CIV3301 PRINCIPLES OF CONSTRUCTION
LECTURE I

▶ PART A - Introduction to Civil Engineering Procedure

A. Definition and functions of the Civil Engineering profession.

Civil Engineering

Engineering generally is concerned with the implementation of a solution to a practical problem. It is the application of mathematics and science to create something of value from our natural resources.

Civil engineering is a professional engineering discipline that deals with the planning, design, construction, management and maintenance of the physical and naturally built environment, including works like roads, bridges, canals, dams, airports, sewerage systems, pipelines and railways.

There are two major types of engineering roles performed by civil engineers;

i. Consultant engineers who focus on design work and generally spend more time in the office or working with clients.
ii. Contractors who are more involved in keeping an eye on the physical construction and are usually based on site.

Some important quotes about Civil Engineering;

"It is a great profession. There is the fascination of watching a figment of the imagination emerge through the aid of science to a plan on paper. Then it moves to

realization in stone or metal or energy. Then it brings jobs and homes to men. Then it elevates the standards of living and adds to the comforts of life. That is the engineer's high privilege" **Herbert Hoover**

"Civil engineering is "the modification of nature to create and improve human habitats." Civil engineers work toward an ideal that is "a standard of perfection, beauty, or moral and physical excellence, especially as an aim of attainment or realization." Civil engineers strive to "match deep functionality with aesthetics in every manifestation of the profession." Engineers should be mindful that there is a "moral compact between the engineer and world society." **Bugliarello (1994)**

"Professional engineers should work for the welfare of the public. They are responsible for observing societal needs, and often have the position and resources to improve society. As professionals, engineers are expected to set examples in the work field and to establish themselves as assets to society." ***T.D. Oates, 1993***

Sub-Disciplines in Civil Engineering

Civil Engineering as one of the oldest and quintessential engineering profession encompasses a variety of sub-disciplines and jobs. Surveying is a skill used by many civil engineers, but there is a separate professional licensure for land surveyors. Likewise, Urban planning is an activity that uses skills from a variety of the civil engineering sub disciplines. The civil engineering curriculum at Bayero University like in many other universities curriculum covers the following;

- structural
- environmental
- water resources
- geotechnical
- construction
- transportation

Structural Engineering

Structural engineering involves the analysis and design of structures such as buildings, bridges, towers, marine structures, dams, tunnels, retaining walls and other infrastructure. Structural engineering underpins and sustains the built environment, where structures must be safe, serviceable, durable, aesthetically pleasing and economical. Structural engineering applies mathematics and physics to traditional construction materials such as concrete, stone, steel, timber, glass and innovative engineering materials, including aluminum, polymers and carbon fibre.

Critical skills that a structural engineer needs include an in-depth understanding of physics and mathematics. A structural engineer must also know the properties of various materials, such as their density, hardness, tensile strength, bulk modulus and bending strength. They need to be able to calculate how different materials will perform under stresses such as compression, tension, bending and twisting, as well as under various environmental conditions of temperature, pressure, corrosive gases and liquids, and even radiation. They also need to be able to predict how these materials will perform over an extended period of time.

Like other branches of Civil Engineering, Structural engineers rely increasingly on computer-aided design (CAD) systems, so proficiency with computers is essential. In addition to speeding up the drafting process, CAD systems allow for quick and easy modifications of designs and three-dimensional (3D) visualization of finished parts and assemblies

Environmental Engineering

Environmental engineering is the application of science and engineering principles to improve the environment (air, water, and/or land resources). Environmental engineering is the branch of engineering that is concerned with protecting people from the effects of adverse environmental effects, such as pollution, as well as improving environmental quality. Environmental engineers work to improve recycling, waste disposal, public health, and water and air pollution control.

Environmental engineers use core engineering skills and a deep understanding of the physical, chemical and biological principles of the local, regional and global environment to help change the world.

The goal of environmental engineering is to ensure that societal development and the use of water, land and air resources are sustainable. This goal is achieved by managing these resources so that environmental pollution and degradation is minimized.

Environmental engineers study water, soil and air pollution problems, and develop technical solutions needed to solve, attenuate or control these problems in a manner that is compatible with **legislative, economic, social and political** concerns. Civil engineers are particularly involved in such activities as water supply and sewerage, management of surface water and groundwater quality, remediation of contaminated sites and solid waste management.

The activities of such engineers include, but are not limited to, the planning, design, construction and operation of water and wastewater treatment facilities in municipalities and industries, modelling and analysis of surface water and groundwater quality, design of soil and remediation systems, planning for the disposal and reuse of wastewaters and sludge, and the collection, transport, processing, recovery and disposal of solid wastes according to accepted engineering practices.

Water Resources & Hydraulic Engineering

Water resources engineering is the quantitative study of the hydrologic cycle, the distribution and circulation of water linking the earth's atmosphere, land and oceans. Surface runoff is measured as the difference between precipitation and abstractions, such as infiltration (which replenishes groundwater flow), surface storage and evaporation. Applications include the management of the urban water supply, the design of urban storm-sewer systems, and flood forecasting.

Hydraulic engineering consists of the application of fluid mechanics to water flowing in an isolated environment (pipe, pump) or in an open channel (river, lake, ocean). Civil engineers are primarily concerned with open channel flow, which is governed by the interdependent interaction between the water and the channel.

Applications include the design of hydraulic structures, such as sewage conduits, dams and breakwaters, the management of waterways, such as erosion protection and flood protection, and environmental management, such as prediction of the mixing and transport of pollutants in surface water. Hydroelectric-power development, water supply, irrigation and navigation are some familiar applications of water resources engineering involving the utilization of water for beneficial purposes. More recently, concern for preserving our natural environment and meeting the needs of developing countries has increased the importance of water resources engineering.

Civil engineers play a vital role in the optimal planning, design and operation of water resource systems. Job opportunities in hydrology and water resources are quite varied.

Geotechnical Engineering

Geotechnical engineering is the study of the behaviour of soils under the influence of loading forces and soil-water interactions. This knowledge is applied to the design of foundations, retaining walls, earth dams, clay liners, and geosynthetics for waste containment. The goals of geotechnical engineers could range from the design of foundations and temporary excavation support, through route selection for railways and highways, to the increasingly important areas of landfill disposal of wastes and groundwater contamination. As such, the geotechnical engineer is involved in field and laboratory investigations to determine the engineering properties of site soils and other geomaterials and their subsequent use in the analytical study of the problem at hand.

Recent computational and computer advances are extending our ability to predict the behaviour of soil and soil-water systems under a wide variety of conditions. In recent years, the activities of geotechnical engineers have also involved geo-environmental engineering. Geo-environmental engineers design strategies for the clean-up of contaminated soils and groundwater and develop management systems for contaminated sites.

Construction Engineering & Management

Construction Engineering is the management and delivery of construction projects. Construction is considered to be any building projects used for residential, commercial or industrial applications. Civil Engineers that are educated in the field of construction management are classified as Construction Engineers.

They are required to plan construction activities, supervise the installation of structural elements and inspect the building upon completion. Construction Engineers work with architects and Engineering technicians on building design and on-site problem solving. Construction Engineers also compile reports which detail the cost feasibility and estimation of the project.

Use of Computer Aided Design software is common, although not to the same extent as a structural engineer. Construction Engineers combine project management skills and mathematical knowledge. Construction Engineers may specialize in residential housing, bridges, skyscrapers, industrial warehouses or any other infrastructure that exists. The health of the construction industry in each country determines the demand for Construction Engineers.

Transportation Engineering

Transportation has always played an essential role in the development of society, originally with regard to trade routes and harbours, but more recently with regard to land- and air-based systems as well. It is the transportation engineer's responsibility to plan, design, build, operate and maintain these systems of transport, in such a way as to provide for the safe, efficient and convenient movement of people and goods.

Increasing environmental concerns have revived an interest in the development and management of public transportation systems. Professional activities can range from road and transit design and operation at the urban scale, to railroad, seaway and airport location, construction and operation at the regional and national scale. Transportation engineering in Nigeria focuses on automobile infrastructures, although it also encompasses sea, air and rail systems.

Automobile infrastructures can be split into the traditional area of highway design and planning, and the rapidly growing area of traffic control systems. The transportation engineer faces the challenge of developing both network links and major terminals to satisfy transportation demands, with due regard for the resultant land-use, environmental and other impacts of these facilities.

CIV3301 PRINCIPLES OF CONSTRUCTION
LECTURE II & III

▶ PART A - Introduction to Civil Engineering Procedure

C. Introduction to the Civil Engineering Design

Applied Civil Engineering Design

Applied civil engineering design is a multidisciplinary process involving detailed analysis, judgment, and experience aimed at producing construction drawings, technical specifications, cost estimates, and bid schedules required to allow contractors to bid and construct heavy civil projects. Civil engineering encompasses such disciplines as structural engineering, geotechnical engineering, water resources engineering, environmental engineering, transportation engineering, and many related subspecialties. Emphasis is mostly given to heavy civil construction projects, also known as infrastructure. It is interesting that there is no precise definition of heavy civil construction. There are several characteristics of heavy construction projects, as follows:

- Equipment cost, expressed as a percentage of total project cost, is about 10 times higher in heavy construction than in building construction.
- Heavy construction projects tend to spread out horizontally, as compared with the vertical nature of a building.
- Heavy construction is usually performed for a public owner, whereas building work is usually performed for private as well as other owners.

- Heavy construction documents are prepared by engineers, whereas building documents are prepared by architects.
- Heavy construction is much more weather-sensitive and allows far fewer working days per construction season than building construction.

These characteristics provide an applicable description of the types of construction projects you may likely get involve in after graduation. Examples of heavy civil construction projects, many of which are public works, include roads and highways, dams, levees, canals, foundation excavations for buildings, tunnels, bridges, airports, pipelines, drainage and flood control facilities, and urban development. A civil engineering designer is a specialized and experienced professional engineer who is licensed and capable of producing construction documents for these projects.

Stages of Civil Engineering Design

The engineering design process usually involves various levels, with each subsequent level more involved and detailed than the previous one, culminating in the so-called final design. For heavy civil projects, there may be concurrent site investigations to obtain relevant data for design at each level of design. The stages are;

- Planning
- Conceptual
- Final

Civil Engineering Design Documents

Broadly speaking, engineering design documents can be divided into two categories:

Documents not for construction—All designs before final design (e.g., during planning level or conceptual level design) are considered "studies," and the products of these studies include design drawings, design reports, data reports, and engineer's cost estimates. These design documents are intended to evaluate technical feasibility and cost feasibility of various alternatives and options to meet project goals and objectives, and to provide a basis for funding the project.

Note that there are no technical specification documents necessary for design studies; all technical requirements are included in the design drawings or described in the design reports. The design drawings in planning-level or conceptual-level designs are not prepared with the same details as final design drawings because construction of these project features is not necessary. In fact, the designer should refrain from putting excessive details (e.g., rebar sizes, fastener sizes, or detailed survey controls) on these drawings. Design drawings in these early design studies should contain only enough details to illustrate the concept and constructability, and to give a reliable construction cost estimate.

Documents for construction—These documents are produced during final design and include construction drawings and technical specifications, design reports, bid schedule, and engineer's cost estimates. Some of these documents are intended to be used by the contractor, construction manager, and inspector for bidding and construction, but some documents are prepared only for the owner of the project.

Typically, the preparation of final design engineering documents is done in several progress submittals to the owner or project reviewers and regulators. These milestones design completion stages can be expressed in terms of percent completion. There are no fixed rules about what percent completions are appropriate, and sometimes the number of intermediate design submittals depends on the project schedule and the review requirements. For example, there may not be adequate time for progress submittals for a fast-track project or for emergency repairs. In any case, under normal circumstances, the following are some guidelines on milestone design submittals:

- Early submittal: 30–35% completion,
- Intermediate submittal: 50–65% completion,
- Substantially complete draft submittal: 90–95% completion, and
- Final submittal: 100% completion.

The submittal contents (so-called "deliverables" in the consulting industry) are different for different milestone design submittals. These guidelines provide the designer with priorities and dedication of design resources to produce various design documents. In many cases, the actual deliverables in a design project are specified in the design contract between the owner and the engineer. It should be noted that the design drawings and technical specifications at 100% design completion are not necessarily the documents used in construction. As we know earlier, drawings and specifications may change during the bidding phase, and the updated documents with those changes (so-called "conformed documents") are actually used in construction. Whereas the drawing and specifications are used by the contractor and the construction inspection and management team, the design report is prepared by the engineer for the owner. The design report should include;

i. the project goals and objectives,
ii. design criteria,
iii. design basis and requirements (technical and nontechnical),
iv. descriptions of the project design features,
v. engineering assumptions and calculations,
vi. designer's operating criteria of the new project features,
vii. key construction considerations and construction schedule, and
viii. documentation of the construction cost estimate.

Even though the construction cost estimate is usually part of the design report, the cost estimate summary and backup calculations are usually confidential, and therefore this information is removed from the report as a stand-alone document. It is important that the bidders and the eventual contractor do not have access to the engineering design report and the cost estimate.

Stages of Civil Engineering Drawings

Planning-level drawings—Planning-level drawings are developed and used at the beginning of a project to illustrate a particular concept or idea being considered. Typically, more than one concept or idea is being considered at this time, and sometimes these concepts lack supporting analysis or precedence, and therefore may not have sound technical bases. In fact, at this level, only limited engineering analysis is performed for each design concept, and most of the time, design drawings are developed based on project requirements and constraints, engineering judgment and experience, precedence, and past projects. Although often considered easier to prepare than final design-level drawings, the preparation of planning-level drawings—without the support of analysis and other design data—requires considerable design experience and judgment on the part of the designer. Therefore, inexperienced and junior design staff should perform this work only when closely supervised by more experienced designers.

