*Using the Autodesk Revit S-File Template*," which can be found by following the link below.

http://www.wbdg.org/references/afbim_tools.php.

Construction Operations Building Information Exchange

The project team, facility occupants, and owners celebrate the handover of a new, or newly renovated, facility. For those responsible for operating, maintaining, and managing that facility, the work is just beginning. To start, the facility manager begins by unpacking boxes of paper documents and retyping asset information and maintenance schedules into Computerized Maintenance Management Systems (CMMS). The pallets of boxes full of paper of O&M manuals and drawings shown in the figure below are typical of the requirements of contractors complying Unified Facility Guide Specifications 01 78 00 - Closeout Submittals, and 01 78 23 - Operations and Maintenance Data. Managing all these documents, like those shown in figure 3–28, literally consumes man-years of effort rather than man-hours.

Figure 3–28. Typical delivery of handover documents.

Construction Operations Building Information Exchange (COBie) is a performance-based specification for facility information delivery. A vendor-neutral data standard specifies how to format design and construction data used by facilities management software. COBie describes both the process of collecting and validating data, and the dataset that contains required data. Two types of assets are included in COBie: equipment and spaces. While manufacturer data for installed products and equipment may one day be directly available, COBie helps the project team organize electronic submittals approved during design and construction and deliver a consolidated electronic O&M manual with little or no additional effort. We can import COBie data directly into CMMS and asset management software, again at no cost. We organize the PDF, drawing, and building information model files that accompany COBie to ease access through the secure server directories already in place at the facility management office. COBie may meet the federal government's requirement for delivery of RPI.

Currently, the Air Force provides a BIM template that will produce COBie compliant data at http://www.wbdg.org/references/afbim_tools.php.

Model development standards

Just like CAD and 2D drawings, BIM models must adhere to set standards. In Unit 1 of this volume, you learned about the CAD/BIM Technology Center, focuses primarily on CAD 2D projects.

Architectural engineering and construction work structure

The A/E/C work structure is a common *environment* that can be used across agencies and engineering applications. The A/E/C environment contains folder structures, tools, and resource files that implement the A/E/C standard and the A/E/C graphics standard documents. Using one environment across agencies and applications gives greater consistency when delivering A/E/C standards-compliant deliverables.

As you can see in figure 3–29, there are a number of guides and videos available to teach you how to set up projects. Each title in the table below links to a video on the CAD/BIM Technology Center Website. If you have an Internet connection available, you can click the link to watch the video. Note that the site may request that you login to the site using your CAC identification.

A/E/C Work Structure Manager's Guide Videos
Installation on a LAN
Creating Shortcuts
New Projects on a LAN
Adding Electrical Building Designer content on a LAN
Customizing the Workspace
Installation in ProjectWise
New Projects in ProjectWise
Adding Electrical Building Designer content in ProjectWise with an unmanaged dataset
Adding Electrical Building Designer content in ProjectWise with a managed dataset

