Plan Reading and Cost Estimating

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1. INTRODUCTION

Construction plan is an essential element of a construction project. Architects and/or engineers prepare construction plans that include drawings and specifications. These plans are subject to the approval of a local authority to obtain a permit for construction. Builders or constructors read the plans, estimate the cost for construction, and bid on the project. In addition, the constructors have to follow the plans to build. In this connection, plan reading capability plays an important role in obtaining and conducting a construction project.

The purpose of this paper is to demonstrate methods in reading plans and estimating the associated cost of the project . The specific objectives of this paper are listed below:

(1) Describe the process of a construction project.

(2) Classify the contents of plans for the construction project.

(3) Specify the requirements of equipment and knowledge in plan reading.

(4) Provide a method on how to read a construction plan.

(5) Explain how to estimate the cost of construction and its relation with engineering work.

2. THE PROCESS OF A CONSTRUCTION PROJECT

A construction project begins with development assessment and ends at the completion of the final inspection. This process can be shown below (Reference 1, ACA):

- The owner of a construction project should generally conduct development assessment. The assessment is a planning process that evaluates the feasibility, potential issues, fee estimates, and other requirements for the project.
- Zoning review is part of the assessment for the construction process, which may impact the development in several ways such as traffic, land use, and environmental conditions.
- Following development assessment, the owner selects architect and/or engineer for the construction of the project, based on their qualifications.
- The architect and/or engineer prepare construction plans and engineering report for the project. These documents are also distributed to the offices of various development service providers.

- The contractor or constructor who are interested in the project must be able to read these plan and report documents in order to estimate the cost of the construction, and in turn, to bid on the project. The owner selects a prime constructor based on the quote of the price, and sometimes also on the value or quality of the bid.
- The prime constructor may recruit subcontractors for part of the construction. The selected subs will have to read the associated portion of the construction plan. All subs must also conduct work according to the project schedule in order to finish the construction on time.
- Value engineering plays an important role in a construction project. Value engineering refers to the tasks of construction plans and the management of the construction. It is to achieve a maximum value for the construction while the cost for the construction can be minimized.

3. CONSTRUCTION PLANS

The technical documents for a construction project are construction plans and engineering report. For plan reading, the contractor or constructor has to understand that the construction plans consist of many elements, as listed below (Reference 2, COA):

(1) Zoning Plan is to identify the characteristics of the land for development, its appropriateness, whether complying with the development requirements, and its impacts on traffic and environment.

(2) Site Plan may include subdivision layout and site design. It shows many site characteristics including, but not limited to, street, utilities, grading, drainage, flood plain, trees/vegetation, and environmental controls.

(3) Structure Plan includes, depending on the types of development, buildings, facilities, various types of infrastructures, etc. Structure Plan has a general layout or sketch and the detailed drawings that take time and experience to read.

(4) MEP Plans refers to mechanical, electrical, and plumbing plans. Mechanical plans usually consist of mechanical equipment and their relations to electrical sources. Air conditioning and heating systems, ventilation facilities, and safety equipment are examples of mechanical plans. Electrical plans show power source and electrical circuits. Electrical drawing is in accordance with electrical loading calculations. It also has elevation plans to show power source locations. Pluming plans are water supply and wastewater systems sketches. They generally have plan layouts, and elevation views to show ventilation and relative locations.

(5) There may be other drawings to be included in the above-described plans, such as commercial signs, traffic routes and barricades, fire safety equipment, waste disposal sites, and underground tanks.

4. KEY ELEMENTS FOR PLAN READING

There are some elements that plan readers should understand in order to read construction plans in a better fashion. The construction plans need to be organized that readers can easily locate a portion of the plan and can better understand the plans. Following provides a description of these elements:

(1) Organization of construction plans:

- Each sheet of the construction plans is labeled with, on one edge of the cover sheet, the specific information about the project. This information generally includes the name of the engineering or architectural firm and its contact information, the seal of the registered engineer or architect from this firm, the name of the job and/or project, the project number, and the date of drawing.
- Each sheet is also assigned a page number. If the category of the construction plans is simple and there are several pages, e.g., eight (8) pages, the page number can be arranged as "1 of 8," "2 of 8," -----, and "8 of 8." Otherwise, the assignment of page number could be more complicate. For a set of plans that there are several categories and each category has some sub-categories, such as site, building, and MPE plans, then a "letter" is placed in front of the numbers for each page. For example, a mechanical plan may have 2 sub-category plans totaling of four (4) sheets, they may be marked as M1-1, M1-2, M2-1, and M2-2. In general, a table is tabulated on the cover sheet, which shows the sheet or page number and the corresponding description for this page.
- Each sheet represents one part or the entire portion of a specific plan. The drawing for the specific plan or for even one sheet of the plan may not be sufficient to identify the required construction. Plan reader has to review the general or specific notes on each or some sheets of the construction plan. These notes specify the additional requirements, and the code or rule of the permitting authority.
- The relative direction for the subjects on a drawing sheet is usually identified by an arrow pointing to the north. This "arrow" is an essential element for some drawing sheets of the construction plan.

