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**Course CE12B - CIVIL ENGINEERING DRAWING**

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## PREFACE

Civil engineering drawing and structural detailing are concerned with translating the work of a civil engineer into drawings which can be used by a builder to guide the construction of the desired structure. It sounds quite simple. The fact that it is not is shown by the many mess-ups that occur during the construction process - many of which are attributable to poor drawings.

The reasons why problems occur are many. For one thing, not all designers have enough technical appreciation of how things are done on site, and for another, contractors often do not understand the logic behind the design. The overriding task of the draftsperson is to anticipate and avoid these shortcomings. Working drawings must be produced that explain the intentions of the designer and are easy for the contractor to follow.

The draftsperson should, ideally, have a good understanding of both theory and practice, and, hence be experienced in both the fields of design and construction. However, this is not always the case.

Firstly, engineering drawing is a 'game' played according to a set of rules. The materials that are used structurally are as standardised as possible. The quality of the material used is specified in detail according to accepted standards, and also the sizes of the sections that are normally used are standardised. This obviously simplifies the process. Non-standard materials can be used, but they are not readily available, usually cost more, and complicate the design process significantly.

**Standardised Materials - 1- quality of material**
**2- size of elements**

In addition to this, the way in which the drawings themselves are presented follows its own set of rules. There are, for example, standard views and projections, standard scales, and standard symbols and notation. These standards are used and accepted by all parties to the process, because they are understood by all, and this common understanding greatly reduces the risk of error due to break downs in communication.

**Standardised drawings - 1- views**
**2- projections**
**3- scales**
**4- symbols**
**5- notation**

The construction industry also has adopted a number of conventions regarding standardisation of specific techniques. There are, for example, standard sizes for spacings, holes, and edge distances as well as for the cover of concrete required over reinforcing steel for specific purposes. These standards have been developed over the years based on vast practical experience, and help to ensure that constructed works provide both safety and good service.

**Standard techniques -**
**1- hole spacings**
**2- hole sizes**
**3- edge distances**
**4- concrete cover on reinforcement**

Standards sound inherently boring, but they do help to ensure that you can understand an engineering drawing anywhere in the world, even if you do not understand the local language.

The rules of the game that we are talking about are contained in a number of documents. Some are in books of Standards, e.g. the British Standards, some in proprietary handbooks and others are in reports and recommendations of learned bodies. It is the draftsperson's responsibility to keep sufficiently up-to-date.

## THE CONSTRUCTION PROCESS

### INTRODUCTION

The construction process starts off with a client, the person or group that wants a structure erected, and who will pay for that structure to be erected. The client generally decides broadly what is wanted - whether it is a house a school, a block of flats, a factory, a warehouse, a road, a harbour or a bridge of a certain size. He will often have ideas about its shape and appearance and what form of construction should be used, and these ideas will usually be constrained by local planning regulations and environmental considerations.

It is the designer's job to ensure that drawings are prepared that will meet the client's needs as well as those of the regulating authorities. This responsibility may fall on the architect or the engineer, or it may be shared between them, with the architect taking responsibility for the project lay-out and the general use of space and the engineer for the structural framework and detailing

The design of the structural framework requires the structural engineer to have and to use knowledge of structural mechanics, of bending moments and shearing forces, of loadings and moments of resistance. The distribution of loadings will enable the sizes of the members required in each position and the nature of the connections between them to be calculated. Aesthetic and structural needs must be balanced in arriving at the design of the finished structure.

## CIVIL ENGINEERING DESIGN FUNCTIONS

Before any structure can be constructed it must go through a variety of different design processes, each of which requires different sets of inputs and produces different forms of output. The information produced during these design processes must be interpreted and incorporated into the physical design, so that it can be transmitted to the contractor(s) who will have the responsibility for building the project. Depending on the type of the project some of these functions may be handled by other professionals, like electrical engineers or architects, but the following list gives some idea of the range of design functions that must be performed.

| **Phase** | **Design function** |
|---|---|
| Feasibility study | Selection of structural alternatives<br>Economic feasibility analysis<br>Environmental Impact Analysis<br>Space (accommodation) mix analysis |
| Programming | Problem structuring<br>Activity data analysis<br>Space needs projection<br>Circulation analysis<br>Preliminary Cost-Benefit Analysis<br>Preliminary bar-chart production<br>Preliminary critical path analysis |
| Site Planning | Site Survey<br>Site mapping<br>Slope analysis<br>Drainage analysis<br>Cut and fill analysis<br>View and exposure analysis<br>Accessibility analysis<br>Site plan synthesis |
| Schematic design analysis | Floor plan layout<br>Roof plan layout<br>Three-dimensional spatial synthesis |
| Performance & cost analysis | Check for compliance with brief<br>Detailed circulation analysis<br>Preliminary structural analysis<br>Heat gain and heat loss computations<br>Natural lighting analysis<br>Artificial lighting analysis<br>Shadow pattern analysis<br>Sound transmission analysis<br>Preliminary detailed cost analysis<br>Prepare sketch plans, elevations & sections<br>Prepare perspectives & models |

| | |
|---|---|
| Detailed design | Building products data retrieval<br>Preparation of details<br>Structural member selection and sizing<br>Mechanical and electrical system detail design<br>Duct, pipe & electrical network layout<br>Plumbing and wastewater disposal designs |
| Costings | Generation of Bill of Quantities<br>Pricing of Bill of Quantities<br>Final Detailed cost analysis<br>Generation of detailed development schedule<br>Generation of specifications<br>Preparation of working drawings |
| Management | Project network analysis<br>Precedence diagramming<br>Project cost control system development<br>Detailed job costing<br>Measurement of work done<br>Preparation of 'As-Made' Drawings<br>Time and payroll functions<br>Invoicing |