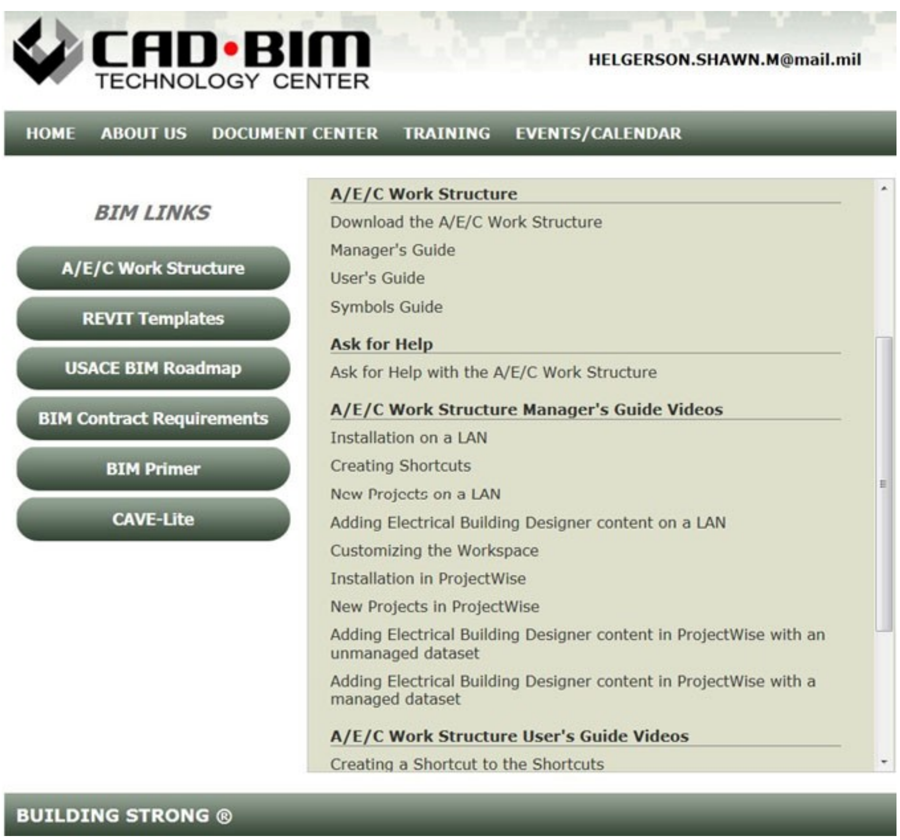


Figure 3–29. A/E/C work structure Website.

General model standards

The origin point needs to be the same as that established during the design phase of the project. All models must be in the correct location in 3D space (x, y, and z coordinates). These coordinates derived from this origin point set by the A-E team and distributed to all consultants and trade contractors for their use. This includes correct floor elevation(s) (z coordinates). *The correct insertion point is critical and ensures that each model will align properly for the master aggregate model without modification.*

Model(s) and model elements must be accurate and dimensionally correct according to contract documents. Tolerances for specific items and systems will be determined as necessary. Model tolerances are *not* construction tolerances.

All units in a BIM model will be imperial units. One (1) unit in the model equals 0 feet, 1 inch (0'–1"). While models may vary in level of detail for individual elements within a model, at a minimum they must include all features that would be included on a quarter inch (¼" = 1'–0") scaled drawing. The ¼" scale model requirement means that the software generates all of the following drawings from content that is in the BIM:

- Plans (overall and enlarged) and elevations.
- Building sections and wall sections.
- Schedules.

Building information modeling templates

BIM with the Autodesk Revit Platform offers the ability to easily configure, save, and deploy a standard working environment. Standardizing Revit templates ensures that graphic representations, data syntax, taxonomy, and software environment are consistent, and that the end deliverable will satisfy industry and USACE CAD/BIM standards.

The USACE and Autodesk collaborated to create a BIM Template Team consisting of seasoned CAD/BIM managers with a working knowledge of Revit. Each member has specific disciplinary strengths and shares a draft working district specific Revit template with the team. Each of the district's templates receives critique and testing by the group, and by teams going through BIM Implementations. The group debates feedback and decides on revisions and enhancements that supported the intent, purpose, and general needs of the USACE.

We minimize upfront time and effort required to set up, configure, and coordinate a Revit project and environment by deploying a Revit template file (.rte). Revit templates increase graphic and non-graphic consistency across teams, districts, and divisions. Templates provide a team with a common starting point and improve the overall USACE product and brand.

Reviewers based the current version of the templates on the "Out of the Box" version of Autodesk Revit 2013. We cannot use version of the template with versions of Revit earlier than 2013. To complete a project in a later version of Revit (2014, 2015, and 2016), load the .RTE template into the Revit version required by the contract and save as a new Template with the name changed to reflect the new version (example: USACE_Revit2015_ Template_ARCH_v2.2.rte).