(2) Scale of the Drawing

Scale ruler is an important tool in plan reading. The actual size of the subject such as a building, a road, or a construction site is usually too large to be drawn on a drafting paper. Engineer or architect identifies a large subject using so called "scales."

Engineer demonstrates scales as 1-inch = n-feet, or $1'' = n'$. For example, $1'' = 4'$ means 1-inch length on the drawing represents 4-feet length for the actual subject. For the same token, $1'' = 20'$ means $1'$ measurement representing a length of $20'$. Architect expresses scale in a little different way, but the result is similar. For example, the scale of $1'' = 4''$ is written as 1/4-inch = 1-foot and zero-inch ($1/4'' = 1'$-0"). A scale ruler has marks of different series. Each series consists of a number of units in inches or centimeters.

One unit or its sub-unit is always divided into ten (10) parts. A plan reader can measure any length on the drawing using a scale ruler, with an adequate accuracy.

(3) Legend

Legend generally consists of “lines” and “symbols,” which are used for drawing, measuring, identifying, and describing objects on the construction plans. Although many “lines” and “symbols” adopted for construction plans follow the same standard, they could be different from one set of drawings to another. A plan reader should review the “legend” being used for any specific plan.

(4) Schedule of Building Components

A schedule for construction plans is an organized method to present information concerning some building components, as specified by Kubba (Reference 3, Kubba). The schedule is generally a tabulation that lists information for specific group of some components. There are many ways to set up a schedule or table. For a door schedule, for example, it provides information of product name, model number, quantity, dimension, material, and color.

Schedule is a convenient way to identify information in the construction plan. It shows the detailed information of an equipment system, or provides the characteristics of each unit for a specific group of items. Many different items or features may be described in schedules, such as doors, windows, columns, beams, light features or equipment, plumbing and mechanical equipment, interior finish, HVAC schedules, etc. It’s easy for a plan reader to identify the quantity, dimensions, and features of the same products of items. In turn, it’s convenient for a contractor to conduct cost estimates for a project.

(5) Calculations

Except layouts, plans, schedules, legend, there may be calculations for a set of construction plans. Calculations for MPE plans are general necessary. For a mechanical plan, ventilation system is generally an essential part of the plan. An exhaust air calculation is necessary. The essential part of an electrical plan is the load calculation. Load is electrical power, which is the “voltage” multiplying by the “current.” The total load or current capacity requirement for a facility must be carefully evaluated. This calculation takes into consideration of power source and the electricity needed for all electrical equipment. As to plumbing, both gas and water require calculations. The size of pipes and equipment should be evaluated by calculation.

A plan reader should generally understand these calculations in order to determine the needs of some important MEP equipment. In turn, the estimator can evaluate the over cost of the MEP installation.

5. PLAN VIEWS

There is a sequence of plans for a construction project, as described in Section 3. These plans for different projects such as building, water facility, street or highway, wastewater collection system, etc. are also different. Nevertheless, the types of plan views are generally uniform for different drawing sheets. According to French, etc. (Reference 4, French), it lists orthographic drawing, auxiliary view, cross section view, and pictorial or three-dimensional sketches. It also presents standard “lines” and “symbols” used for technical drawing.

This study covers orthographic, auxiliary, and cross-sectional views, as well as the explanation of standard “lines” used for drawing these views. This presentation may be useful in assisting local contractors on how to read plans and bidding on construction projects.

(1) Orthographic view

This view of plan is a three-view drawing as specified by Olivo, etc. (Reference 5, Olivo). The drawing has three views, i.e., front view, top view, and side view, to describe an object. Each view is a perpendicular projection of the corresponding surface of this object. For example, top view is the perpendicular projection of its top surface.