**TYPES OF DRAWINGS**

It will be clear from the foregoing list that there are many functions which call for the preparation of the different types of drawings which are required from the time the architect or engineer has first contact with the client to when the construction project is completed. These drawings include everything from freehand to hard line work, from sketches on ordinary letter size paper to ink on polyester film. Basic drafting skills are utilized in every facet of the development of building construction drawings.

Various types of drafting techniques are required to illustrate the concept of the finished structure during the different phases from programming through contract documents which include working drawings and specifications. Addendum drawings may be required during the bidding phase and bulletin (modifications) drawings during the construction. Most construction projects consist of six phases. For the purposes of this discussion the six phases are listed below:

a. Programming
b. Schematic design phase
c. Preliminary (design development) phase
d. Working drawing phase
e. Bidding or negotiation phase
f. Construction phase

**a. Programming**
The programming phase requires graphic representations for two main purposes:

***1. Planning & Scheduling Charts***

Clients invariably wish to be provided at least with sketches of the proposed building, as well as some indication of how the overall development will be programmed. Civil engineering drafters are not involved in this phase unless a preliminary bar-chart or network needs to be presented.

***2. Renderings***

Renderings are three-dimensional pictorial drawings used to illustrate the project. Frequently it is necessary for architects to prepare pictorial drawings that can be easily understood by persons without technical training. The primary purpose of such drawings is to show buildings as they will appear to an observer after the buildings are completed. Some A/E firms even construct scale models of the project to define more clearly the intended end result of the construction. Modelmaking is a specialty business and should usually be left to the experts.

There are excellent texts available for those drafters who desire to explore further the subject of rendering drawings (perspectives and axonometrics).

**b. Schematics**
The schematic design phase is the first phase of building construction drawing development and is also the first stage of involvement for drafters. A schematic drawing is basically an outline drawing showing the bare essentials of the structure. Some firms do all schematic work on 210x279 mm sheets, while others use full-sized drawings. The drawings developed at this stage are never used by contractors for building construction, but the quality of drafting should satisfy the intended purpose, that is, the line work should be sharp and clear, and the lettering should be legible.

The type of drawings developed depends upon the scope of the project and practice of the firm. Whatever the case, a basis of design will be developed for presentation to the client for approval. This could include a simple floor plan with elevations developed from initial freehand sketches. The end result of this work is to adequately define the intended structure in sufficient detail to convince the client that his needs have been interpreted properly.

**c. Preliminary Drawings**
Preliminary drawings are usually on full-sized sheets similar to those used for working drawings. These are primarily single-line drawings showing architectural and engineering design in greater detail. This is actually the design development phase and includes the following information:

> *a. Architectural* - floor and roof plans showing space assignment, sizes and outline of fixed and movable equipment; elevations and typical sections; shafts and stairways; site plans showing roads, parking areas and sidewalks, utilities, and site conditions and constraints.

*b. Mechanical & Piping* - single line layouts of all duct and piping systems; riser diagrams where applicable; scale layout of boilers and major associated equipment and central heating, cooling and ventilating units; fire protection system; and plumbing piping and riser diagrams.

*c. Electrical* - plans showing space assignment, sizes and outline of fixed equipment such as transformers, main switch and switchboards, and generator sets; riser diagram showing arrangement of feeders, subfeeders, bus work, load centers, and branch circuit panels; and security and fire alarm systems.

*d. Structural* - basic building structural systems; column locations; footings and foundations.

The information shown on preliminary drawings must be sufficient to describe the project adequately. The design is frequently done at 1:200 scale, but then these drawings are usually *discarded* after the preliminaries are completed and approved by the client. The drawings are *discarded* to reference use only and new 1:100 or 1:50 scale drawings are made for working drawings. On smaller and less complex projects, the preliminaries are done at the scale intended for working drawings; for example, 1:100 or 1:50 scale. These drawings are then developed to the point necessary to describe the project adequately, and obtain approval from the client. After such approval, work is continued on these drawings until they are fully documented and detailed for use as working drawings. In this way no drawings are wasted and usually design time is reduced and money is saved for the A/E. Details may be at 1:20 or larger.

**d. Working Drawings**

Working drawings are actually the end result of the entire drafting and design effort. These are the drawings used by contractors to construct the structure. From 40 to 70% of the design time and total fee is consumed during the working drawing phase, therefore it deserves due consideration by the engineer and client.