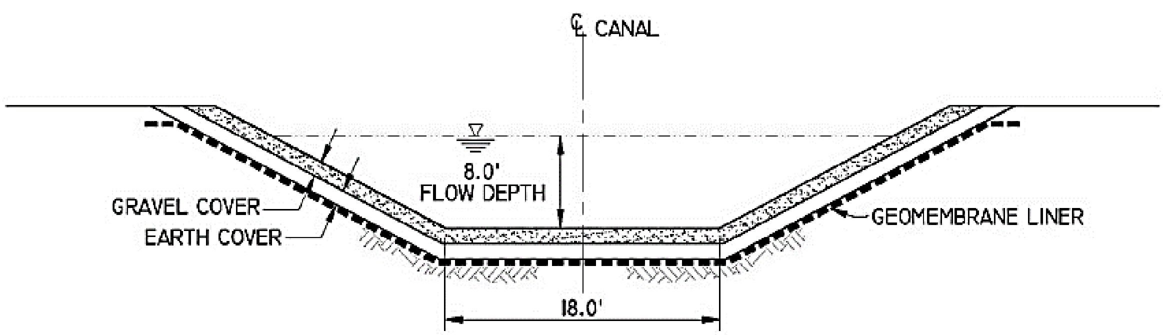


Fig. 1.0 Geomembrane Liner Concept for a Planning-Level Canal Design Project

Conceptual-level drawings—Conceptual-level drawings for each project option are developed primarily to compare construction costs, to evaluate advantages and disadvantages, and to identify potential fatal flaws so that a preferred concept can be selected for final design. The evaluation criteria for various concepts may vary considerably from project to project and may include cost, schedule, risk, environmental, regulatory, operation and maintenance, and other nontechnical considerations. For many projects, construction cost estimates developed at this level are used as a basis for funding of the project, so it is important that the project cost is not underestimated. With this goal in mind, these drawings should be developed with sufficient details and dimensions to define all of the significant cost items associated with each concept. These drawings should not be used for construction, and not all the information needed for construction is necessary for conceptual-level drawings. No technical specification document is required at this level.

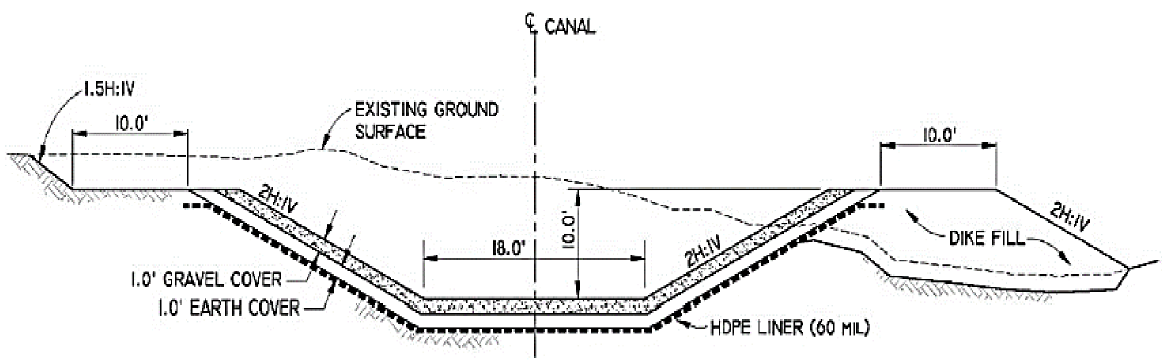


Fig. 2.0 HDPE Liner Concept for a Conceptual-Level Canal Design Project (Concept Design)

Final design drawings—Final design drawings, or construction drawings, are used for construction. These drawings contain all of the information necessary for a contractor to bid and build a particular project. Most heavy civil projects require permits from various regulatory agencies (municipal, county, state, and federal); these drawings are used to support applications for these permits. Construction drawings are used in conjunction with a set of technical specifications to define completely the spatial, material, installation, and quality requirements of a project. Construction drawings are also used during final design to obtain an accurate estimate of quantities for a construction cost estimate and for developing the bidding schedule.

Occasionally, bid amendments are used to change design drawings during bidding. After the contract is awarded and before construction begins, these design changes can be incorporated into the drawing set, and the revised set of drawings is referred to as ***conformed drawings***. When a construction project is completed, the construction drawings are updated and modified to reflect all of the changes made during construction. The resultant drawings are called ***record drawings***.

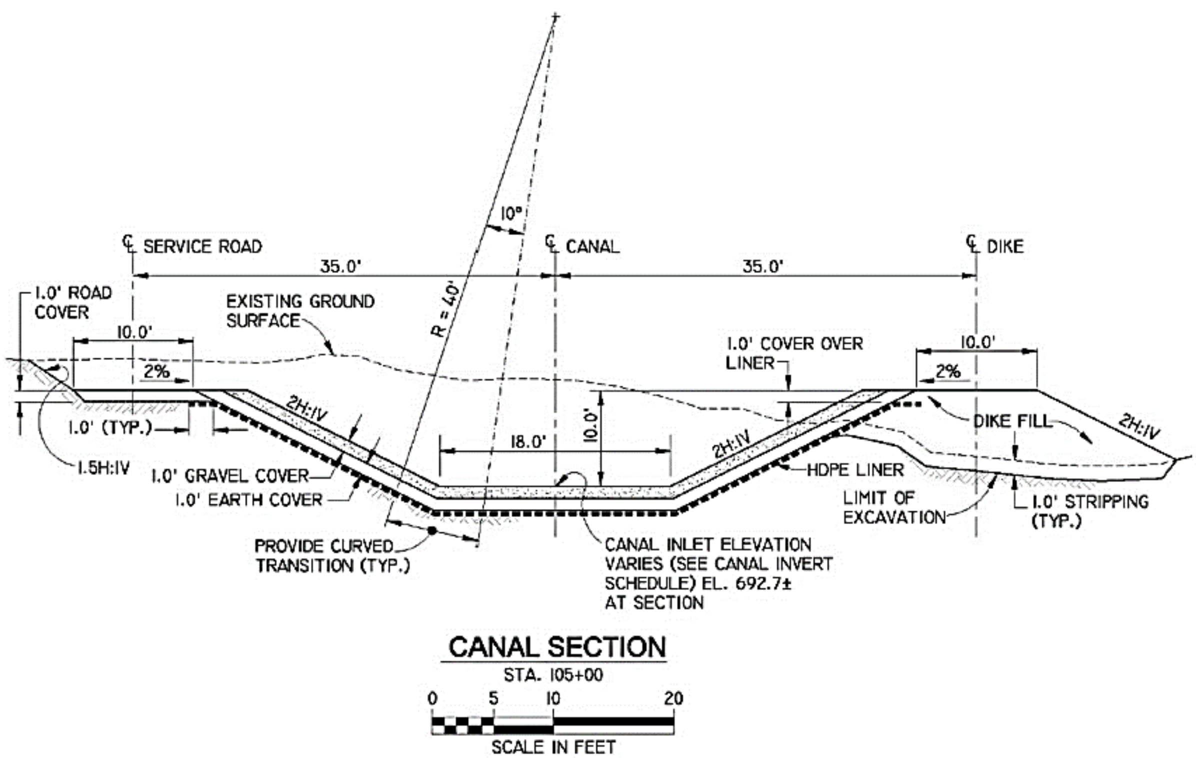
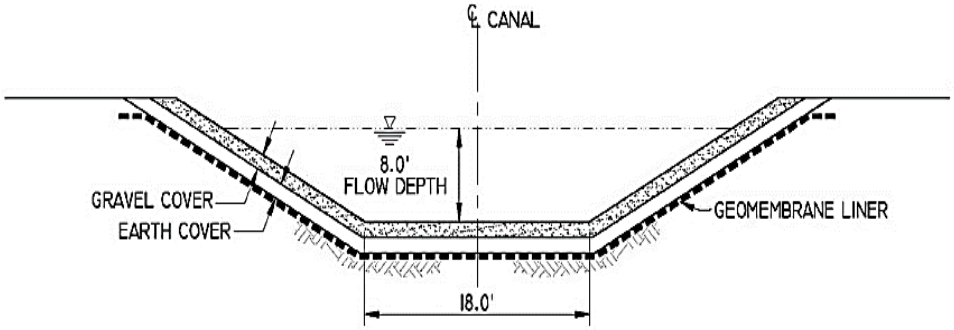
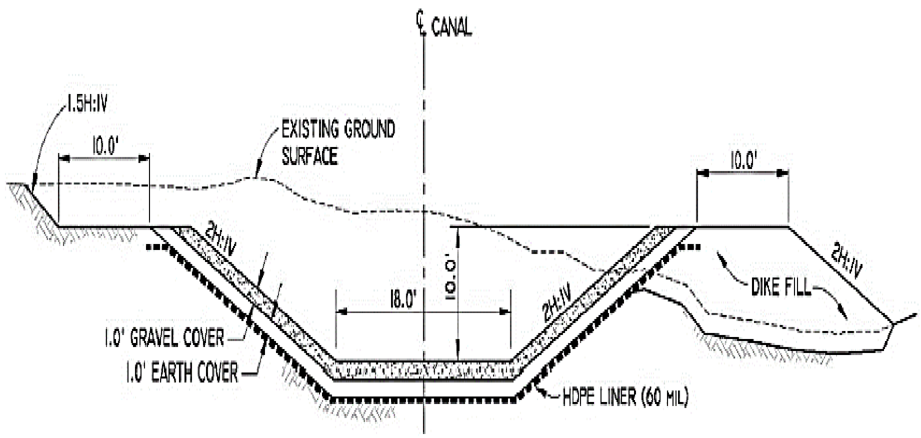


Fig. 3.0 HDPE Liner Section for a Canal Final Design Project (Final Design)

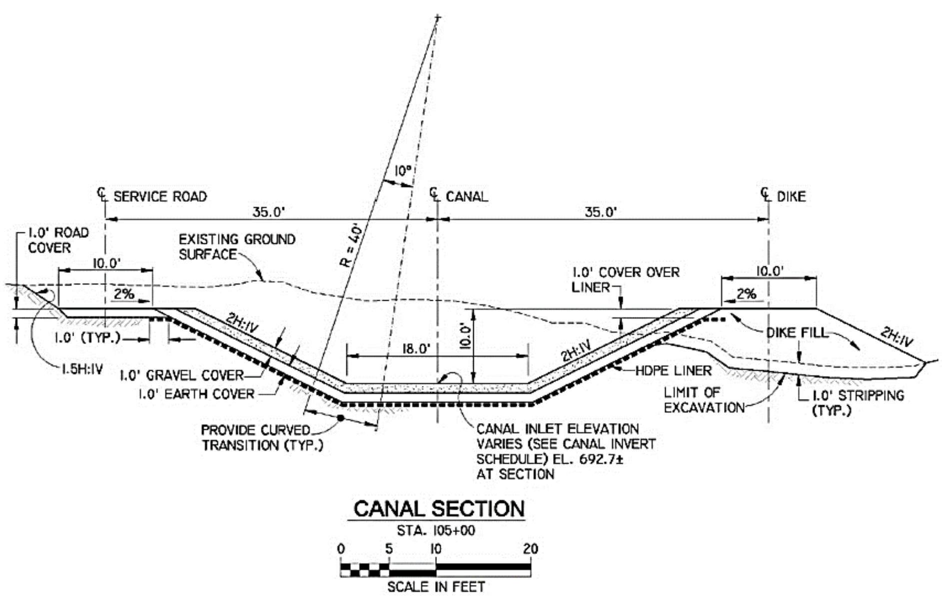
Now Compare;



℄ CANAL
8.0'
FLOW DEPTH
GRAVEL COVER
EARTH COVER
GEOMEMBRANE LINER
18.0'



℄ CANAL
1.5H:1V
10.0'
EXISTING GROUND SURFACE
10.0'
2H:1V
10.0'
18.0'
2H:1V
DIKE FILL
2H:1V
1.0' GRAVEL COVER
1.0' EARTH COVER
HDPE LINER (60 MIL)



10°
R = 40'
℄ SERVICE ROAD
℄ CANAL
℄ DIKE
35.0'
35.0'
1.0' ROAD COVER
EXISTING GROUND SURFACE
10.0'
2%
1.0' COVER OVER LINER
10.0'
2%
2H:1V
10.0'
DIKE FILL
2H:1V
1.0' (TYP.)
18.0'
2H:1V
1.5H:1V
1.0' GRAVEL COVER
1.0' EARTH COVER
HDPE LINER
LIMIT OF EXCAVATION
1.0' STRIPPING (TYP.)
PROVIDE CURVED TRANSITION (TYP.)
CANAL INLET ELEVATION VARIES (SEE CANAL INVERT SCHEDULE) EL. 692.7± AT SECTION
CANAL SECTION
STA. 105+00
0 5 10 20
SCALE IN FEET

The Knowledge and Skills for Civil Engineering Design

A student may not get the necessary training or skills to practice design immediately upon graduation from a bachelor's or master's degree program. Frequently, the design skills of a civil designer are gained through many years of design practice and mentoring under a senior professional, combined with experiences gained through field construction observations. Certainly, the basic technical background and courses in engineering graphics, computer-aided drafting (CAD), surveying, engineering contracts, and mathematics that one learns in a typical engineering curriculum are important in building these design skills. However, contrary to other design disciplines, such as mechanical, electrical, or architectural design, the production of civil engineering design documents is not taught in academia, nor are there readily available guidelines for young practicing civil engineers to gain these vital skills. These skills MUST be learnt on the job and through other trainings such as those organized by Nigerian Society of Engineers.