An orthographic view may not be able to represent, or clearly represent, an object when the shape of the object is irregular or more complicate. In this connection, more project plans or other type of drawings should take place. Figure 1 of the next page shows the projections of an orthographic view. Figure 2 is a completed plan of orthographic view. This plan is composed of different lines, which draw the object in three views. Table 1 of the next page provides an explanation of all lines that constitutes the object and its dimensions.

Table 1

Lines used in a Plan Drawing

Line ID	Name of Line	Description
A	Object line	Thicker line; represents shape & boundary of the object
B	Hidden line	Dotted line; inside the object being hidden or invisible
C	Center line	Thin, broken line of long & short dashes, alternately spaced
D	Extension line	Thin line for presenting dimension of any side of an object
E	Dimension line	Thin line broken at the “length” mark and ending at two sides with arrowheads
F	Cutting plane line*	Thick, broken line with one long & two short dashes, spaced alternatively; two arrows identify the direction that the section is drawn

* Cutting plane line is shown in Figure 4.

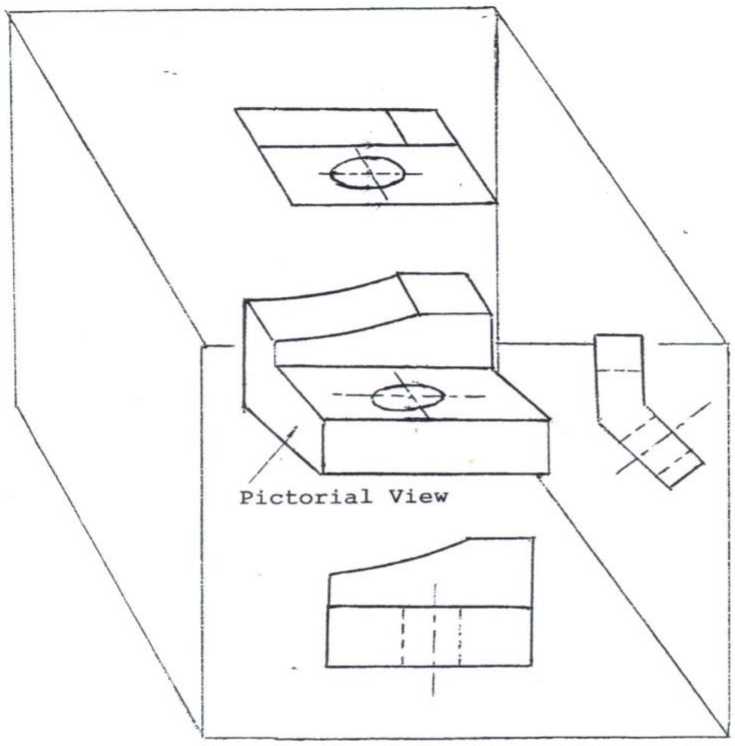

Figure 1. The pictorial view of an object and its orthographic or perpendicular projections

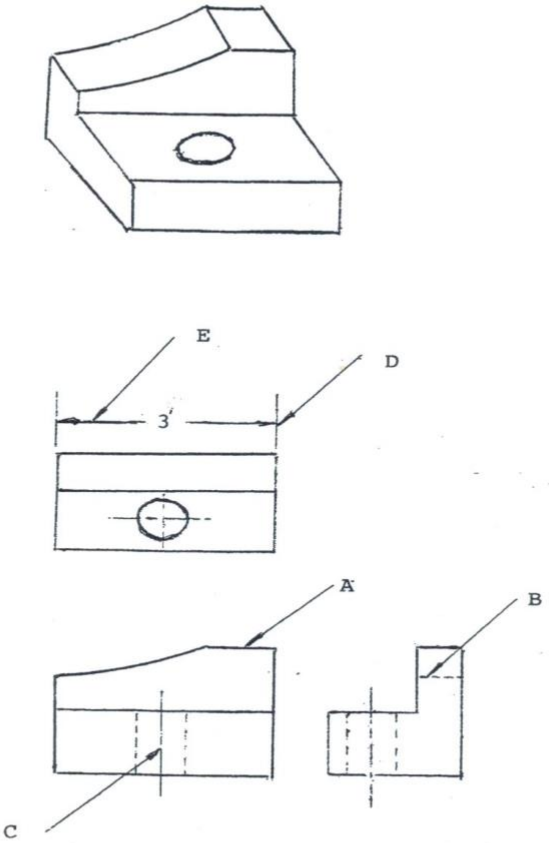

Figure 2. Orthographic view and line types of plan drawing

(2) Auxiliary view

In the orthographic drawing, the object for drawing is regular. One of the three views of the object is regularly projected to the other two views. In other words, any one side of a view is either parallel or perpendicular to any one side of the other two views. Therefore, the object can be clearly expressed. In some cases, the object is irregular. Its orthographic view cannot adequately identify the object.