After the preliminary (design development) drawings have been completed and approved by the client, they are used as the basis for the development of working drawings. A recent contract describes what is expected of working drawings *WORKING DRAWINGS SHALL BE COMPLETE AND ADEQUATE FOR BIDDING, CONTRACTING, AND CONSTRUCTION PURPOSES.*

## DETAILING

### 1. The role of the detail

Once the finished design has been agreed upon, the detailed drawings can be prepared which will enable the structure to be erected. The main structural elements in a steel structure are invariably fabricated off site, in a factory, where the different elements can be cut very accurately to length. Reinforced concrete structures are generally erected directly on site *(in situ) ,* though certain elements may be made off site in a factory (precast), before being brought together for assembly.

Producing detailed drawings requires that the structure be broken down into its component parts and that drawings are made of each part. These drawings must tell the fabricator precisely how each is to be made, of what materials and in what quantity. The parts must be detailed so that they will fit together and be erected in the most economical way. This sounds simple, but is no mean task and it does require the detailer to know how the structure is going to be manufactured and erected. This requires the draftsperson/detailer to become familiar with the problems that arise in fabrication and erection.

## 2. The role of the detailer

It should be apparent that the draftsperson/detailer is an extremely important person, who can make a considerable contribution to the construction process. He/she is essentially a communicator using a drawing to transmit information. It is crucial that the draftsperson, works in a methodical way to present the fabricator with all the information required, in a logical order. The best way to do this is to imagine oneself in the position of the person whose task it is to fabricate the piece. Consider the simple example of a steel beam - what is it necessary to know?

What type of section is required - is it a universal beam, a joist or a channel?
What nominal size?
What mass per metre?
What length is required?
What notches have to be cut and where?
What sized holes have to be drilled and where?
What cleats are required and where are they to be fixed?
How many of such beams are required?
What mark number is to be painted on each?
How should the beam be finished in the factory?

The good detailer will provide all this information in related groups, so that the fabricator does not have to hunt for a missing dimension. The information should be given once only and not repeated in different views of the same piece. Should it become necessary to change a dimension, there is a danger that only one may be changed if it is shown more than once, and then there will be two conflicting values.

The good detailer will adhere to accepted standards and conventions. The fabricator and the builder get used to these and there is less risk of misinterpretation. Practice does vary from office to office, but adherence to *BS 1192: Construction Drawing Practice* (British Standards Institution), *Metric Practice for Structural Steelwork* (British Constructional Steelwork Association) and the *Standard Method of Detailing Reinforced Concrete* (The Concrete

Society and the Institution of Structural Engineers) is strongly recommended as the basis for all drawings and schedules.

## DESIGN FUNCTIONS

## ENGINEERING DRAWINGS

The drawings required for any but the most simple of structures will usually be produced by the disciplines that match the building trades in construction. For example, electrical engineers develop drawings that will be used by the electrical contractor to perform his work. Electrical engineers also produce the electrical section of the specifications related to the electrical drawings.

HVAC drawings, mechanical plant (elevators etc.) and fire protection/security systems drawings are generally produced by specialists. Civil engineers produce structural drawings and (usually) water and sewerage proposals. Architects produce the architectural drawings, and these are usually required on all but the smallest or most functional of structures. They are used in conjunction with the associated engineering drawings by the general contractor (GC) who may act as a broker and subcontract all of the work or may perform some and subcontract some, depending on the terms of the contract.

On single prime (general) contract projects, the General Contractor (GC) will subcontract specific trades such as mechanical, electrical, etc. On multiple separate-trade contracts, which are mostly used on public works projects, the various trades bid separately and each performs its own work.

In small firms and on small projects, engineers may perform the basic architectural work plus the engineering design of the building structure, and in many cases may even do the site work. In large firms and on large projects, architects will provide their specialist input and the structural design and drawings will be done by engineers. Site work may include input from civil, mechanical, electrical, plumbing, and fire protection and security specialists. The drawings used are often identified by a prefix that indicates the various trades involved. This prefix may include one or more letters, such as C, E, M, P, FP, as required. This indicates to the contractor exactly what work is included on the drawing.

Generally, the engineering disciplines are broken down as follows:

## ENGINEERING DISCIPLINES

1. Structural
    a. Building structure
    b. Civil (site)
    c. Soils consultants
    d. Testing services

2. Electrical
    a. Power and light

b. Security
c. Instrumentation
d. Communications
e. Lighting consultants
f. Lightning consultants

3. Mechanical
a. Steam and power
b. HVAC
c. Automation
d. Mechanical acoustics
e. Testing and balancing

4. Plumbing
a. Potable water distribution
b. Sanitary drainage
c. Storm drainage

5. Fire protection
a. Sprinkler system
b. Life safety

Again, this breakdown depends upon the type and size of the firm and the size and complexity of the building construction project. For example, on small projects the mechanical contractor may perform: heating, ventilating and air conditioning; automation; plumbing; and fire protection.