BIM object libraries

BIM library objects are families/parts applied to assembly or component models. These can include individual walls, rooms, entire facilities, HVAC air handlers, pumps, generators, or any other sort of component part that is non-specific (not designed for) a particular building.

There are two types of elements created and stored in the object libraries: Manufacturer's Model Elements, and Custom Created Model Elements.

Elements Created and Stored in BIM Object Libraries	
Element	**Description**
Manufacturer's Model Elements	Elements created by and acquired from manufacturers often have more information than is prudent to keep in the BIM model; they retain the appropriate level of detail for the design element. However, embedded performance data needs to remain for analysis and specification purposes.
Custom Created Model Elements	Custom model elements must use appropriate BIM Authoring tool templates. Custom model components need to part of a family or group.

Model storage and maintenance

Before it begins, each BIM project needs to have a plan of development called the project execution plan (PxP). This plan ensures that the design firm clearly understands their responsibilities and expectations during project development. We use the PxP to communicate and define individual model types delivered, including production models during the design phase, coordination models during design and construction phases, and as-built models at hand-off.

During the project development, the model has to comply with the Industry Foundation Classes (IFC) data model. The IFC is a BIM platform-neutral file format specification not based on any specific software vendor. It provides better interoperability in the A/E/C industry with BIM based projects. ISO, as an official international standard (ISO 16739:2013), registers the IFC model. It is based on the building SMART alliance ™ data model (http://www.buildingsmart-tech.org/)

Once the model is delivered to the Air Force for building lifecycle use, the generation of an open, neutral format deliverable such as an IFC allows operational and maintenance applications and other various databases access to the BIM data, especially if authoring tools change after production and delivery.

Reverse BIM

If BIM is the process of creating a model of a building from conception through maintenance, then reverse BIM is creating a model of an existing building. Think of this like surveying an installation to create a GIS, but instead of an installation, it is a building (fig. 3–30).

The technology for 3D imaging systems has been around since the 1970s. However, it has only been in the past decade that the use of 3D imaging systems has become more prevalent. The applications for 3D imaging cover the spectrum from industrial metrology to remote sensing. These applications include creating 3D models (e.g., as-builts, inventory, maintenance, visualization), surveying and mapping, reverse engineering, quality control, autonomous vehicle navigation, collision avoidance, object and target recognition, forensics, historic preservation/archaeology, disaster reconnaissance, space exploration (docking of space craft and assessing damage to the exterior of space shuttle), and forest management.

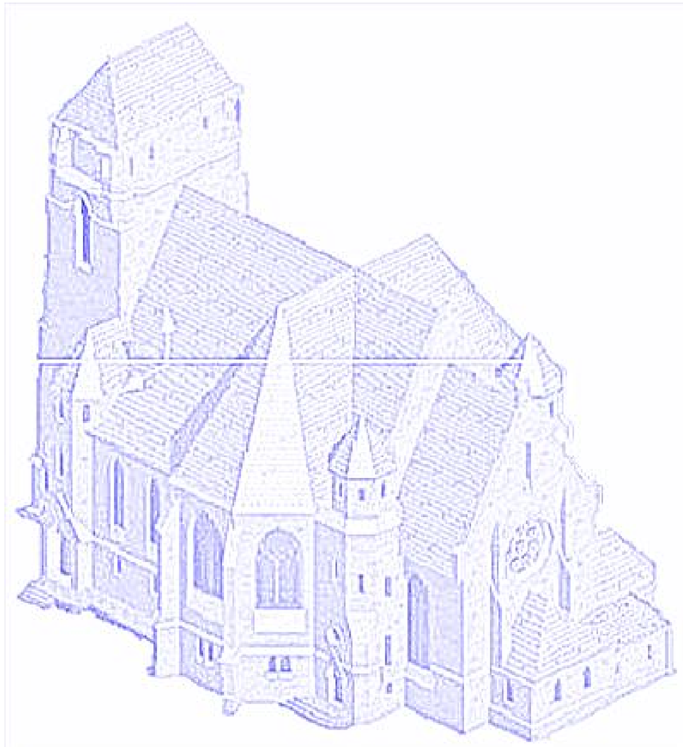


Figure 3–30. 3D models, as-builts, as-is documentation, historical preservation.