The Project Teams

Project teams are composed of members vital to the success of the project and must include a leader to guide overall efforts. The team leader is the Project Manager (PM) and the PM must rely on the team for technical expertise. The PM also acts as a coach, answers questions, clears the way for progress, and makes sure desired outcomes are understood by all team members.

The PM influences a diverse set of individuals with sometimes competing goals, needs, and perspectives. The PM needs to motivate these individuals since often the members may be assigned to the project from other departments within the firm. The PM often deals with multiple teams within the organization including administrative, budget office, health and safety, and various engineering disciplines. The design team organizations may include engineers (for heavy projects), architects, sub-consultant engineers, and CAD specialists. Construction teams have a different culture and may have a shorter-term perspective

on the project. The PM must possess team management skills, since these various sub-teams need to be an integral part of the project organization, referred to as the ''project team.'' The project team must have a well-defined mission with goals and trust instilled by the PM. As part of the team management skill, the PM will likely conduct team building exercises, such as the project kick-off meeting, where they will stress that:

i. All participants need to use effective communications and should confirm that information given and received is clearly understood
ii. All participants have a common customer
iii. Team success will allow continuity of project team
iv. Remembering key words ''responsibility,'' ''honesty,'' ''kindness,'' ''respect,'' and ''communications'' is critical
v. The positive aspects of the project lead to success and perhaps future work for the same client

With regard to the project team, the PM likely will request or pick members in accordance with the client's requirements for the scope, budget, and schedule; acquire resources for the project; develop processes for decision making; and develop a leadership style that is respected and accepted by the whole project team.

Managing the Construction Process

Management of the construction process is best performed by the individuals educated and trained in the profession, that is, engineers and architects. While the laws of various countries differ, they are consistent relative to the registration requirements for practicing engineering or architecture. No individual may legally indicate to the public that he or she is entitled to practice as an engineer or architect without a professional certificate of registration as a professional registered in the locale in which the project is to be constructed. In addition to the requirements for individual practice of engineering, most states and countries require a certificate of registration for a single practitioner and a certificate of authorization for an entity such as a corporation or partnership to conduct business in that locale.

All documents intended for use in construction are required to be prepared and administered in accordance with the standards of reasonable skill and diligence of the profession. Care must be taken to reflect the requirements of country and state statutes and county and municipal building ordinances. Inasmuch as engineers and other professionals are licensed for the protection of the public health, safety, and welfare, documents prepared by them must be of such quality and scope and be so administered as to conform to professional standards.

Nothing contained in the law is intended to prevent drafters, students, project representatives, and other employees of those lawfully practicing as registered architects from acting under the instruction, control, or supervision of their employers, or to prevent employment of project representatives from acting under the immediate personal supervision of the registered engineer or other professional who prepared the construction documents.

CIV3301 PRINCIPLES OF CONSTRUCTION
LECTURE IV

▶ PART B – General Considerations in Civil Engineering Works

A. Site Analysis, Investigation and Lay-out

Site Analysis

The physical characteristics of the site and its immediate environment will influence the decisions to be made about a building's design and construction. The information gathered from a thorough site analysis is, therefore, a vital exercise and must be completed before any design or construction work commences. This information can then be collated in a performance appraisal document from which informed decisions about the best way to proceed may be made.

Function of Site Analysis

Prior to any construction operations, the client/developer will want to know whether it is economically viable to build on the proposed site. Because the **nature and condition** of the ground and soil below the surface of the site are an unknown quantity they pose a considerable risk to the construction project, with the potential to cause **delays and additional costs**, both of which can be substantial. Inadequate soil investigation and hence inappropriate foundation design can lead to structural problems at a later date, which is a problem for the owners and users as well as the insurers. Many projects are built on brownfield sites (land that has been previously built on and used) and it may be necessary to seal, stabilize or remove any contaminated ground, toxic waste or other dangerous substances before commencing the main construction works. The extent of contamination must be established before any work commences on the site.

The main purpose of site analysis is to identify and hence reduce the risks associated with the development by recording site features and soil characteristics, helping to determine the design and cost of suitable foundations and structure. A thorough site analysis is an essential first step that will assist development, design and construction decisions. The site analysis helps:

i. The client to assess whether the project is viable (best done in consultation with professional advisors)
ii. The client, designer, structural engineer and contractor to locate the best position for the building, avoiding or accommodating identified problems where possible, while making the best possible use of physical features and environmental conditions
iii. The engineers to design the most suitable foundation system
iv. The mechanical and electrical consultants to design the service provision
v. The designers and contractor to ensure that safe construction methods are used
vi. The environmental consultants to identify the most suitable way of dealing with any contaminants and problem materials, e.g. remediation works, material reuse, on-site treatment and disposal options to licensed tips.

Sequence of Activities in Site Analysis

The site analysis comprises three interrelated research activities as shown in Figure 1.0: the desk-top study, the site reconnaissance, and the ground and soil investigations. The soil investigation may also involve laboratory tests on liquids and gases found in soil samples. The order in which these activities are carried out will depend to a large extent on the nature of the development and the timescales involved.

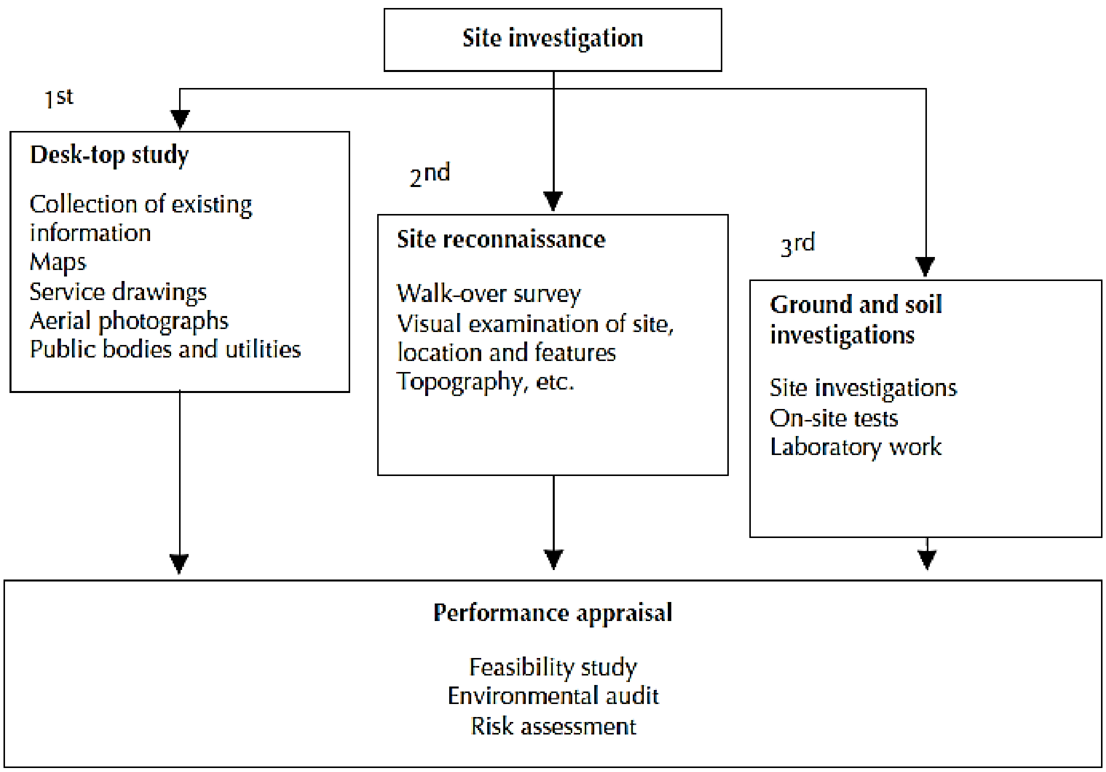


Fig. 1.0 Sequence of site analysis

1. **Desk-top Study**

   The 'desk-top study' is a vital element in any site analysis exercise. The study involves the collection of all documents and materials that can be obtained without having to visit the site. There is a considerable amount of information available from local and national authorities, museums, private companies, research groups and individuals. The client or previous owners may also have relevant information to hand.

Although the different site investigation operations often overlap, care should be taken not to commence with expensive ground exploration and soil tests before the desk-top study is completed. This is partly to avoid unnecessary work and expenses – for example, information from the desk-top study may reveal that recent site and soil investigations are available – and partly a health and safety issue since the approximate location of services and potential hazards must be known before carrying out any physical investigations. Early and thorough research may also show that the site is unsuitable for development, or that special measures are required before proceeding further.

Information required at Desk-top Study Stage

Ownership(s) and legal boundaries

The client should provide, via a legal representative, information pertaining to the exact location of the site boundaries and responsibilities for maintaining them. These will need to be checked against a measured survey and any areas of uncertainty checked by the legal representative. Other issues to be determined by the client's legal representative include:

- Rights of way
- Rights of light
- Rights of support (for adjoining properties)

- Legal easements
- Ownership of land (essential where parcels of land are being assembled to make a larger site)
- Rights of tenants, etc.

Ground conditions

As a first step it is usual to collect information on soil and subsoil conditions from the state and local authority. This includes knowledge from maps, geological surveys, aerial photography and works for buildings and services adjacent to the site, which may in itself give an adequate guide to subsoil conditions. Geological maps from the Nigerian Geological Survey, information from local geological societies, Ordnance Survey maps, mining, river and coastal information may also be useful.

Services

All suppliers of services and relevant agencies should be contacted to confirm the position of pipes and cables and the nature of the existing supply, i.e. its capacity. This includes gas, mains water, sewage and surface drainage pipes as well as electricity, broadband and telephone cables. It is usual for a representative of the supplier to visit the site to identify their equipment (which might be in a different location to that shown on plans).

Contaminated land

Previous use of land can give some clues as to the likely contaminants to be found and the local authority may have records that can help in this regard. However, extensive soil testing should be carried out to ascertain the nature and extent of any contamination.

Mining activity

Some parts of Nigeria have a long and varied history of mining. Coal and Tin mining is the most common and advice on mining records and coverage can be accessed via the Ministry of Solid Minerals; however, certain geographical areas may have specific mining issues, e.g. gold mining in areas of Zamfara. The position of mines and mine shafts, and their size, depth and condition may affect the positioning of structures on a site. Work to make old mine workings safe may add significant costs to the development, hence the need for thorough research before finalizing site layout or commencing any work on site.

Flooding

Damage to property and possessions and the associated disruption to businesses and family life has become a serious concern in recent years as the frequency of flooding has increased (even in cities like Kano). Factors include heavy rainfall, buildings sited on, or too close to, flood plains and inadequate maintenance of rivers, watercourses and surface water drainage. Thorough checks should be made about previous flooding of the site (if any), proximity to flood plains and any special requirements suggested or required by the various authorities and insurers.

Typical sources of information

Information will always be site-specific; however, the following list of information sources serves as a general guide:

- National Survey and Controls – detailed maps and controls in many different formats are available from the office of the Surveyor General in many states of the country.
- Historical maps and libraries local to the site
- Geological maps – the Nigerian Geological Survey is the national repository for geosciences data.
- Hydrogeological maps – soil reports and publication lists
- Meteorological information – monthly and annual reports are available on air temperature, wind speed, rainfall and sunshine. Such information is useful when designing the infrastructure and for scheduling construction operations. Statistics on averages and extremes are also available from NIMET.
- Hydrological information – surface water run-off data are collected by water authorities, private water undertakings and local authorities
- Site history:
    - Previous owners and developers
    - Site surveys and drawings used for previous development

  - Records held by Building Control
  - Local newspaper archives
  - Records held by the local planning authority
- Gas supplier – location of gas mains
- Electricity supplier – location of electricity cables
- Electricity generating board – mains electricity cables
- Water suppliers – water supply mains
- Mains sewers
- Local authority – local sewers
- Telecommunications authority – telephone and optical cables
- Rail authority – railways
- Aerial photographs – there are many collections of aerial photographs dating back over many decades and can be obtained from the office of the Surveyor General.

2. **Site reconnaissance**

Written approvals from the client and/or the property owners must be in place and a thorough risk assessment exercise must be carried out before entering the site, especially before any invasive investigations are carried out (which may require separate written permission). Obvious considerations are related to trespass and criminal damage, although the prime concern must be for the safety of those doing the investigations. The majority of sites will have been used previously (and may still be in use) and might contain buildings that are structurally unsound (which may be redundant or still in use despite their condition).

Specialists should be appointed to establish the condition and safety of existing structures and whether or not prohibited material like asbestos is present. Figure 2.0 provides an overview of the type of information that can be collected during a site reconnaissance.

The visual inspection of the site

A visit to the site and its surroundings should always be made to record everything relevant to the proposed development. The site reconnaissance is often referred to as the visual inspection or the 'walkover'. From experience we have found that two pairs of eyes (or more) are always better than one and so the visual inspection should be undertaken by at least two, and preferably three, people, e.g. the engineer, contractor, and the architect (in the case of buildings) with each taking their own notes but discussing features as they come across them.