Engineering drawings are not stand-alone drawings. Engineering work is indicated on basic architectural building outline drawings and therefore this drafting cannot be performed until architectural plans are developed. While architectural drawings are fully dimensioned so that the structure can be constructed precisely as shown, engineering drawings are not always dimensioned in the same sense.

Engineering drafting, while similar to architectural drafting, requires a somewhat different approach. First, buildings are constructed from architectural, and/or structural drawings, depending upon the scope of the project. On smaller projects, both the structural and the architectural work may be included on the same drawings, and all building construction is performed from these drawings.

Engineering drawings, with the exception of the structural ones, are graphical in nature and in many instances piping and duct runs are indicated by single lines in the general location. HVAC ductwork is dimensioned for size but not for location. Electrical and mechanical equipment on floor and roof plans are not dimensioned. The exact location will be indicated on architectural and/or structural drawings. Where dimensioning and exact location are necessary, larger scale drawings are made for those specific areas.

Some firms provide what is known as transparent, erasable polyester film from the original architectural drawings. Erasable films are reverse printed with lighter line weight building outlines to permit prominent illustration of engineering work, yet reproducible for building outline background. These are given to the various engineering disciplines. Electrical usually receive two floor plans, one each for lighting and power. Mechanical, plumbing, and fire protection usually get one each. With this technique the building outline and interior walls and partitions are identical on all architectural and engineering drawings. These reproducibles are made without any architectural dimensions, architectural equipment and features, room identifying names or numbers, and may or may not show doors.

In larger firms, each chief engineer has one or more project engineers, who, as the title implies, is responsible for one or more projects. As a licensed professional engineer, project engineers have technical responsibility for the project. The amount of responsibility delegated by the project engineer depends upon the qualifications of the designers and drafters. Designers may be involved in various technical aspects of the project such as system design, equipment selection, and specifications. Drafters seldom have technical responsibilities but must know systems and equipment and be able to layout drawings, place equipment accurately, develop interconnections, and must be familiar with the use of appropriate symbols because drafters make the drawings.

Some firms provide the engineers with prints made from the architects drawing. The engineer drafter will have to, at least, trace the essential information from the architect's prints. The building outline should be traced with lighter line work than will be used for the equipment. In neither case is the engineering drafter required to do detailed building work.

This is not intended to imply that engineering drafting is simple, to the contrary, the unique requirements of the various engineering disciplines are sufficiently different so that in all but the smallest engineering offices, drafters work in only one discipline. Drafters, and this applies also to designers, may specialize in structural, electrical, HVAC, plumbing or fire protection.

While architects may provide either transparencies or prints of floor plans to the engineers, there are other drawings engineers must make. Electrical, HVAC, plumbing, and fire protection drafters are generally required to draw roof plans, enlarged plans of rooms where their specific work is involved, show all equipment and interconnecting piping, ductwork, etc., plumbing riser diagrams, electrical single-line diagrams, and numerous details showing how equipment is installed, mounted, attached, hung, and interconnected. Depending upon the scope of the project, these could be very involved.

Structural drafting is different from other engineering disciplines. For example, structural drawings do not usually show floor plans as such, but shows the structural support for the floors and roof. Essentially, structural drawings show the structural skeleton of the building and appropriate details necessary for the erection of the structure. The structure of the building must be fully coordinated with the architecture to ensure compatibility.

**WORKING DRAWINGS**

The principal drawings of the structure to be built are often described as being the 'architectural drawings' and are as listed below:

1. **Title sheet**
2. **Site plan**
3. **Floor plan**
4. **Roof plan**
5. **Reflected ceiling plan**
6. **Elevations**
7. **Sections**
8. **Details**
9. **Schedules**

All drawings must contain certain basic, essential information, this may include all or part of the following:

1. **Name and address of the project**
2. **Name and address of the architect or engineer**
3. **Sheet title**
4. **Sheet number**
5. **Project number**
6. **Date project is completed**
7. **Space for initials of person making the drawing**
8. **Space for initials of person checking the drawing**
9. **Mark, date and description of all revisions**
10. **North arrow; this may include true north and building north**
11. **Key plan**
12. **Vicinity map**

*Title blocks* are required on all drawings (except renderings) and similar information must appear on the title page of all specifications prepared and sealed by architects and/or engineers. The design of the blocks and the information required may vary somewhat from one country or state to another, but certain basic information *should* be included.

Title blocks must be distinct and separate from any other title block, box, plaque, or other similar device of illustration or lettering. Drawing mediums may be purchased with a *standard* title block, or *custom* title blocks may be ordered with the drawing medium or separately with adhesive backing to be placed on plain drawing sheets. Title blocks are placed along the bottom of the sheet, bottom right-hand corner, or along the right-hand edge reading from the bottom up.

Space must be provided either in the title block or adjacent to it for *sealing* by the architect and/or engineer. Some states require that all original drawings be sealed with an inked stamp; others require that prints be sealed by a signature and indent stamp, and still others require that the professional sign it and write his license number on the drawings or prints. These requirements vary from state to state and may change with time.