3D imaging, or reverse BIM, can meet a number of benefits for understanding existing buildings:

- Repair and restoration of an historic building's façade. The 3D imaging data provides 2D CAD elevations and section profiles, 3D geometric models, and/or 3D building information models to document as-built conditions. The data also assists in developing architectural and engineering restoration and renovation designs.
- Generation of 2D CAD and/or elevations of building exteriors where none exists. There may not be a need to document representative as-built conditions due to deficiencies in the original construction. Designers use the 3D imaging data to analyze beam deflections and develop retrofit measures.
- Provide a facility plan to map and link several buildings in a BIM site model. Visualization of data in 3D will greatly aid in the development of physical security and force protection models.
- Document mechanical, electrical, plumbing (MEP)/above ceiling conditions. In this sense, we use 3D imaging data to develop reflected ceiling plans (fig. 3–31).
- Document roof patterns.
- Document deformation or current assessment of existing structures. The renovation A/E was able to use the point cloud and 3D model information throughout the design and allowed them to see different views of the building without the need to return to the site.

The scanners use laser technology to create a 3D cloud of points, called a *point cloud* (fig. 3–32). A point cloud is a set of vertices in a three-dimensional coordinate system. We define vertices using X, Y, and Z coordinates, which are typically intended to be representative of the external surface of an object (fig. 3–33).

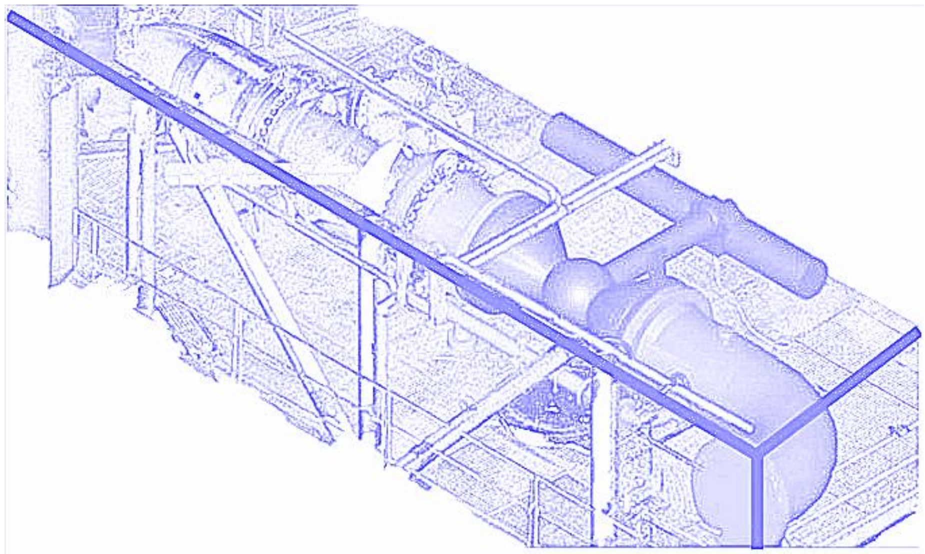


Figure 3–31. Interference checking retrofits/revamps, reverse engineering, decommissioning.