Careful observation should be made of the nature of the subsoil, vegetation, evidence of marshy ground, signs of groundwater and flooding, irregularities in topography, ground erosion and ditches and flat ground near streams and rivers where there may be soft alluvial soil. A record should be made of the foundations of old buildings on the site. Cracks and other signs of movement in adjacent buildings should be noted. When undertaking site reconnaissance on contaminated land, ensure as far as possible that all hazards have been identified and that correct safety procedures are followed. In preparation for the site reconnaissance, all of the maps and records should be assembled so that any differences or omissions found when walking over and observing the site can be recorded. A visual inspection of physical site boundaries should be made and compared with any legal documents that show boundaries.

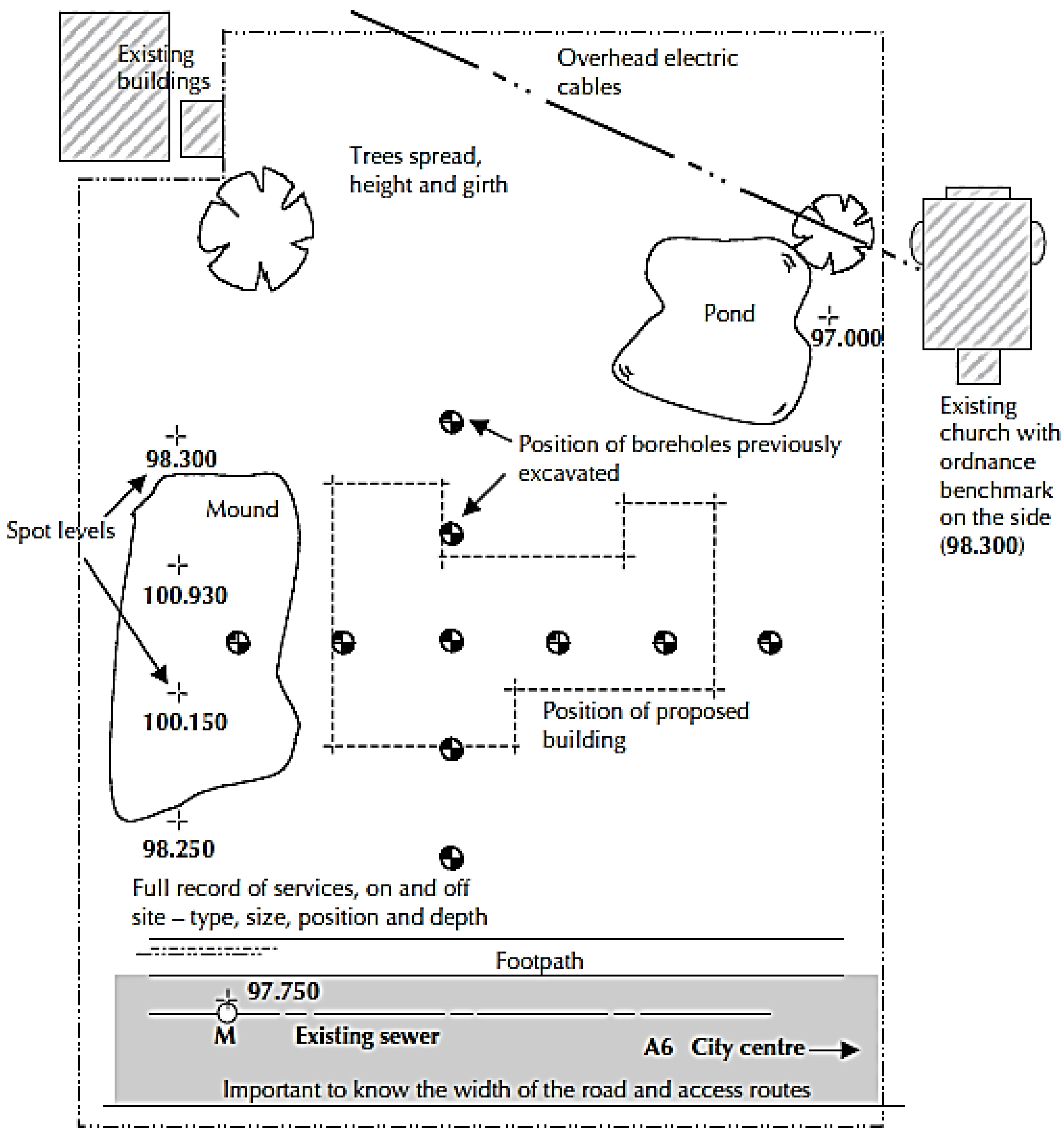


Figure 2.0 Schematic showing information collected during site reconnaissance.

Procedure for walkover surveys

When conducting a walkover survey, the British Standard for site investigations (BS 5930:1999) suggests that the surveyor should:

- Traverse the whole area on foot (if possible and safe to do so)
- Establish the proposed location of work on plans
- Identify and record any differences on the plans and maps
- Record details of existing services, trees, structures, buildings and obstructions
- Check access and determine capability of sustaining heavy construction traffic
- Record water levels, fluctuations in levels, direction of flow and flow rate
- Identify adjacent property and the likelihood of it being affected by proposed works
- Identify any previous or current activities that may have led to contamination
- Record mine or quarry workings, old structures and other features
- Record obvious features that pose immediate hazard to public health and safety or the environment
- Record any areas of discolored soil, evidence of gas production or underground Combustion During a site reconnaissance the following ground information and features should be noted (BS 5930:1999):
- Record surface features on site and on adjacent land, note the following:

- Type and variability of surface conditions
- Compare land and topography with previous records; check for fill, erosions and cuttings.
- Any steps in the surface that may indicate geological faults. Steps in mining areas may be the result of subsidence. Other evidence of subsidence caused by mining may include compression or tensile damage to structures and roads, structures out of plumb and interference with the line of drainage patterns.
- Where the ground is terraced and broken on hill slopes this may be due to landslips; small steps and inclined tree trunks may be evidence of creep and ground movement.
- Crater-type holes in chalk or limestone usually indicate swallow holes that have been filled with a soft material.
- Low-lying flat areas in hill country may be the site of a previous lake and can indicate the presence of soft silts and peat

➢ Record details of ground conditions in quarries and cuttings.

➢ Record groundwater levels (these are often different from streams, ponds and lakes).

➢ Identify the position of wells and springs.

- Note the nature of vegetation in relation to soil type and wetness of soil. Unusual green patches, reeds, rushes, willow trees and poplars usually indicate wet ground conditions.
- Investigate structures in the vicinity of areas having a settlement history.

Identification and physical location of services

Before undertaking any digging, e.g. for trail holes, it is necessary to clearly identify the nature of the services on the site and their actual position. Unfortunately, the majority of the plans provided by the service providers only give an approximate location of their pipes and cables; therefore, some detective work is required on site. The first task is to identify all inspection covers and the nature of the service, and to compare their positions with those on the drawings. Handheld sonic and magnetic detecting devices to help locate the position of services are available from most plant hire firms. Exact position and depth can be established by carefully hand digging trial pits to expose pipes, cables and conduits. The service providers will also be keen to establish exact positions in an attempt to prevent damage to their pipes and cables. The organizations responsible for particular services should be invited to the site to help to establish the exact position, size and capacity of their supply and to resolve any uncertainty.

In order to develop the site to its full potential services may need to be re-routed, if the appropriate authority will give permission. This is usually an expensive option, which could threaten the viability of the project. Alternatively, the proposed position of the structure may need to be adjusted to enable the project to proceed without undue disruption to major service routes.

Surveys

Measured survey

A land surveyor will conduct a topographical survey to establish the physical boundaries, existing features and variations in ground level. Most land surveyors have a standard list of features to be established during the land survey, although it is not uncommon to direct the land surveyors to particular areas so that they record all the necessary features on and immediately adjacent to the site. The survey will be provided as a digital file to import directly into computer aided design (CAD)/building information modelling (BIM) software.

Condition survey

Condition surveys are used to record the physical condition of boundaries and adjoining property as well as the buildings on the site to be protected, refurbished or altered. Before commencing any work that is likely to result in vibration (e.g. demolition, excavations, piling, heavy construction traffic, and so on) it is important to undertake a full condition survey of surrounding and adjoining properties and structures. This serves as a record for any subsequent claims for damage and also serves as a good source of design information, for example, indicating how particular materials have weathered. Detailed drawings and written descriptions of the property should be supported with photographic evidence.

Photographic and video surveys

Photographic and video surveys are useful tools to prompt one's memory when back in the office. They also provide a record of the original condition of the site and adjoining land/property in case of any dispute or claim for damage. Photographic surveys should be conducted in a systematic and thorough manner, with the position of the photographer and direction of view noted on a site plan to avoid any future confusion.

CIV3301 PRINCIPLES OF CONSTRUCTION
LECTURE V

▶ PART B - General Considerations in Civil Engineering Works

B. Site Investigation

Site investigation or Sub-Soil explorations are done for obtaining the information about subsurface conditions at the site proposed for construction. Soil exploration consists of determining the profile of the natural soil deposits at the site, taking the soil samples and determining the engineering properties of soils using laboratory tests as well as in-situ testing methods.

Details of the subsoil should include soil type, consistency or strength, soil structure, moisture conditions and the presence of roots. From the nature of the subsoil the bearing capacity, seasonal volume changes and other possible ground movements are assumed. To determine the nature of the subsoil below foundation level it is necessary either to excavate trial pits some depth below the assumed foundation level or to bore in the base of the trial hole to withdraw samples.

The common methods of obtaining samples include:

- Trial pits
- Boreholes – cable percussive boreholes and rotary drilled borehole
- Window sampling and dynamic probe testing

When proposing work to existing structure (e.g. adding another floor) it will be necessary to expose the existing foundation in a number of places to check if it was built as detailed on drawings (if available) and also to check the subsoil below the foundation. Whichever system is adopted will depend on economy, the proposed construction works and the nature of the subsoil. Trial pits or boreholes should be sufficient in number to determine the nature of the subsoil over and around the site of the building and should be at most, say, 30m apart.

Generally, sub-soil exploration is aimed at collecting valuable geotechnical information sufficient enough to form the basis for foundation stability. Poor site investigation leads to erroneous design and subsequently the structure may encounter excessive settlement among other defects. Ground movements that may cause settlement are:

- Compression of the soil by the load of the building
- Seasonal volume changes in the soil
- Mass movement in unstable areas such as made up ground and mining areas where there may be considerable settlement
- Ground made unstable by adjacent excavations or by de-watering, for example, due to an adjacent road cutting.

Foundation design and subsoil examination

To select a foundation from tables, or to design a foundation, it is necessary to calculate the loads on the foundation and to determine the nature of the subsoil, its bearing capacity, likely behavior under seasonal and groundwater level changes, and the possibility of ground movement. Where the nature of the subsoil is known from geological surveys, adjacent building work, trial pits or borings and the loads on foundations are small, as for single domestic buildings, it is generally sufficient to excavate for foundations and confirm, from the exposed subsoil in the trenches, that the ground is as anticipated. Table 1.0 provides a guide on the allowable bearing pressure of different classifications of ground.

Where loads may be more substantial or there is little evidence available on the nature of the ground, boreholes and trial pits will need to be excavated. The depth of exploration will be related to the proposed foundation and loads imposed on the subsoil. Under pad foundations there is a significant pressure on the subsoil to a depth and breadth of about one-and-a-half times the width of the foundation; the depth of pressure is slightly greater for strip foundations (Table 2.0 and Figure 1.0). If, at any point where the foundation exerts this bulb of pressure, the soil-bearing capacity is less than the load exerted by the foundation, then appreciable settlement of the foundation can occur and damage the building (Figure 2.3). It is important, therefore, to know or ascertain the nature of the subsoil both at the level of the foundation and for some depth below.

Table 1.0 Allowable bearing pressure of soil and ground

Soil and ground classification	Bearing capacity (kN/m^2)
Rocks	
Strong sandstone	4000
Schists	3000
Strong shale	2000
Granular soils	
Dense sand and gravel	>600
Medium dense gravel	200–600
Loose sand and gravel	<200
Compact sand	>300
Loose sand	<100
Cohesive soils	
Stiff boulder clay	300–600
Stiff clay	150–300
Firm clay	75–150
Soft clay and silt	<75

Table 2.0 Depth of effective bulb pressure

Foundation type	Effective bulb pressure
Strip	3 × the width of foundation
Pad	1.5 × the width of foundation
Raft	1.4 × the width of foundation

If the pressure exerted by the foundation is greater than the bearing pressure of the soil then settlement will occur

If it is predicted that the bulb of pressure will exert force on a weak stratum then a different foundation system will need to be used

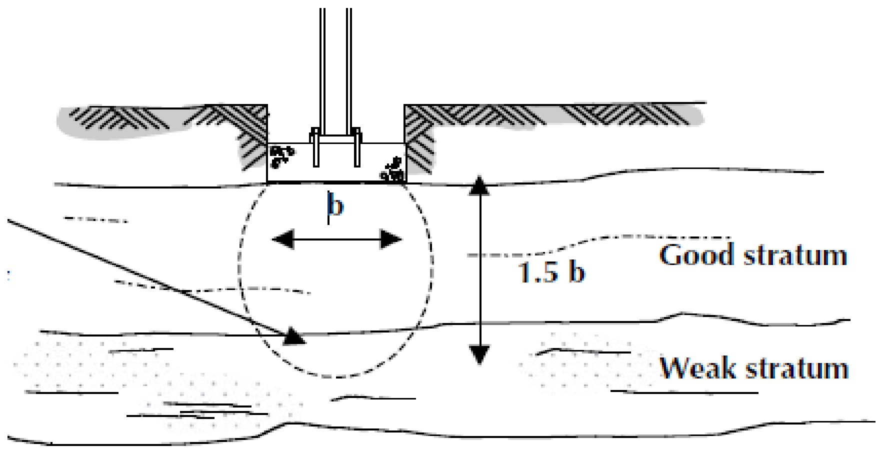


Figure 1.0 Example of foundation exerting pressure on weak stratum: may lead to settlement.