Title blocks are an essential part of working drawings, and uniformity of the title blocks and the manner in which they are completed enhance the professional quality of a set of drawings. All lettering on the set should be done by a similar method, i. e., pencil or ink, freehand, template, press-type lettering, or mechanical lettering device. Even the seemingly insignificant uniformity of the date of the drawing is important, for example, when the engineer or architect decides that Mar. 24, 1995 is to be used, drafters should use that format on all drawings of the set and not Mar. 24/95, or 3/24/95, etc., on different drawings of the set.

## 1. TITLE SHEET

Most projects contain a title sheet as the first sheet of the drawing set. What is included on the title sheet depends upon the type and size of the project. For example, on smaller projects, the sheet may contain only the name and location of the project in large bold letters up to 5 cm high for the title or name of the project and letters up to 2.5 cm for the address. On larger and more involved projects, a site plan may be shown along with the symbols used for the site plan, sheet index, vicinity map, and key plan. The key plan is frequently shown on all drawings of the set.

## 2. SITE PLAN

Site plans usually contain all appropriate site information detail including building outline, lot (property) lines, existing and new grade contour lines, power and water lines, trees to be removed and remaining, storm drainage, catch basins and manholes, building floor slab elevations, paved areas, sod and/or seeded areas. Space permitting, this drawing should also contain all appropriate legends pertaining to the site plane.

Site plans are frequently one of the first drawings completed, since they define site constraints, locate all site services, and establish property lines. On small projects the architect usually includes the site plan in the "A" set, while on large projects the various engineering disciplines produce individual site drawings. Sometimes site plans are combined to show all architectural and engineering information and then these drawings are so identified, - e.g. as "AEP-1", indicating that architectural, electrical, and plumbing information is included.

## 3. FLOOR PLANS

Drawings are generally divided into two groups_horizontal (plan) views, and vertical (elevation and section) views. Plan views are usually titled by what is shown as floor plans, reflected ceiling plans, and roof plans. These views are drawn to scale and the various building materials, equipment, and fixtures are indicated by symbols or notes, whichever is more appropriate for the situation. Sometimes a combination of symbols and notes is used to reduce actual drafting time.

When the scale of a building is large enough to show walls by two lines, symbols are used to indicate the various construction materials. Remember, specifications describe the type of dry wall, block, concrete or brick as intended, and the drawing should merely indicate the different types.

Symbols are similarly used for windows and doors. These are usually identified by a *number* or *letter* appropriately enclosed and the type is described in the schedule.

The floor plan is of primary importance for the development of working drawings. It is the drawing from which all other architectural and engineering design is done. It is used to develop exterior and interior elevations, sections, and appropriate details. Working drawing floor plans are the result of all prior design effort and the culmination of many meetings with the client and in coordination with the other professionals involved.

A floor plan is a horizontal view of the building taken at an appropriate level so that all openings in walls and partitions will be shown. Floor plans are fully dimensioned, showing interior and exterior dimensions, wall thickness, and room and space sizes. On small projects, rooms and spaces are identified by name; on large multi-story buildings, room numbers are used, such as 100, 101, 102 for the first floor; 200, 201, 202 for the second floor, and so on through the building.

The following are some of the items generally included on floor plans:

1. All wall types are identified by appropriate symbols and keyed to the wall symbol list.
2. Wall thickness is dimensioned.
3. Door openings showing door swing and type identifications.
4. Window with type identifications.
5. Equipment below window openings.
6. Location of all wall section cuts and interior elevations keyed to drawing where they appear.
7. Concrete slabs and steps at exterior doors.
8. Roof overhang may be indicated by light dashed lines.
9. Plumbing fixtures.
10. Floor drains and slopes where necessary.
11. Kitchen equipment (except if extensive, then show on a separate enlarged drawing)
12. Water fountains, built-in and surface cabinets.
13. Wall-mounted items, bulletin boards, and chalk boards*.
14. Fire extinguishers by type and locations*.

15. Telephone outlets on small projects.
16. Floor elevations.
17. Room identifications.

*Note: these items may not be included if they do not represent permanent fixtures or fittings.

The amount of information included on floor plans depends entirely on the scope of the project and the complexity of construction. This is the drawing used by contractors to install the floor and to layout and construct walls and partitions. Where additional detail is required, these areas are identified and keyed to the drawing where this information is located. The essential consideration in drawing a floor plan is to know how much to show and that depends on the scale of the drawing and the complexity of construction. A typical set of working drawings contains elevations, sections, and enlarged scale detail drawings to provide additional information related to the floor plans. For example, exterior elevations and wall sections are always used to describe wall construction. Enlarged detail plans are frequently used to show necessary details of toilet rooms, locker rooms, and similar special areas. Sections and details are usually required to describe construction materials and methods at entrances. Elevations and sections are generally required for stairs. Enlarged details are required at various interconnecting points of construction.