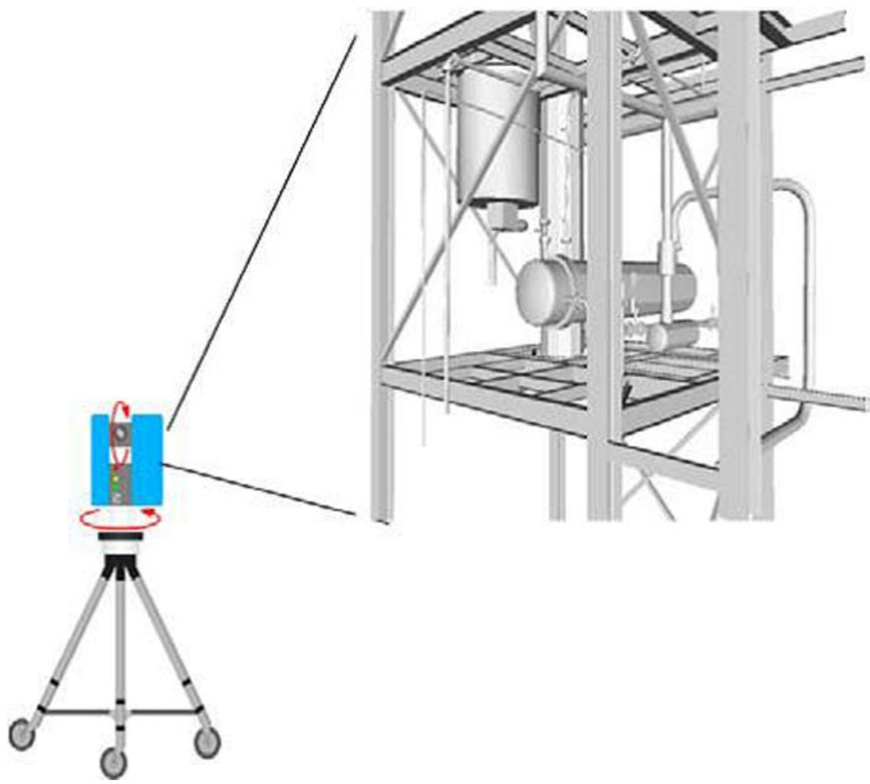


Figure 3–32. Example of laser scanner scanning industrial area.

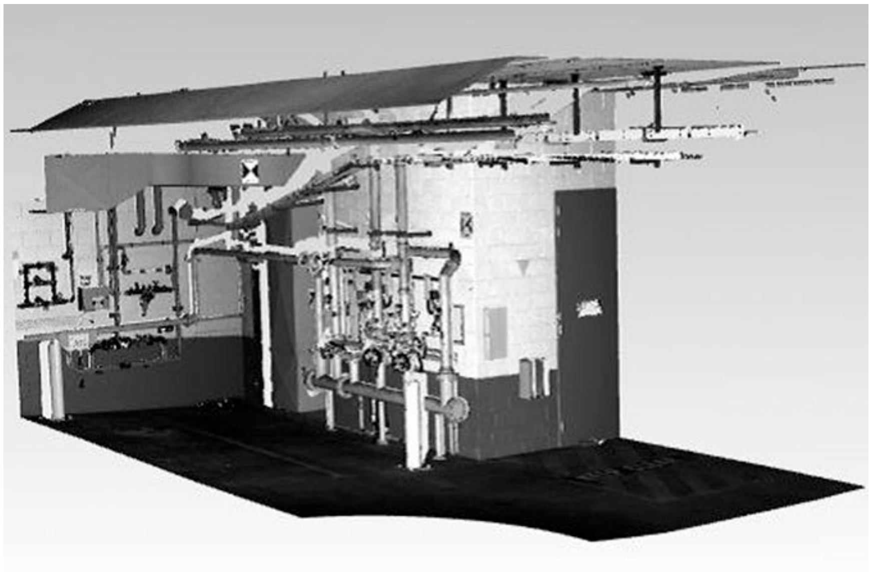


Figure 3–33. Example of a high definition point cloud.

Converting the point cloud to building information modeling

The industry uses advanced 3D modeling applications for automatically extracting simplified, highly accurate, editable 3D CAD models from point clouds.

These applications revolutionize the process of creating 3D CAD models. Using computer vision algorithms, they automatically extracts crisp, clean vectors from a scanned point cloud, creating accurate polygon models within minutes. Using this technology, we can complete complex CAD models much more quickly (fig. 3–34).