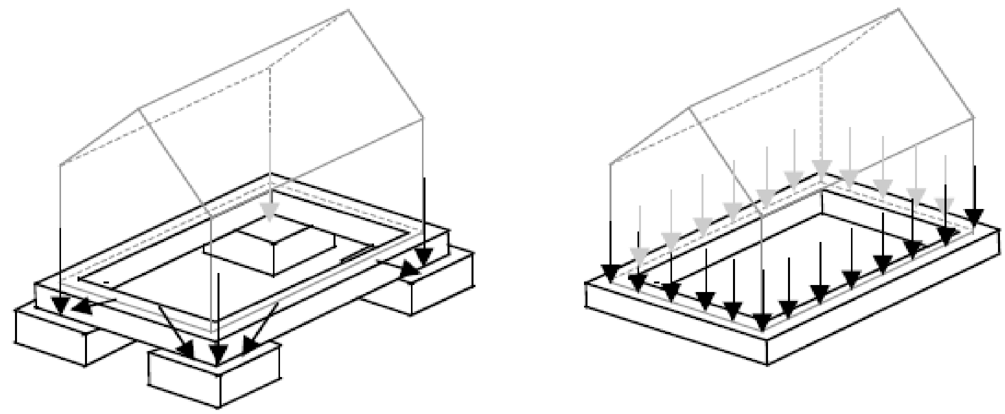
Figure 2.0 shows typical forces exerted on the substructure at a depth of one-and-a-half times the width of the foundation. The loads placed on a pad foundation are generally distributed over a greater surface area, reducing the load per unit area. Strip foundations transfer the loads from the wall directly to the ground. Although strip foundations do spread the load over a slightly greater surface area they exert continual pressure along the ground (Figure 2.0b).

Care should be taken where foundations are positioned close to each other, or a new foundation is placed next to an existing structure. Each foundation exerts a force on the ground that is distributed at an angle of approximately 45°. Where the pressure exerted on the ground by the foundations overlaps, the soil has to bear the force of both foundations (Figure 3.0). If the force exerted by both foundations is greater than the bearing capacity of the soil, the ground will fail and the foundation may settle.

Trial pits

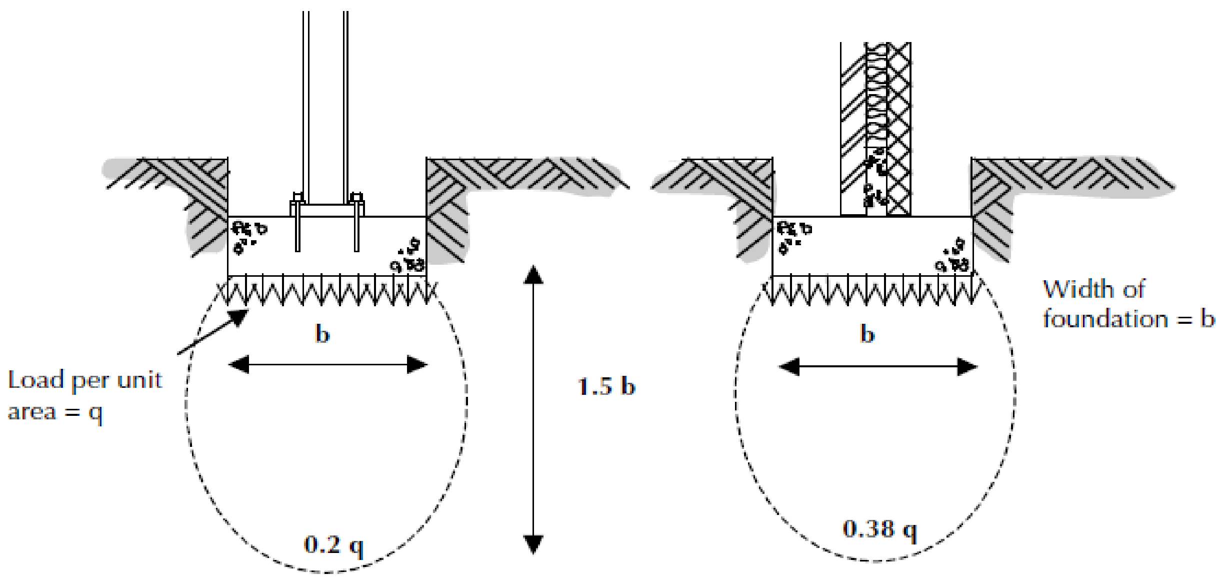
To make an examination of the subsoil trial pits and/or boreholes are excavated. Trial pits are usually excavated by a mechanical excavator, or in some cases by hand tools, to a depth of 3–4m. The nature of the subsoil is determined by examination of the sides of the excavations.

Soil and rocks can be examined in situ on the faces of the excavated pit, and samples taken for further laboratory tests. **The trial pit also provides an indication of the ease of dig (or excavation), trench stability and groundwater conditions**. For exploration of shallow depths (up to 3m) this is usually more economical than boreholes. The pits are usually rectangular, being approximately 1.2 × 1.2m in plan. The pits should be excavated in the vicinity of the proposed structure; if the pit is located under a proposed foundation particular attention needs to be given to the material used to backfill the hole. In such situations material should be of sufficient strength and well compacted. As each trial pit is excavated and inspected a report should be made of the inspection. Typical information contained in the inspection, the trial pit log, is shown in Figure 4.0



Pad foundation

Strip foundation



a. Pressure at this point is less than 0.2 of the load per unit area of the foundation

b. Pressure at this point is less than 0.38 of the load per unit area of the foundation

Figure 2.0 (a and b) Bulb of pressure exerted under a pad and strip foundation.

Where foundations are close together the stress exerted on the soil can overlap increasing the force in this area

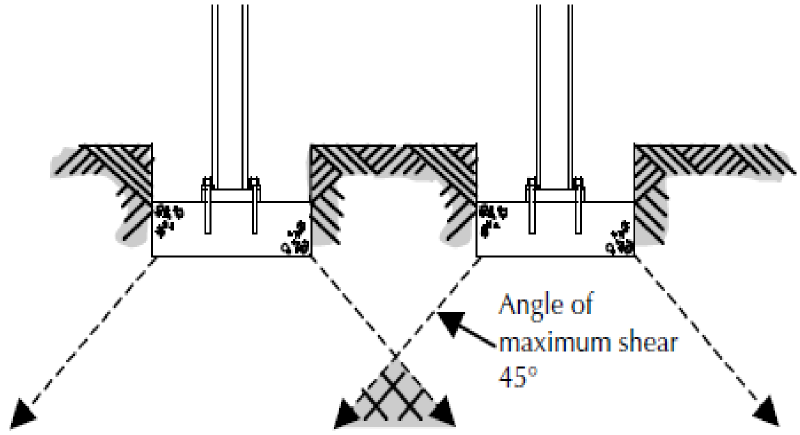
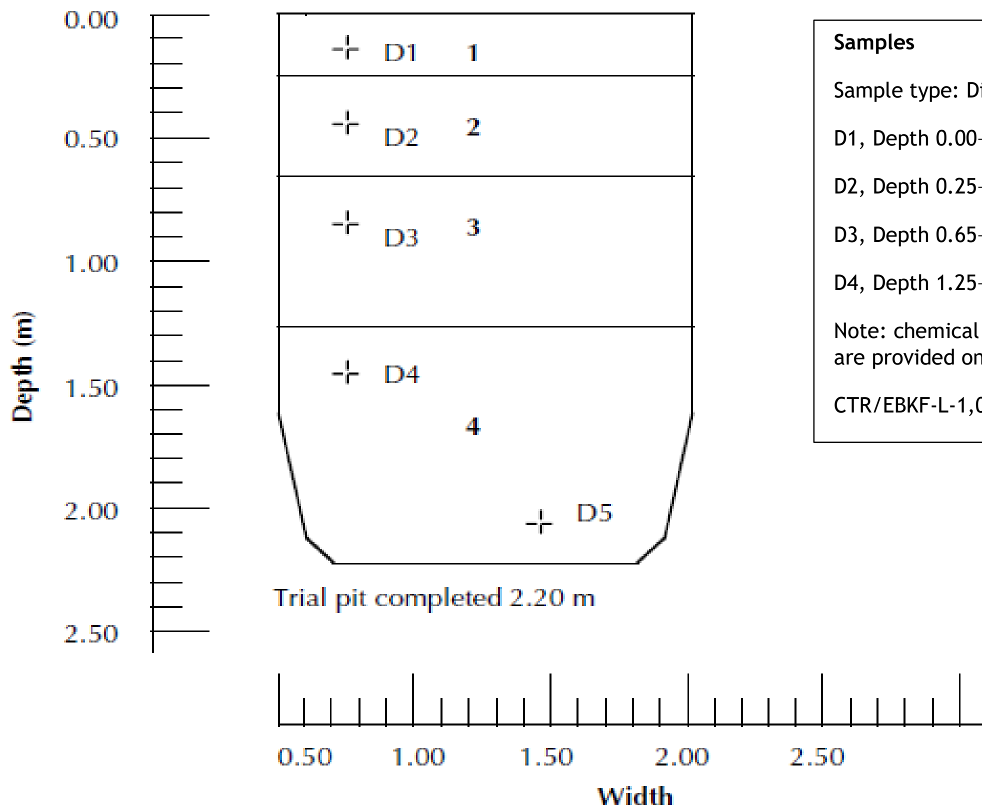


Figure 3.0 Combined stress exerted on subsoil from foundations in close proximity.

Sketch of face of trial pit
Location: Ebuka's Farm - Kano
No 4. - Face - A
Date 09/09/2019
Coordinates 102.300 : 98.580 (Provided by the Client)



Samples

Sample type: Disturbed

D1, Depth 0.00-0.25

D2, Depth 0.25-0.65

D3, Depth 0.65-1.25

D4, Depth 1.25-2.25

Note: chemical test results on soils are provided on document

CTR/EBKF-L-1,09/09/2019

Strata

(1) Topsoil and grass 220 mm
(2) Made ground: firm to stiff orange brown sandy clay with a little gravel of limestone
(3) Made ground: soft to firm dark grey clay with occasional rootlets
(4) Medium dense dark grey clay

Notes:

(1) Groundwater: no groundwater encountered
(2) Variability of faces: all faces were similar
(3) Stability of faces: all faces were stable
(4) Weather: Clear

Figure 4.0 Trial pit log.

Boreholes

'Borehole' is often used as a generic term that represents the various methods used to excavate and extract disturbed and undisturbed soil samples. All samples taken from boreholes should be sealed as soon as possible to minimize any loss of moisture before testing. Some of the most commonly used methods are as follows.

Auger boring – rotary boring methods

These holes are usually made by hand or powered auger into the ground. Auger holes are typically 75–150mm in diameter. Short helical augers are used and disturbed samples of soil are collected as they are brought to the surface. Such methods are not widely used as they do not allow the soil to be examined in situ and are not capable of penetrating to the depth of boreholes. Rotary drilling is used where the boreholes are being cut into very dense gravel or bedrock. Samples or bedrocks are recovered in seamless plastic tubes, are logged by an engineer, and then taken for laboratory testing

Figure 5.0 Typical Hand Augers

Figure 6.0 Rotary Drilling Equipment

Window samplers

A window sampler is a steel tube about 1m long with a hole cut into the wall of the tube allowing the disturbed sample to be viewed or soil samples taken from the tube. The tube is driven into the ground using a lightweight percussion hammer and extracted with the aid of jacks. A range of tube diameters are available. In practice the large tubes are driven in first and removed leaving a hole for smaller tubes to be inserted and driven in further. Samples can be obtained down to a depth of 8m.

Window sampling can be carried out using either handheld pneumatic samplers or tracked percussive samplers (Figure 7.0). The samples are retrieved in seamless plastic tubes. The recommendation is that; a qualified engineer logs the samples. Window sampling is suited to sites with restricted access, where disturbance is to be kept to a minimum and contamination investigation. The percussive samplers are also normally capable of doing penetrometer testing. Penetrometer testing is a continuous soil test procedure which enables the relative density or strength of the ground to be determined.

Figure 7.0 Window Sampler

Percussion boring

Boreholes are normally made using light percussion equipment. The 150–200mm diameter weighted hollow tube is dropped into the hole so that the soil becomes lodged within the tube. The tube is then lifted to the surface and the sample removed. In clay soils the method relies on the cohesive properties of the soil to hold it in the tube (clay cutter). In granular soils a hollow tube with a flap over its base is used (shell or bailer). A single day's drilling can excavate up to 15m (typically 7–15m).

The materials that are collected during the drilling and excavation can be retained as disturbed samples; however, in cohesive soils a 100mm diameter tube can be dropped to the bottom of the hole to collect an undisturbed sample (undisturbed sampling is generally confined to cohesive soils). The tube is then taken back to the laboratory for further tests. Standard penetration tests (SPTs) and vane tests can be carried out in the borehole as the drilling and excavation process proceeds.