On a 1:100 scale less can be shown and more detail is needed. On a 1:50 scale more can be shown and less needs to be detailed. The drafter and designer need to understand the use of elevations, sections, details, and schedules to develop floor plans properly and adequately. Never draw more than is necessary.

Floor plans should be made at a scale large enough to show all essential information on a drawing that is not over-sized for convenient handling in the drafting room and in the field during construction. When these two conditions cannot be met, the building must be cut and the parts placed on two separate sheets. A match line is used to indicate where the building is cut. This line is much darker than the building lines to avoid confusion, and the match line is appropriately identified. Once the decision has been made that the building must be cut, all subsequent and relevant drawings must be so shown. This includes architectural roof and reflected ceiling plans, and all associated engineering drawings.

The drawings that follow the floor plans depend to some extent upon office practice. It could be followed, as indicated here, by the roof plan, reflected ceiling plan, exterior elevations, and wall sections. In larger offices, all of these may be worked on simultaneously. Roof plans and reflected ceiling plans are usually developed concurrently with the appropriate engineering design because their input is required before these two drawings can be completed. Exterior elevations and wall section designs are usually performed at the same time. The wall sections show the construction of the wall, and where exterior brick, block, etc., coursing type material is used, it is necessary to determine the locations of the various courses in order to define the elevation fully.

## 4. ROOF PLAN

While the roof plan is usually one of the simplest drawings to make, certain essential details must be properly illustrated to ensure a weather-tight construction. A waterproof roof is absolutely necessary for the building since it is the ultimate weather shield or umbrella; if the roof fails, so does the building. The result of a poorly designed and constructed roof is more obvious than almost any other element of the building. A roof plan is required for all but the simplest structure, except residences, and similarly sloped roof buildings.

The roof plan is usually drawn at the same scale as the floor plan and is the view as seen from above the roof. This drawing usually shows all equipment on the roof, including mechanical, electrical, etc., but the details and descriptions are included on those plans made by the various other professional disciplines. Roofing materials and methods of installation may be included on the drawing or included in notes or in the specifications. Some drawings indicate in phantom the structure below the roof, such as joists, beams and columns, for information only. Joists and beams are usually partially shown to indicate location and not the complete length of the roof. Roof plans should not be confused with roof framing plans; these are separate drawings and show the structural framing as it appears beneath the roof. On larger and more involved projects, the engineering disciplines frequently make roof plans that address that specific engineering discipline's work.

Roof plans usually show overall dimensions and dimensions to specific features such as hatches (scuttles), expansion joints, penthouses, water tanks, skylights, roof ventilation, walkways, scuppers, etc. These plans also show all roof penetrations and all equipment on the roof.

Most frequently, equipment and materials that penetrate or are on the roof are indicated by symbols or abbreviations because they are described on other drawings or in schedules, details, or specifications. On small projects, where there is only one roof plan drawn by the architect, the equipment may be fully described on that plan or by notes on the same drawing.

One major concern is the method of terminating the roof at parapets, expansion joints, equipment curbs, and at the various penetrations. These details are usually drawn at an enlarged scale on the same sheet, space permitting, to ensure proper construction methods at these points. The amount and number of details depend upon office practice and the complexity of the work. The methods used must agree with manufacturer's recommendations.

## 5. REFLECTED CEILING PLAN

The reflected ceiling plan is a composite drawing usually made by the architect and is included in the architectural drawing set. It contains, in addition to the ceiling which is often an architectural feature, electrical and mechanical items that penetrate the ceiling and are visible from below. The architectural features include ceiling type and material, and methods of attachment to all adjacent surfaces such as walls, windows, columns. Engineering items may include lighting fixtures, HVAC diffusers and registers, smoke detectors, sprinkler heads, access panels, and communication speakers.

A reflected ceiling plan is best described as the reflection that would be seen in a mirror placed directly below the ceiling, hence the name, *reflected ceiling.* Every visible construction feature of the ceiling is shown, but nothing above the ceiling is included. For example, HVAC diffusers are shown but the connecting ductwork is not, that is shown on HVAC drawings. Similarly, sprinkler heads are shown but associated piping is not, that appears on fire protection drawings. Since the view is cut just below the ceiling, the doors, windows and other wall openings are not shown in the wall outline.

The reflected ceiling drawing is the result of the coordinated effort of the architect and engineers and will be used by contractors for the exact placement of their individual equipment. For example, the electrical drawings show the approximate location of lighting fixtures and the reflected ceiling plan establishes the exact position.

When they are involved, the architects develop the basic reflected ceiling plan indicating the type and material of the ceiling and issue copies of this to the various engineering disciplines involved. Sometimes, this initial plan is developed in coordination with the engineering disciplines to ensure a compatible ceiling system.

As with other plan views, ceiling symbols should be included on the same sheet with the plan, space permitting; essential details may also be drawn on that same sheet. In cases where the plan sections and details must be located on other sheets, these sections and details should be placed in an organized manner so that they can be easily and rapidly located by the contractors. Reflected ceiling plans are most frequently drawn at the same scale as the floor plan. All devices on the plan are identified by unique symbols and one or more letter designations, as appropriate. Where more than one type of lighting fixture, HVAC diffuser, etc., is used, different letters are needed and these are keyed to the symbols and/or descriptions in the notes, schedules, or specifications.