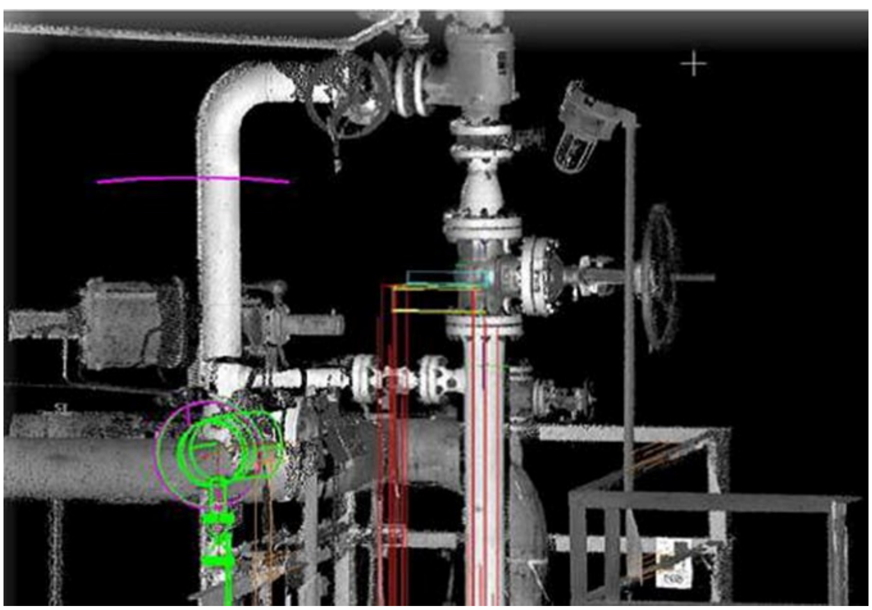


Figure 3–34. Example of a hybrid point cloud/BIM model.

The simple user interface lets you import point clouds, rapidly create ground surface models, and extract clean CAD models of any planar structures within the scene. It outputs a reconstructed model of the observed planar surfaces, fitted using least-squares regression to retain the accuracy of the original scan data.

The GSA has done a lot of work with incorporating BIM into their facility and asset management programs. To learn more about 3D-4D information modeling, go to http://www.gsa.gov/portal/content/105075.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

422. Building information modeling design applications

1. List the three ways from which we approach BIM.

2. What is the difference between a tool and a platform?

423. Organizational impact

1. What does our career field do with engineering information and design from local civilian and military engineering staff?

2. Describe a dynamic prototype.

424. Building information modeling implementation

1. What is the purpose of the DD Form 1391?

2. Describe clash detection.

425. Building information modeling in operation

1. What is contained within the A/E/C environment?

2. Describe BIM library objects.

3. What is reverse BIM?

Answers to Self-Test Questions

418

1. Better picture of the final building and it shows places where phases of construction may conflict.
2. Data.
3. By associating data within each feature of the facility.
4. Legal, financial, geospatial, designer, occupier, and environmental.

419

1. Computer processing speed, time, and budget.
2. Compatible scale.
3. 3D Orbit allows rotation around the object through all the axes simultaneously while 3D Axis allows rotation around a single axis while locking the other two.
4. Taking a 2D shape and giving it a value on the third axis.

420

1. Time, as in the project's schedule.
2. (1) Sequencing logic.
   (2) Crew sizes.
   (3) Productivity rates.
   (4) Local pricing.

421

1. B-rep and CSG.
2. Once we create an object, we can use it repeatedly without having to redefine its parameters or properties.

422

1. As a tool, platform, and environment.
2. A tool is a specialized application and a platform is a group of tools.

423

1. Create and maintain the construction documents of local O&M projects.
2. Flexible, adaptable models of buildings, or building parts already modeled and ready for use.