As shown in Figure 3, an auxiliary view has to be drawn to clearly identify the object. In Figure 3, any side of the auxiliary view is either parallel to or perpendicular to line AB, or the top side of the object's side view. The height of the auxiliary view is equal to the length of AB. The width of the auxiliary view is equal to CD, the width of the object's front view. The diameter of the hole on auxiliary view is equal to the longer axis of the oval type hole on the front view.

(3) Sectional view

In addition to orthographic and auxiliary views, plan reader should understand sectional view which is important in many cases. Frequently, it's difficult to show an object when the other views present too many hidden lines. To see an interior section, a reader has to image to cut a portion or the cross section of the object. This appearance of the interior section is a sectional view. The plane cut can have different types, mainly a full section or a partial section.

Figure 4 provides an example of a section view, which is the result of an imaginary cut. A "cutting plan line" is composed of thick, long dashes of equal length. This line cut through to show the cross section of a small earth dam. The cross section is identified by the letters A-A. The two arrows indicate the direction in which the section is taken.

A cross section is to show the details of the interior portion. As shown in Figure 4, this section provides a detailed view of an earth dam. It shows the crest, the core, the trench, the foundation, the embankments, and the seepage drain of the earth dam.

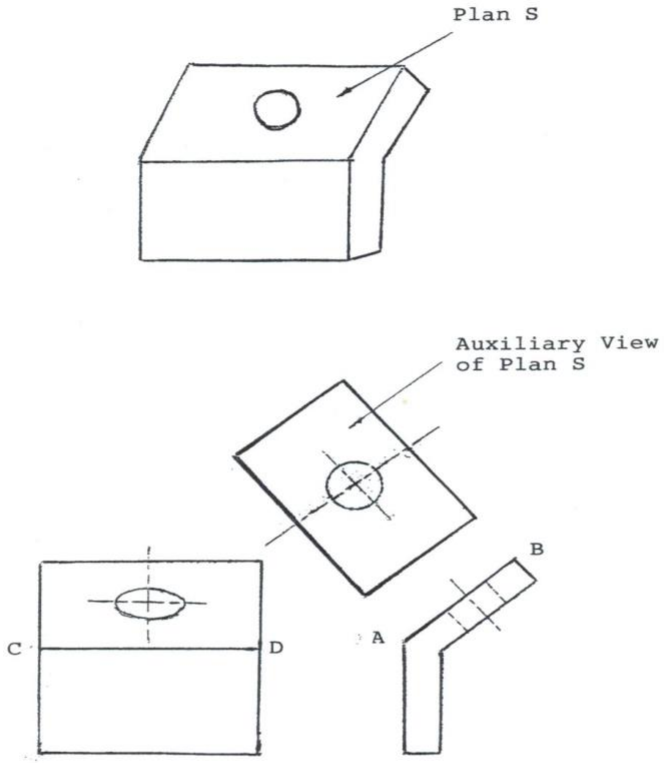

Figure 3. Auxiliary view for plan drawing

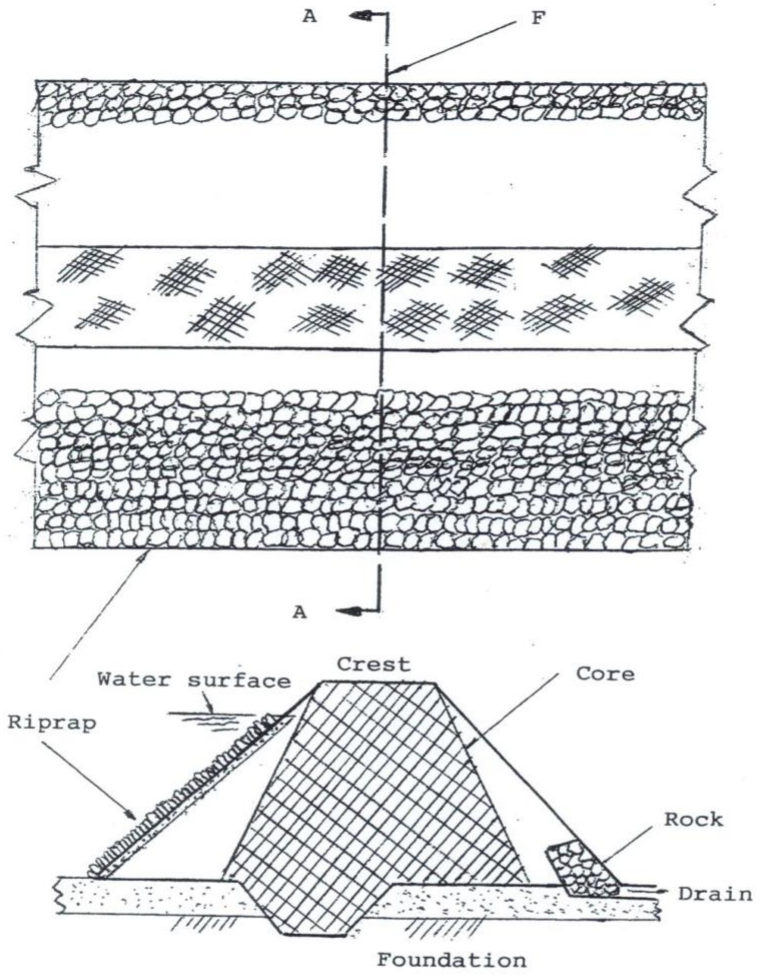

Figure 4. Sectional view of plan for an earth dam

6. COST ESTIMATING

In general, a contractor has to read construction plan and engineering report to decide whether to bid on a project. Plan reading provides information as listed below:

- Types and scheduling of construction.
- Dimensions or measurements of objects in the construction plan.
- Quantity of objects to be constructed.
- Specifications and/or requirements for the construction.
- Degree of difficulty pertaining to the construction.

(1) Value engineering in cost estimating (Reference 6, Ding)

By obtaining the above information, the contractor can evaluate project cost by knowing the costs of materials, equipment, and labor. In addition, it's necessary to know the prices of bonding, insurance, and overhead costs such as site visits, bid preparation, and desired profit. Sometimes hiring subcontractors may save some insurance and labor costs. Cost comparisons with similar jobs of the past can play an important role too.

Job quality is another important factor, especially when quality value is part of the bid. In this connection, the quality of materials, the selection of labor or subcontractors, the construction schedule, and the tolerance of measurements are all associated with the cost estimation.