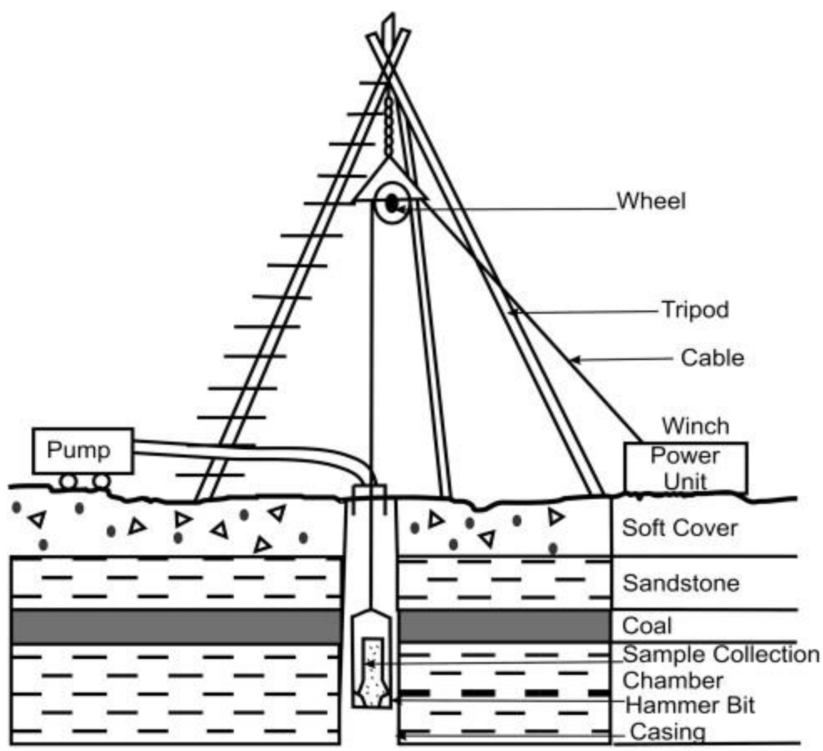


Figure 10.0 Percussion Equipment Set-up

Photographic evidence from boreholes

In very stiff clays and fissured rock it is possible to take photographs of the strata using a remote-controlled borehole camera. If it is clear that a borehole has entered a void, photographic evidence may determine the nature of the void, e.g. mine shaft, sewer, cave, and so on.

CIV3301 PRINCIPLES OF CONSTRUCTION
LECTURE VI

▶ PART B – General Considerations in Civil Engineering Works

CONSTRUCTION EQUIPMENT

TRACK OR TYRE?

Most equipment moves on tracks or tires, and this has a major influence on productivity (how much dirt can be moved or excavated in a certain amount of time or how fast material can be transported). Both types of movements offer advantages and disadvantages based on working and surface conditions. The following table clear which is the most appropriate for every case

Requirement	Best Choice
High Tractive effort required	Tracks
Low Tractive effort required	Tires
Stable work surface	Tires
Unstable work surface	Tracks
Short push or travel distance	Tracks
Long push or travel distance	Tires
Muddy work conditions	Tracks
Side sloping	Tracks
Loading heavy unstable loads (dump truck)	Tracks
Maneuverability required	Tires
Speed required	Tires

WORK ACTIVITIES AND EQUIPMENT PACKAGES

Each work activity has a unique or combination of equipment for its execution. The following table shows several work activities with their respective equipment requirement.

Activity	Dozer	Loader	Grader	Scraper	Dump Truck	Backhoe	Excavator	Front Shovel	Concrete Pump	Mobile concrete Mixer	Crane
Excavating above grade	X							X			
Excavating below grade	X			X		X	X				
Grubbing	X						X				
Heavy ripping											
Light ripping	X										
Tree stump removal	X						X				
Topsoil removal/Storage	X		X	X							
Rough cutting	X			X			X				
Rough filling	X	X		X	X						
Finish grading			X								
Foundation excavation						X	X				
Foundation backfilling		X				X	X				
Road base construction	X	X	X		X	X	X				
Temporary road construction	X	X	X		X						
Concrete mixing and transport										X	
Concreting above or below grade									X	X	X

EARTH MOVING EQUIPMENT

1. Bulldozer

A bulldozer is a tractor unit with a blade attached to its front. The blade is used to push, shear, cut, and roll material ahead of the tractor. It is an ideal surface earthmover that performs best at about 5kmph. Each model of bulldozer has an operating range for blade size and adjustment. Larger machines have greater operating ranges than smaller machines. A larger machine can pitch and tilt deeper than a smaller machine typically. For heavy civil work, bulldozer blade widths can range from about 80 inches (≈2m) to 220 inches (≈5.6m) and operating weights can range from about 7 tons to over 120 tons.

The hard clay-like soil had to be ground up, pushed into piles by the bulldozer, and then loaded by front-end loaders into dump trucks to be hauled away. This was more efficient than using excavators due to the denseness of the soil.

The bar connecting the blade to the body of the bulldozer is parallel to the travel surface and just above it. This positioning can deliver maximum forward force to push a pile of dirt or a scraper. If the work surface is hard and compact, the dozer will make a pass with the ripper first, breaking up the soil and follow another pass using the blade.

2. Frontend Loader

Front-end loaders typically are tractor powered and operate on tires. They are typically articulated and very maneuverable, making them ideal for constricted areas. They are used primarily for material moving and re-handling. They are ideal for scooping and hauling materials in storage piles, where it is to be permanently placed, or loading it into dump trucks. Loaders are ideal for dumping soil back into the hole after the necessary below grade work is done. Tracked loaders may be required for extreme surface conditions demanding greater traction or stability.

Every concrete or asphalt batch plant has a tire equipped frontend loader to stock the feed to the batch hopper with aggregate and sand. Fixed cycle times for loaders (raise, dump, and lower the bucket) range from about 9s to about 20s depending on the size of the loader. General-purpose bucket capacities range from about 0.57m3 to about 13.8m3. Small loader is ideal for confined spaces and smaller loads. These small loaders are very maneuverable and are ideal for use in constricted limited working areas.

A very common type of frontend loader is the Skid-steer loader (Bob Cat). They are used often for moving sand within slab forms or with fork attachments to carry brick, mortar, or sand. They are excellent for surface movement of small amounts of material.

3. Motor Graders

   This type of equipment has been around since the start of road building, though originally powered by a team of oxen, mules, or horses. The need for a smooth stable travel surface has always been an important part of a road system. Another name for a motor grade is ''maintainer,'' This name is appropriate because this equipment is typically used to maintain grade and a smooth surface for rural nonpaved travel roads or haul routes on construction sites. The blade is used to push dirt straight ahead or to the side at a desired level. The grader can be used for light surface excavation but is mainly used to move soil to create a level surface.

Note in Figure 3, the ring to which the blade is attached underneath the frame. This ring can be swiveled vertically, and the casting angle of the blade adjusted on it. The blade can be angled to shape road banks. Standard blade widths range from 120 inches (3.048m) to 140 inches (3.556m) and speed in midrange gear is approximately 9.6 kmph. Front tires are usually leaning to resist the force created when the blade is cutting and side casting the material. As the dirt is pushed ahead of the blade it fills voids in the surface over which it is moving. Excess dirt is pushed into other surface voids or to the side. When the dirt is cast to the side of the grader, this is called a windrow (row of piled dirt).

Usually a front-end loader will follow behind the grader to scoop up excess dirt in the windrow if necessary. For a small amount of excess, a backhoe scoop can be used. Laser level readers can be attached to the motor grader blade so that the operator can establish a desired elevation using the level signal, not having to rely on feel and experience as much. The grader depth of cut is adjusted based on the signal setting.

4. Scrapers

Scrapers are designed to load, haul, and dump loose material. The greatest advantage is their versatility. They can be used for a wide variety of material types and are economical for a range of haul distances and conditions. They are a compromise between a bulldozer, an excavator, and a dump truck. Scrapers are articulated, tractor powered, and pull a bowl that holds the soil. A blade is mounted on the bottom of the bowl that cuts into the travel surface and the disturbed soil flows into the bowl as the scraper moves forward. Scrapers can self-load or be assisted by another scraper or a bulldozer

Scrapers are classified in the following categories: Scrapers are classified in the following categories:

i. Single engine: A tractor pulling a bowl that can operate under its own power or be push-assisted. This is the most common type of scraper on large earthmoving jobs.

ii. Tandem or twin engine: This type has a second engine mounted in the rear and can develop greater power. This is ideal for steeper hauls at greater speeds. Typically cost about 30% more than a conventional scraper.

iii. Push–pull scraper: This type is designed with a push block mounted on the rear and a bail mounted on the front to assist other scrapers or be pushed by other scrapers. They are ideal for dense soil-excavating projects when a dozer is not utilized for pushing.

iv. Elevating: These are self-contained loading and hauling units. The chain elevator serves as a loading mechanism. The extra weight of the loading mechanism is a disadvantage during the haul cycle, but this type is ideal for short-haul situations where the ratio of haul time to load time is low. These are used generally for utility work, dressing up behind high-production spreads, or shifting material during fine grading operations. The chain breaks the soil as it enters the bowl and is easier to discharge. These units can be push-assisted

5. Truck (Dumper Truck)

Trucks are an extremely important part of the earthmoving and material-moving process. They are basically a tractor and a trailer with sides. Like the rest of the equipment categories, there are a wide range of trucks based on hauling conditions and need. Typically, trucks are sized by trailer volume. Obviously, the larger and heavier the load, the larger a tractor you need to pull the trailer. Trucks are typically used with excavators and loaders for excavation and soil haul off or delivery. Compared to other earthmoving equipment, they can obtain high travel speeds. Rough terrain trucks have frames, suspension systems, and motors designed to traverse rough surfaces and radical travel grades.

Trucks designed for hauling on the highway are designed for less rigorous conditions. Two basic considerations for choosing a truck trailer are the method of dumping and the class of material hauled. Trucks may dump from the rear (the most common), from the bottom (belly dump), or from the side depending on the type of material and work activity. Common rear dump trucks are typically not articulated, but larger rough terrain trucks are typically articulated for greater maneuverability.

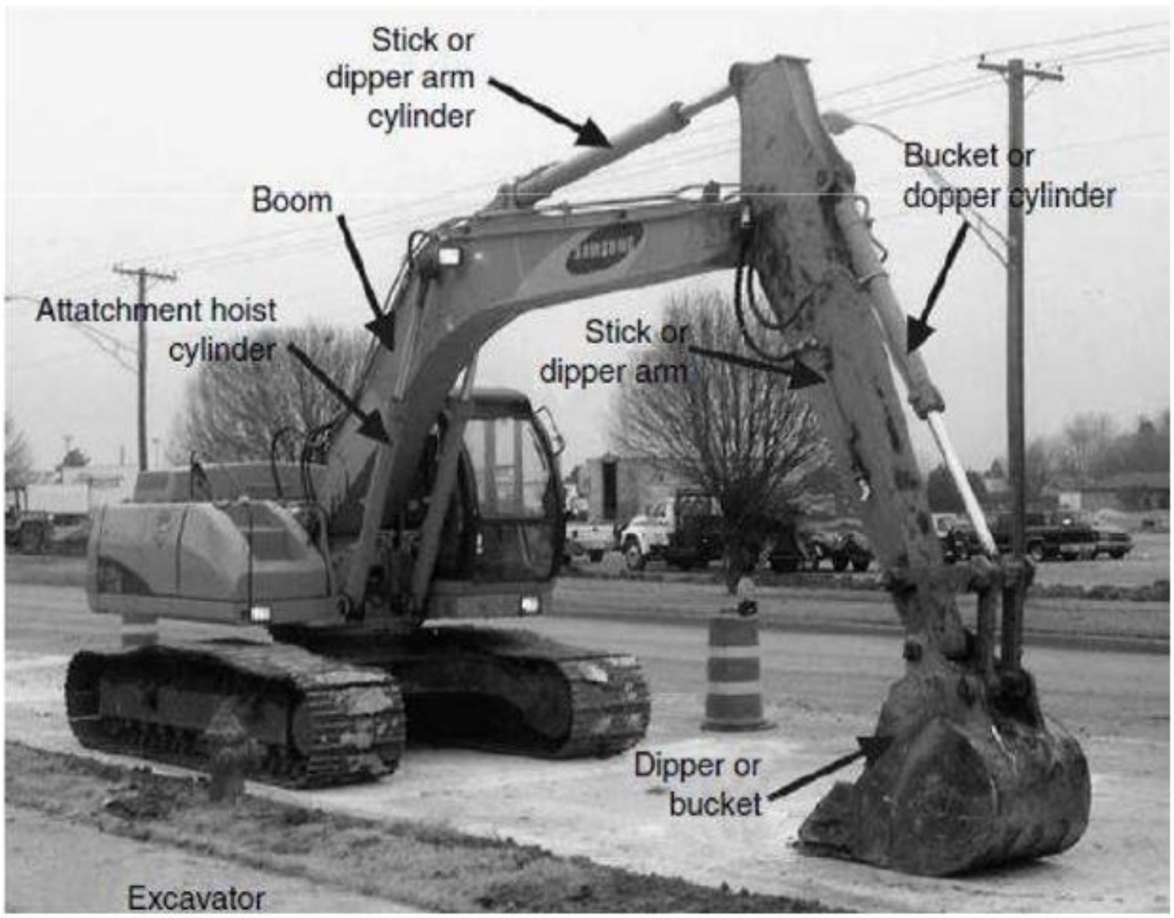
6. Excavating Equipment

The excavator combines digging and lifting abilities. Excavators come in a wide range of sizes. Bucket size, boom length, and operating speed are primary considerations for choosing the proper excavator. Typically, the faster the operating speed, the faster the machine can load, swing, dump, return, and dig (the normal excavator production cycle). Excavators are ideal for digging and dumping into a dump truck or a pile. Excavators are ideal for underground utility construction. For trenching, the operator fills the bucket and dumps to the side above grade.