424

1. To submit requirements and justification to Congress to support funding requests for military construction.
2. Algorithms that identify and address clashes between objects of different trades.

425

1. Folder structures, tools, and resource files that implement the A/E/C Standard and the A/E/C Graphics Standard documents.
2. Families/parts applied to assembly or component models.
3. Creating a model of an existing building.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

50. (418) What kind of depiction of a building provides a better picture of the final product?
    a. Elevation.
    b. Isometric.
    c. Floor plan.
    d. Three-dimensions.

51. (418) Building Information Modeling (BIM) combines the best of two-dimensional (2D) and three-dimensional (3D) drafting with the best of
    a. builder software.
    b. Access databases.
    c. estimating software.
    d. geographic information systems (GIS).

52. (419) What do we call the relationship between the parts of a project and their environment?
    a. Scale.
    b. Detail.
    c. Volume.
    d. Exaggeration.

53. (419) What is the name given to the ability to highlight or subdue aspects of a drawing?
    a. Realism.
    b. Volume.
    c. Proportion.
    d. Exaggeration.

54. (419) Which tool allows you to select an object or overall model and rotate it throughout the X, Y, and Z-axes?
    a. Pan.
    b. Walkthrough.
    c. Three-dimensional (3D) Axis.
    d. Three-dimensional (3D) Orbit.

55. (420) What do we add to change a four-dimensional (4D) Building Information Modeling (BIM) design into five-dimensional (5D)?
    a. Cost estimates.
    b. Maintenance.
    c. Occupancy.
    d. Schedules.

56. (420) What do we add to change a five-dimensional (5D) Building Information Modeling (BIM) design into six-dimensional (6D)?
    a. Estimates.
    b. Schedules.
    c. Occupancy.
    d. Maintenance.

57. (421) In Building Information Modeling (BIM), what name do we apply to rules that determine an objects geometry?
    a. Features.
    b. Attributes.
    c. Principles modeling.
    d. Parametric modeling.

58. (421) Which form of solid modeling represents a shape by a set of mathematical functions?
    a. Boundary Representation (B-Rep).
    b. Constructive Solid Geometry (CSG).
    c. Constraint Boundary Illustration (CBI).
    d. Bound Framework Construction (BFC).

59. (422) What do we call the applications used to create estimates, model an object, or create a schedule?
    a. Tools.
    b. Platforms.
    c. Accessories.
    d. Environments.

60. (422) What do we call a group of applications produced by a vendor or vendors that interact to create a model?
    a. Tools.
    b. Platforms.
    c. Accessories.
    d. Environments.

61. (423) Who is currently the primary source for construction document creation, storage, and maintenance at an installation?
    a. Operations.
    b. Contracting.
    c. Engineering.
    d. Force Support.

62. (423) What is a flexible, adaptable model of a building, or building parts already modeled and ready for use?
    a. Architect-Engineer (A-E) design.
    b. Three-dimensional (3D) object.
    c. Dynamic prototype.
    d. Pre-made build.

63. (424) Which Department of Defense (DOD) standard do spatial validation report Space Naming conventions follow?
    a. Engineering Floor Plan Guide (EFPG).
    b. Real Property Categorization System (RPCS).
    c. Facility Space Utilization Conventions (FSUC).
    d. Open Standards Consortium for Real Estate (OSCRE).

64. (425) What work structure is a common environment that we use across agencies?
    a. Computer-aided drafting (CAD).
    b. Recurring Work Program (RWP).
    c. Building Information Modeling (BIM).
    d. Architectural Engineering and Construction (A/E/C).

65. (425) Which file extension is the suffix for a Revit template file?
a. .rte.
b. .jpg.
c. .exe.
d. .dwg.