In summary, the optimum estimate of cost is to minimize the project cost, subject to quantitative and qualitative requirements as specified in the above two paragraphs This estimation complies with the meaning of value engineering, which is to achieve a maximum quality value for a specific expenditure in a project.

(2) Estimation of labor cost

The labor cost is an essential portion in total project cost. The contractor may use information below to estimate labor cost for a specific job.

The unit labor rate can be estimated in two ways. Labor for each profession has a prevailing rate depending on the geographic areas. Also, there is a unit labor rate for a specific type of job or project (References 4-5). The total time needed for a specific job depends on the project schedule and the work experience for the similar project. There must be a time schedule for each construction project. This information can also be obtained from available references such as those specified above. The overhead cost and the desired profit for a project are not be necessary included in the labor cost for an easier estimation.

(3) Overhead costs

The overhead costs for a project normally consist of these items as listed below:

- Costs of insurance, bonds, work comp.
- Transportation related costs.
- Equipment rental costs and the depreciation of the owned equipment.
- Cost of preparation for bidding, which may include bid, proposal, or qualification.
- Cost of office use and the expenses for furniture.

(4) Requirement of skills for cost estimation

To be effective in cost estimates, a contractor should have adequate knowledge in construction, engineering, and management. This may include:

- Understand the process of construction and the details of each process so that the required labor and materials for each specific job can be quantified.
- Be able to read construction plans so that the project items, and the dimensions and specifications of each item can be identified.
- Be able to develop project schedule and project management plan for the construction so that the project cost can be better estimated.

7. CONCLUSION

This study described plan reading and cost estimating for a construction-related project. Plan reading has two functions. First, the contractor has to follow the plans to build. Secondly, the cost of the project can be estimated by reading the plans. As a contractor working in the field of construction, one should be capable of reading engineering or construction plans.

The study presents engineering drawings in different forms. The drawings can be considered as examples of a construction plan. These drawings provide a clear reading of the dimensions and specifications for some objects. By knowing the dimensions and specs of an object, the cost pertaining to the object can be quantified. And in turn, the cost of the project is estimated.

In addition to the cost of material and labor, there are overhead costs such as the expenses of insurance and transportation. In general, the overall cost for a project should be optimized. The optimization is to minimize the total cost, subject to the quality and quantity requirements for the project.

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