Reflected ceiling drawings require complete coordination among all disciplines involved to permit proper placement of the numerous devices involved. For example, the lighting fixtures must provide effective lighting distribution, ceiling diffusers must permit proper air throw and diffusion, sprinkler heads must satisfy spacing requirements and, at the same time provide a ceiling that appears uncluttered and symmetrical.

Where roof overhang is involved at that particular floor, the soffit is drawn and the devices are shown on the ceiling plan. Room names or numbers may be placed outside the plan proper with leaders indicating the space identified, or for single spaces, the identification may be placed under the drawing as, CONFERENCE ROOM REFLECTED CEILING PLAN.

## 6. ELEVATIONS

The term elevation is commonly applied to exterior views of a building. It is a vertical view and is identified by the exposure of the structure; for example, the south elevation is a drawing of the southern exposure or south face of the exterior wall as viewed by looking directly at it. Unlike the perspective drawing where objects further from the viewer are foreshortened, an elevation is an orthographic drawing. All dimensions are drawn to the same scale. Perspectives produce *pictorial drawings* that appear like actual photographs. Orthographs are graphic projections of buildings as viewed from an infinite distance.

Elevations are drawn at the same scale as the floor plan from which they are developed and when placed side by side on a drawing, adjacent elevations are placed together. For example, when the four elevations of a four-sided building are placed side by side, moving from one elevation to the other would present the same views as would be seen by walking around the building, i. e., adjacent corners are placed next to each other.

Elevations show the wall elements and materials, form of the roof where appropriate, and all wall openings. Windows and doors are identified by symbols related to the floor plan or by notes described in the window and door schedules. Overall horizontal and vertical dimensions, and intermediate dimensions to ceiling height, etc., are shown. Wall openings for doors, windows, wall louvers are not dimensioned on elevations; this relevant information should be on the associated floor plan. A grade reference line at the base indicating existing and new lines are shown. Hidden foundation work below grade may be indicated on the drawing by broken lines, particularly where step footings or other irregularities occur that cannot be adequately addressed on section cuts through the elevation. In cases where foundations are at a uniform elevation throughout and are detailed on sections, it is not necessary to redraw it on the elevations.

Elevations are frequently developed simultaneously with the sections through the elevations. This is necessary to coordinate the materials of construction with components such as doors, windows, and exterior heights. In the interest of economy of construction, full-sized coursing material is used and the related detail is usually best determined from a section taken through the elevation.

*Interior elevations*, sometimes called section elevations, are seldom identified as *elevations;* instead they are described as to application. For example, when vertical information is necessary to describe a particular wall, an elevation of the entire wall is drawn and may be identified as SOUTH WALL OF CONFERENCE ROOM.

Interior elevations are used to provide additional detail about interior features that cannot be adequately described on the floor plans. They are similar to exterior elevations, except that in most instances they show only floor-to-ceiling levels. Their primary function is to illustrate walls and portions of walls exactly as they would appear after construction. These drawings depict all visible features. Interior elevations serve two specific functions:

a. Provide adequate information to the contractor so that the project can be bid and eventually constructed.
b. Illustrate design intent to the client.

Floor plans show protrusions from, indentations into, and openings in walls. Floor plans are horizontal views of the floor and merely show walls as they appear in section. Elevations are vertical views between floor and ceiling lines and show all design and surface features of the wall. Interior elevations are not required and should not be drawn for walls that contain no surface mounted or built-in items or have no specific openings.

Interior elevations are usually drawn for kitchen, toilet, and special rooms. They are usually drawn at a larger scale than floor plans and exterior elevations. Interior elevations need not be drawn when the same information is described in room schedules.

Isometrics are often used to describe two adjacent interior room surfaces. Perspectives are used when three sides of a room can be better illustrated on one drawing of the interior space than with three separate elevations.

## 7. **SECTIONS**

There are several types of section drawings that are used to provide additional information that cannot be adequately described on plans and elevations. One type is cut through the building and shows interior spaces in elevation. Another is cut through walls to describe wall construction materials and methods. Cuts are also made through windows and doors to provide the necessary details of construction and installation. These cuts are described as:

- Building cross sections
- Building longitudinal sections
- Wall sections
- Window and door sections
- Stair sections

Other than elevations, all drawings discussed so far have been horizontal views; these includes site plans, floor plans, reflected ceiling plans, and roof plans. Sections are vertical views slicing the building or wall. The best example of a section is to take, for example, a birthday cake and slice it vertically through the middle. The exposed piece is a section through the cake. The same principle applies to all section cuts.

Building sections are usually drawn at 1:50 scale. Wall, door, openings, and stair sections are drawn at larger scales of 1:10 or 1:20 depending upon the degree of detailing needed to show the important elements.