With the excavator in the same path, the operator can also use the bucket side and bottom to scrape the dirt back into the trench and compact it after the work is done. Another reason that the excavator is ideal for underground utility construction is its lifting ability. Most buckets have an ''eye'' for securing rigging. Pipe can be easily rigged and placed in the trench. If necessary, the load can be picked up and ''walked'' to the placement point. Obviously, the excavator should be rated for the load.

Excavators can accommodate numerous attachments such as pinchers for lifting logs or pipes, a jackhammer for busting up concrete or compacted soil, or a magnet for metal material moving. Excavator attachments are like backhoe attachments and are run by hydraulics. Along with the many attachments, excavators can be equipped with long reach booms, demolition arrangements, different shoe selections, and different quick coupler systems. Bottom dump buckets permit more accurate loading of narrow trucks and reduce spillage.

Heaped bucket capacities range from very small (0.08m^3), to extremely large for mass excavation (over 5.352m^3). Most excavators accommodate a range of bucket sizes. Maximum digging depths range from about 70 inches (1.78m) to 340 (8.636m), depending on the boom and stick lengths and combinations. Lifting capacities over the front of the excavator range from about 590kg to over 29,000kg.



CHOICE OF CONSTRUCTION EQUIPMENT AND STANDARD PRODUCTION RATE

Typically, construction equipment is used to perform essentially repetitive operations, and can be broadly classified according to two basic functions:

(1) operators such as cranes, graders, etc. which stay within the confines of the construction site, and

(2) haulers such as dump trucks, ready mixed concrete truck, etc. which transport materials to and from the site.

In both cases, the cycle of a piece of equipment is a sequence of tasks which is repeated to produce a unit of output. For example, the sequence of tasks for a crane might be to fit and install a bridge girder beam, the sequence of tasks of a ready mixed concrete truck might be to load, haul and unload two cubic meters (or one truck load) of fresh concrete.

In order to increase job-site productivity, it is beneficial to select equipment with proper characteristics and a size most suitable for the work conditions at a construction site. In excavation for box culvert construction, for examples, factors that could affect the selection of excavators include:

1. **Size of the job:** Larger volumes of excavation will require larger excavators, or smaller excavators in greater number.
2. **Activity time constraints:** Shortage of time for excavation may force contractors to increase the size or numbers of equipment for activities related to excavation.

3. **Availability of equipment:** Productivity of excavation activities will diminish if the equipment used to perform them is available but not the most adequate.

4. **Cost of transportation of equipment:** This cost depends on the size of the job, the distance of transportation, and the means of transportation.

5. **Type of excavation:** Principal types of excavation in building projects are cut and/or fill, excavation massive, and excavation for the elements of foundation. The most adequate equipment to perform one of these activities is not the most adequate to perform the others.

6. **Soil characteristics:** The type and condition of the soil is important when choosing the most adequate equipment since each piece of equipment has different outputs for different soils. Moreover, one excavation pit could have different soils at different stratums.

7. **Geometric characteristics of elements to be excavated:** Functional characteristics of different types of equipment makes such considerations necessary.

8. **Space constraints:** The performance of equipment is influenced by the spatial limitations for the movement of excavators.

9. **Characteristics of haul units:** The size of an excavator will depend on the haul units if there is a constraint on the size and/or number of these units.

10. **Location of dumping areas:** The distance between the construction site and dumping areas could be relevant not only for selecting the type and number of haulers, but also the type of excavators.

11. **Weather and temperature:** Rain, snow and severe temperature conditions affect the job-site productivity of labor and equipment.

By comparing various types of machines for excavation, for example, power shovels are generally found to be the most suitable for excavating from a level surface and for attacking an existing digging surface or one created by the power shovel; furthermore, they have the capability of placing the excavated material directly onto the haulers. Another alternative is to use bulldozers for excavation.

The choice of the type and size of haulers is based on the consideration that the number of haulers selected must be capable of disposing of the excavated materials expeditiously. Factors which affect this selection include:

1. **Output of excavators:** The size and characteristics of the excavators selected will determine the output volume excavated per day.

2. **Distance to dump site:** Sometimes part of the excavated materials may be piled up in a corner at the job-site for use as backfill.

3. **Probable average speed:** The average speed of the haulers to and from the dumping site will determine the cycle time for each hauling trip.

4. **Volume of excavated materials:** The volume of excavated materials including the part to be piled up should be hauled away as soon as possible.

5. **Spatial and weight constraints:** The size and weight of the haulers must be feasible at the job site and over the route from the construction site to the dumping area.

Dump trucks are usually used as haulers for excavated materials as they can move freely with relatively high speeds on city streets as well as on highways.

Standard Production Rate

The cycle capacity C of a piece of equipment is defined as the number of output units per cycle of operation under standard work conditions. The capacity is a function of the output units used in the measurement as well as the size of the equipment and the material to be processed. The cycle time T refers to units of time per cycle of operation. The standard production rate R of a piece of construction equipment is defined as the number of output units per unit time. Hence:

$$R = \frac{C}{T}$$

$$T = \frac{C}{R}$$

The daily standard production rate P_e of an excavator can be obtained by multiplying its standard production rate R_e by the number of operating hours H_e per day. Thus:

$$P_e = R_e H_e = \frac{C_e H_e}{T_e}$$

where C_e and T_e are cycle capacity (in units of volume) and cycle time (in hours) of the excavator respectively.

In determining the daily standard production rate of a hauler, it is necessary to determine first the cycle time from the distance D to a dump site and the average speed S of the hauler.

Let T_t be the travel time for the round trip to the dump site, T_o be the loading time and T_d be the dumping time. Then the travel time for the round trip is given by:

$$T_t = \frac{2D}{S}$$

The loading time is related to the cycle time of the excavator T_e and the relative capacities C_h and C_e of the hauler and the excavator respectively. In the optimum or standard case:

$$T_o = T_e \frac{C_h}{C_e}$$

For a given dumping time T_d, the cycle time T_h of the hauler is given by:

$$T_h = \frac{2D}{S} + T_e \frac{C_h}{C_e} + T_d$$

The daily standard production rate P_h of a hauler can be obtained by multiplying its standard production rate R_h by the number of operating hours H_h per day. Hence:

$$P_h = R_h H_h = \frac{C_h H_h}{T_h}$$

This expression assumes that haulers begin loading as soon as they return from the dump site.

The number of haulers required is also of interest. Let w denote the swell factor of the soil such that wP_e denotes the daily volume of loose excavated materials resulting from the excavation volume P_e. Then the approximate number of haulers required to dispose of the excavated materials is given by:

$$N_h = \frac{wP_e}{P_h}$$

While the standard production rate of a piece of equipment is based on "standard" or ideal conditions, equipment productivities at job sites are influenced by actual work conditions and a variety of inefficiencies and work stoppages. As one example, various factor adjustments can be used to account in approximate fashion for actual site conditions. If the conditions that lower the standard production rate are denoted by n factors F_1, F_2, ..., F_n, each of which is smaller than 1, then the actual equipment productivity R' at the job site can be related to the standard production rate R as follows:

$$R' \approx R F_1 F_2 \ldots F_n$$

On the other hand, the cycle time **T'** at the job site will be increased by these factors, reflecting actual work conditions. If only these factors are involved, **T'** is related to the standard cycle time T as:

$$T' \approx \frac{T}{F_1 F_2 \ldots F_n}$$

Each of these various adjustment factors must be determined from experience or observation of job sites. For example, a bulk composition factor is derived for bulk excavation in building construction because the standard production rate for general bulk excavation is reduced when an excavator is used to create a ramp to reach the bottom of the bulk and to open up a space in the bulk to accommodate the hauler.

In addition to the problem of estimating the various factors, F_1, F_2, ..., F_n, it may also be important to account for interactions among the factors and the exact influence of particular site characteristics.

Example 1: Daily standard production rate of a power shovel

A power shovel with a dipper of one cubic meter capacity has a standard operating cycle time of 30 seconds. Find the daily standard production rate of the shovel.

For C_e = 1 m^3, T_e = 30 sec. and H_e = 8 hours, the daily standard production rate is found as follows:

In practice, of course, this standard rate would be modified to reflect various production inefficiencies.

Example 2: Daily standard production rate of a dump truck

A dump truck with a capacity of $6m^3$ is used to dispose of excavated materials at a dump site 4 km away. The average speed of the dump truck is 30 kmph and the dumping time is 30 seconds. Find the daily standard production rate of the truck. If a fleet of dump trucks of this capacity is used to dispose of the excavated materials in Example 1 for 8 hours per day, determine the number of trucks needed daily, assuming a swell factor of 1.1 for the soil.

The daily standard production rate of a dump truck can be obtained thus:

Example 3: Job site productivity of a power shovel

A power shovel with a dipper of cubic meter capacity (in Example 1) has a standard production rate of 960m^3 for an 8-hour day. Determine the job site productivity and the actual cycle time of this shovel under the work conditions at the site that affects its productivity as shown below:

Work Conditions at the Site	Factors
Bulk composition	0.954
Soil properties and water content	0.983
Equipment idle time for worker breaks	0.8
Management efficiency	0.7

Example 4: Job site productivity of a dump truck

A dump truck with a capacity of $6m^3$ (in Example 2) is used to dispose of excavated materials. The distance from the dump site is 4km and the average speed of the dump truck is 30kmph. The job site productivity of the power shovel per day (in Example 3) is $504m^3$, which will be modified by a swell factor of 1.1. The only factors affecting the job site productivity of the dump truck in addition to those affecting the power shovel are 0.80 for equipment idle time and 0.70 for management efficiency. Determine the job site productivity of the dump truck. If a fleet of such trucks is used to haul the excavated material, find the number of trucks needed daily.

The actual cycle time T'_h of the dump truck can be obtained by summing the actual times for traveling, loading and dumping:

CIV3301 PRINCIPLES OF CONSTRUCTION
LECTURE VII & VIII

▶ PART C – Elements of Construction

Foundations

The foundation of a structure is that part of walls, piers and columns in direct contact with, and transmitting loads to, the ground. The building foundation is sometimes referred to as the artificial foundation, and the ground on which it bears as the natural foundation. Early buildings were founded on rock or firm ground; it was not until the beginning of the twentieth century that concrete was increasingly used as a foundation base for walls.

Functional Requirement of Foundations

The primary functional requirement of a foundation is strength and stability.

Strength and stability

The combined, dead, imposed and wind loads on a building must be transmitted to the ground safely, without causing deflection or deformation of the building or movement of the ground that would impair the stability of the building and/or neighboring structures. Foundations should also be designed and constructed to resist any movements of the subsoil.

Foundations should be designed so that any settlement is both limited and uniform under the whole of the building. Some settlement of a building on a soil foundation is inevitable. As the building is erected the loads placed on the foundation increase and the soil is compressed. This settlement should be limited to avoid damage to service pipes and drains connected to the building. Bearing capacities for various rocks and soils are assumed and these capacities should not be exceeded in the design of the foundation to limit settlement.

Foundation construction

The move to closely regulated systems has resulted in the use of foundations that are less prone to problems than some earlier methods of construction. One negative effect of this standardized approach is that some foundations may be over-designed for the loads they carry, either to avoid any possibility of foundation failure or simply through the application of inappropriate foundations for a particular building type. For example, it is not uncommon for timber-framed buildings to be built off foundations designed for heavier loadbearing masonry construction, essentially a lack of thought resulting in wasted materials and unnecessary expense.

Types of Foundation

Strip foundations

Strip foundations consist of a continuous strip, usually of steel-reinforced concrete, formed centrally under loadbearing walls. This continuous strip serves as a level base on which the wall is built. The width of the foundation is that necessary to spread the load exerted on the foundations to an area of subsoil which is capable of supporting the load without undue compaction. The bearing capacity of the soil should be greater than the loads imposed by the building's foundation.

The continuous strip of concrete is spread in trenches that have been excavated down to an undisturbed level of compact soil. The strip of concrete may well need to be no wider than the thickness of the wall. In practice the concrete strip will generally be wider than the thickness of the wall for the convenience of covering the whole width of the trench and to provide a wide enough level base for bricklaying below ground. A continuous strip foundation of concrete is the most economic form of foundation for small buildings on compact soils.

The width of a concrete strip foundation depends on the bearing capacity of the subsoil and the load on the foundations: the greater the bearing capacity of the subsoil, the less the width of the foundation and vice versa.

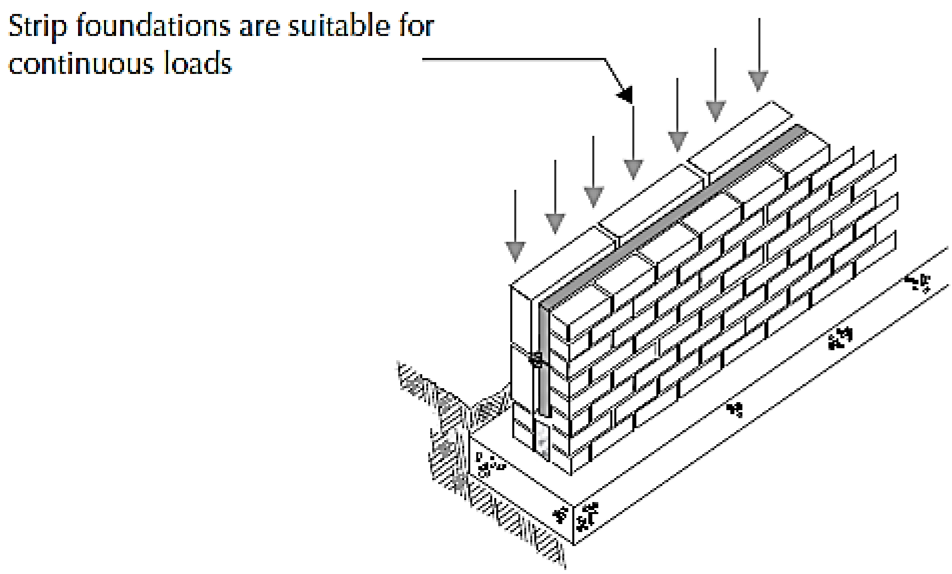


Figure 1.0 Strip foundation.