Student Notes

Glossary

Abbreviations and Acronyms

°	degree
2D	two-dimensional
3D	three-dimensional
4D	four-dimensional
5D	five-dimensional
6D	six-dimensional
AC	asphalt concrete
ACC	asphalt cement concrete
ACES	automated civil engineering system
ACU	air conditioner unit
A-E	architect-engineer
A/E/C	architectural engineering and construction
AF	Air Force
AF/A7C	Air Force Civil Engineer
AFCEE	Air Force Center for Engineering and the Environment
AFI	Air Force instruction
AFMAN	Air Force manual
AFNet	Air Force Network
AFPAM	Air Force pamphlet
AFSC	Air Force specialty code
AGS	Architectural Graphics Standard
AHU	air handler unit
AM	Asset Management
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BCE	base civil engineer
BIM	building information modeling
BOM	bill of material
B-rep	boundary representation
CAC	Common Access Card
CAD	computer-aided drafting
CAD-BIM	Computer-Aided Drafting-Building Information Management

CADD	computer-aided drafting and design
CBR	California Bearing Ratio
CDC	career development course
CD-ROM	compact disc read-only memory
CE	civil engineer
CES	civil engineer squadron
CGTC	Computer-Aided Drafting and Design/Geographic Information System Technology Center
CMMS	Computerized Maintenance Management Systems
CO	contracting officer
COBie	Construction Operations Building Information Exchange
CoS	Centers of Standardization
CSF	one hundred square feet
CSG	Constructive Solid Geometry
CSI	Construction Specifications Institute
DBA	Davis-Bacon Act
DCP	Dynamic Cone Penetrometer
DD	Department of Defense
DI	design instruction
DO	delivery order
DOC	delivery order contract
DOD	Department of Defense
EA	engineering assistant
ETL	engineering technical letter
FAA	Federal Aviation Administrations
FAR	Federal Acquisition Regulation
FARS	Federal Acquisition Regulation System
FY	fiscal year
GEN	generator
GFE	government-furnished equipment
GIS	geographic information system
GSA	General Services Administration
HMA	hot mix asphalt
HVAC	heating, ventilation, and air conditioning
IDIQ	indefinite delivery indefinite quantity
IFC	Industry Foundation Classes

IMT	information management tool
Incl	including
ISO	International Standards Organization
IT	information technology
IWMS	Integrated Workplace Management Systems
JOC	job order contract
LAN	local area network
LEED	Leadership in Energy and Environmental Design
LL	liquid limit
MACC	multiple award construction contracts
MAJCOM	major command
MBF	one thousand board feet
MEP	mechanical, electrical, and plumbing
MFR	memorandum for record
MILCON	military construction
mm	millimeter
MTO	materials takeoff
NOAA	National Oceanic and Atmospheric Administration
O&M	operations and maintenance
O&P	Overhead & Profit
OBC	optimum binder content
OCA	Office of Chief Architect
OSCRE	Open Standards Consortium for Real Estate
OSHA	Occupational Safety and Health Administration
$\mathbf{P_{be}}$	Permeable void
PBS	Public Building Service
PCC	Portland cement concrete
PDF	portable document format
pdf	public domain format
PI	plasticity index
PL	plastic limit
psi	pounds per square inch
PxP	project execution plan
QD	quantity-distance
RED HORSE	Rapid Engineer Deployable Heavy Operational Repair Squadron Engineer

RFI	request for information
RFP	request for proposal
RPCS	Real Property Categorization System
RPI	real property inventory
RWP	Recurring Work Program
SABER	simplified acquisition of base engineer requirements
SCA	McNamara-O-Hara Service Contract Act
SDSFIE	Spatial Data Standards for Facility, Infrastructure, & Environment
SOW	statement of work
SSD	saturated surface dry
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specifications
UPB	unit price book
US	United States
USACE	United States Army Corps of Engineers
USCS	Unified Soils Classification System
V_a	voids with air
VA	Veterans Affairs
VFA	voids in asphalt
VMA	voids in mineral aggregate
WAN	wide area network
WBDG	Whole Building Design Guide
WORB	Work Order Review Board
XD	existing/demolition

Student Notes

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