Building sections are also used to illustrate surface mounted or built-in features on interior partitions. Frequently, additional sections are cut through these sections to provide additional information. Unfortunately, some section cuts are noted as details and this may cause some confusion to entry-level drafters.

Sections are essential not only to building contractors for bidding and construction work, but also to drafters so that they can check to make sure that all elements fit in place as intended by design. Often the third dimensional investigation by the drafter may indicate that revisions or dimensional adjustments must be made to previously completed plans or elevations to make things work in actual construction. The number of sections and details developed depends upon the complexity of the building components.

In some instances, elevations are used with appropriate notes for simple construction methods, but in cases where the item to be installed is field constructed, it is better to show by a section the intended materials and methods.

## 8. DETAILS

Details are enlarged drawings that provide essential specific information. They are used to describe and define areas that require additional emphasis. The best way to visualize a detail drawing is as a close-up photograph. Take for example, a typical window installation:

1. The plan shows the window's horizontal location and its dimensions; it is keyed to the window schedule by a symbol.
2. The elevation then provides additional information, such as appearance and vertical dimensions. This view should also use the symbol for identification.
3. The section through an elevation at a window shows still another picture. It shows, generally, in simple form the window relationship to the wall and more specific dimensions. Details are usually not provided for standard manufactured windows in simple wall construction. When the wall construction at the window sill jamb and the head is unusual, a detail is required.
4. This area is usually circled up on the section view and that portion of the construction is enlarged sufficiently to describe every minute detail, hence the name, *detail.*

Details are also provided for areas that are too small on plans to describe fully and dimension accurately. These areas include toilet rooms, locker rooms, kitchens, stairs, mechanical rooms, etc. The areas are usually identified on the plan views (or elevations) by a simple note *SEE DETAIL A-7.* These details are generally combined on the sheet entitled *DETAILS.*

Detail drawings are drawn at a 1:20 or 1:10 scale, or even larger if necessary. This information is primarily for the contractor's benefit. Most contractor's questions, possible errors, and construction delays are the result of poorly detailed drawings. A well-designed building with all required details reduces the total involvement of the engineer or architect during the construction phase. Details may be cut or indicated on plans, elevations, and sections. Some of the more common areas where detailing should be used are as follows:

1. Building framing connections, including columns, beams, joists, and walls.
2. Roof openings and terminations at walls showing flashing details, gravel stops, and cant strips.
3. Poured concrete foundations, floor and footing connections showing reinforcement, water stop insertion, sealant application, vapor barrier and insulation attachment, and expansion joints around columns.
4. Stairs to describe framing, connections to stair wells, riser and run dimensions, and railings and its method of attachment.
5. Door and window sill and lintel installation.

Details are identified similar to sections cuts. When detail drawings are not in close proximity to their cut location where a leader can be used to connect the detail to the cut, the two-number system is used. To repeat, the top number identifies the detail and the lower number identifies the drawing sheet where the detail appears.

Details are sometimes identified by circling up the specific area intended to be enlarged. This circle is then identified by a leader and the numbers. Where details are cut through another drawing, the cut and direction of view are indicated.

Some firms, depending upon the scope of the detailing required, frequently cluster all details on one drawing identified as the detail drawing. On small and less complex projects, it is more common to place the detail on the same sheet where it applies.

In the past, and to some extent even today, many manufacturers include various details in their literature that drafters merely have to trace onto their drawings. More and more manufacturers today provide these details in adhesive backed film or vellum that drafters merely apply to their drawings.

Many offices design their own typical details of components that are frequently used. These are also on adhesive-backed transparencies that can be stuck to the drawing. With this technique the drafter merely letters in the identification and the detail is completed. This practice is more common in engineering design than architecture. Engineers have more items that are repeated more frequently on various building design.

## 9. SCHEDULES

Schedules are shorthand techniques used by architects and engineers to simplify drafting and reduce drafting time. Schedules are a tabulation of common items required on the project that have similar characteristics. Whenever three or more similar items are required on a building, schedules should be used. When this information is properly organized in schedules, much of the detail lettering on drawings is eliminated. Since building construction drawings are graphical presentations of the project, they should not be unduly cluttered with notes.

Architectural schedules are usually developed for doors, windows, room finish, hardware, kitchen equipment, lintels, access panels, fire extinguishers. Additional schedules may be required depending upon the particular building type and the requirements of construction.

Schedules should be prominently titled with larger letters than those used in the body of the schedule. The tabular format contains horizontal and vertical line separations and the entire schedule is boxed. The first left-hand column contains the schedule equipment identification number, and what follows depends upon the particular schedule. The far right-hand column is used for notes. The symbol used for the schedule should be included adjacent to the title of the schedule.

Horizontal line spacing of 1 cm is usually adequate since this permits two lines of 0.5 cm lettered notes, if needed. Column spacing of 2 cm is commonly used but should be wide enough to permit adequate spacing for the text. Abbreviations may be used on schedules providing that they are defined under the list of abbreviations. Lettering on schedules must be as neat and distinct as all other lettering on the drawings. Schedules are a useful shorthand technique and should be considered whenever practical.