Wide strip foundation

Distributing the load over a larger area reduces the load per unit area on the ground. Strip foundations on subsoils with poor bearing capacity, such as soft sandy clays, may need to be considerably wider than traditional (narrow) strip foundations. However, to keep increasing the width and depth of the concrete ensuring that the foundation does not shear makes the process uneconomical. The alternative is to form a strip of steel-reinforced concrete, illustrated in Figure 2.0. Concrete is strong in compression but is weak in tension. The effect of the downward pressure of the wall on the middle of the foundation and the opposing force of the ground spread across the base of the foundation attempts to bend the foundation upwards; this places the top of the foundation in compression and the base of the foundation in tension.

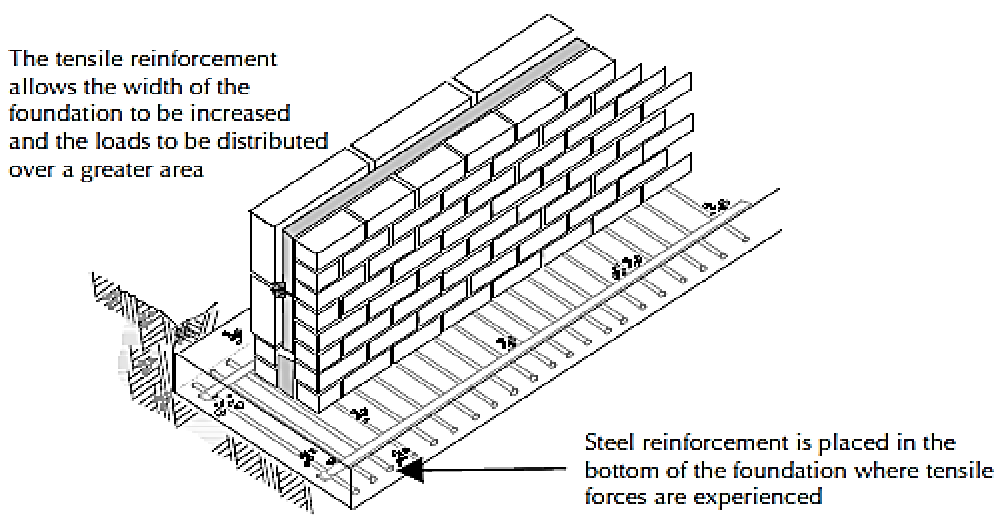


Figure 2.0 Steel-reinforced wide strip foundation.

These opposing pressures will tend to cause shear cracking in the foundation concrete. To add tensile properties to the foundation, steel reinforcing bars are cast in the lower edge where tension will occur (Figure 3.0). There has to be a sufficient cover of concrete below the steel reinforcing rods to ensure a good bond between the concrete and steel and to protect the steel from corrosion. Together the steel and concrete make up a composite material that can resist both tensile and compressive forces.

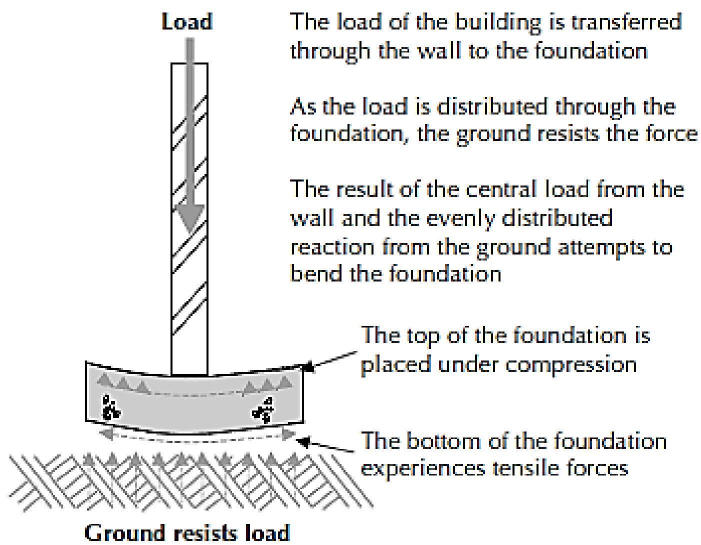


Figure 3.0 Distribution of forces in strip foundations

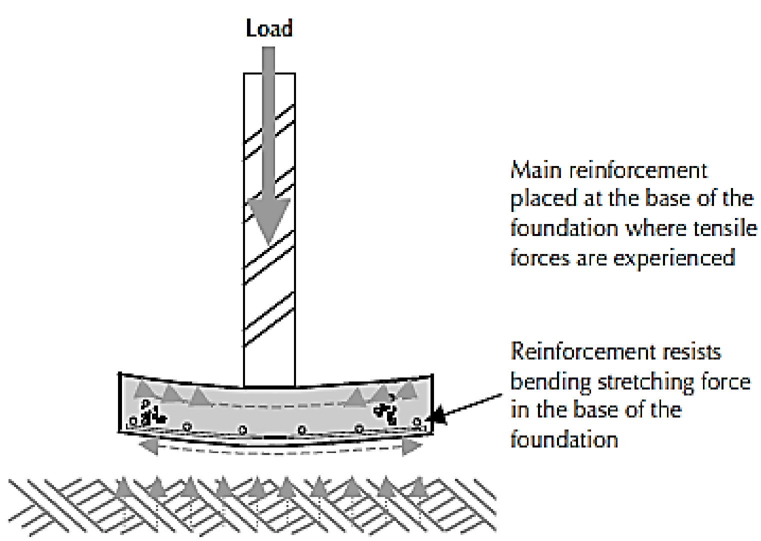


Figure 3.0a Accommodating tensile forces within strip foundations

Narrow strip (trench fill or deep strip) foundation

Stiff clay subsoils have good bearing strength but are subject to seasonal volume change. Because of seasonal changes and the withdrawal of moisture by deep-rooted vegetation (such as shrubs and trees) it is practice to adopt a foundation depth of at least 0.9m to provide a stable foundation. Although the base of a deep strip foundation will go to a depth where the clay soil is unaffected by seasonal changes in moisture content, the soil at the external face of the foundation will still expand and contract as it becomes saturated and dries out. To prevent lateral pressure being applied to the side of the foundation, a 50mm thick compressible sheet material may be used (Figure 4.0).

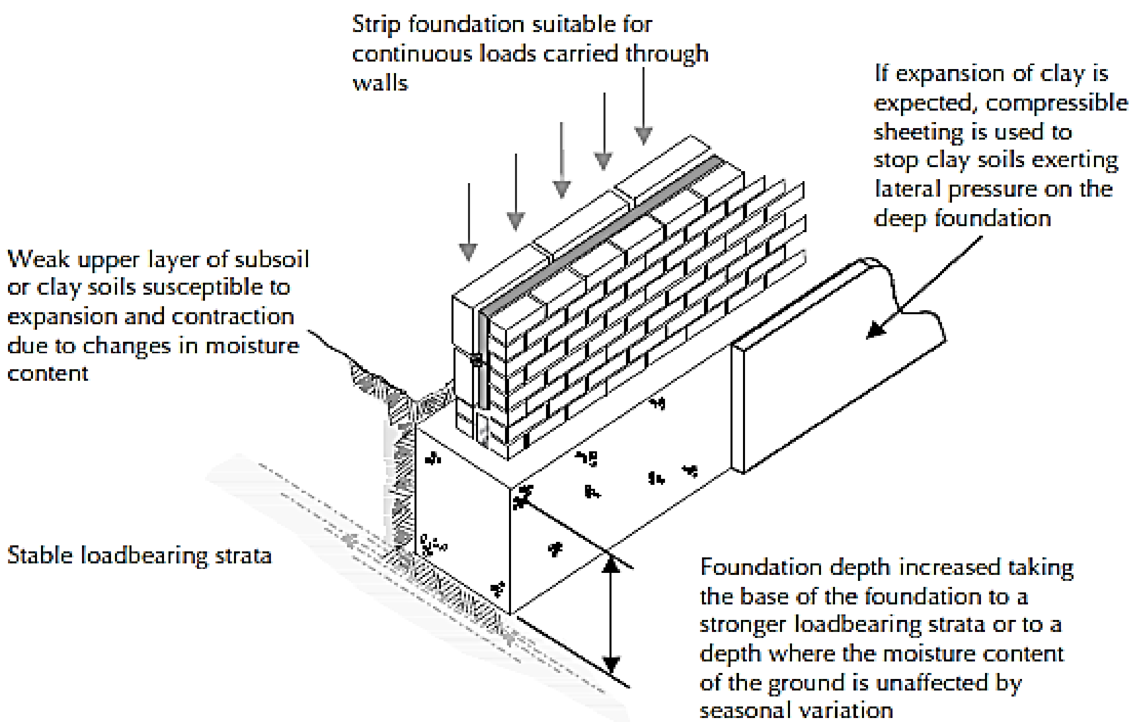


Figure 4.0 Deep strip or mass fill strip foundation.

Because of the good bearing capacity of the clay, the foundation may need to be a little wider than the thickness of the wall to be supported. Trenches are usually formed by using mechanical excavators; thus the width of the trench is determined by the width of the excavator bucket available, which should not be less than the minimum required width of foundation. The trench is filled with concrete as soon as possible so that the sides of the trench do not fall in and the exposed clay bed does not dry out and shrink. Where the trench is particularly wide and it is uneconomical to fill the whole trench with concrete it is common practice to use trench blocks. The trench blocks are laid flat and are often the full width of the walling above them as shown in Figure 4a&b.

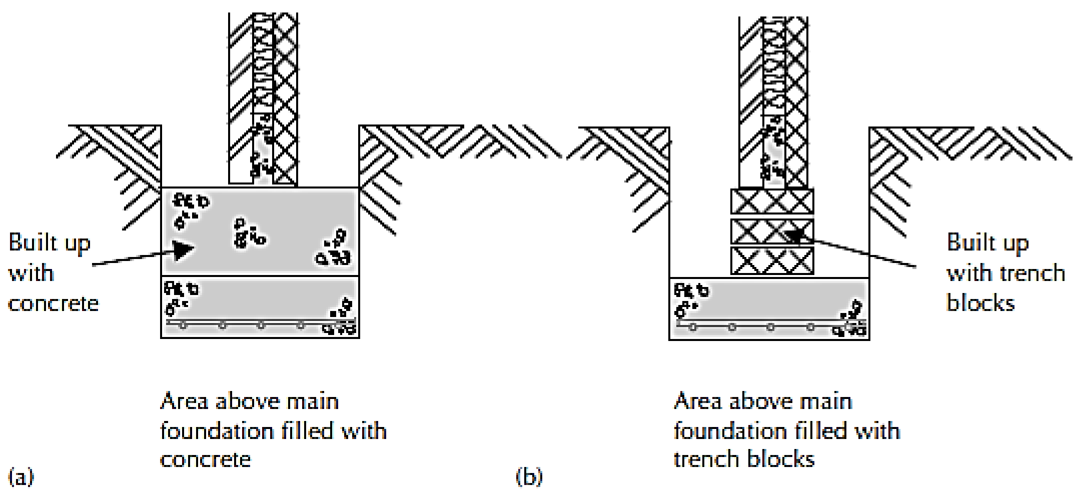


Figure 5 (a and b) Use of trench fill and trench blocks in strip foundations.

Short-bored pile foundations

Piles are concrete columns, which are either precast and driven (hammered) into the ground or cast in holes that are augured (drilled) into the ground down to a level of a firm, stable, stratum of subsoil. It is often economical to use short-bored piles where the subsoil is of firm, shrinkable clay, which is subject to volume change due to deep-rooted vegetation for some depth below the surface and where the subsoil is of soft or uncertain bearing capacity for a few meters below the surface.

Piles that are excavated to a depth of less than 4m below the surface are termed short bore, which refers to the comparatively short length of the piles as compared with the much longer piles used for larger structures. Short-bored piles are generally from 2 to 4m long and from 250 to 350mm in diameter.

Holes are augered into the ground by machine. An auger is a form of drill comprising a rotating shaft with cutting blades that screw into the ground. The soil is either withdrawn and lifted to the surface as the shaft rotates or, with small augers, once the auger has cut into the ground, it is withdrawn and the soil is removed from the blades. The advantage of this system of augered holes is that samples of the subsoil are withdrawn, from which the nature and bearing capacity of the subsoil may be assessed. The piles may be formed of concrete or, more usually, a light steel cage of reinforcement is lowered into the hole and concrete poured or pumped into the hole and compacted to form a pile foundation. The piles are cast underneath the corners and intersection of loadbearing walls and at regular intervals between to reduce the span and depth of the reinforced ground beam, which transfers the wall and building loads to the foundation. A reinforced concrete ground beam is then cast over the piles as illustrated in Figure 5.0. The spacing of the piles depends on the loads to be supported and on economic sections of ground beam as presented in Figure 6.0.

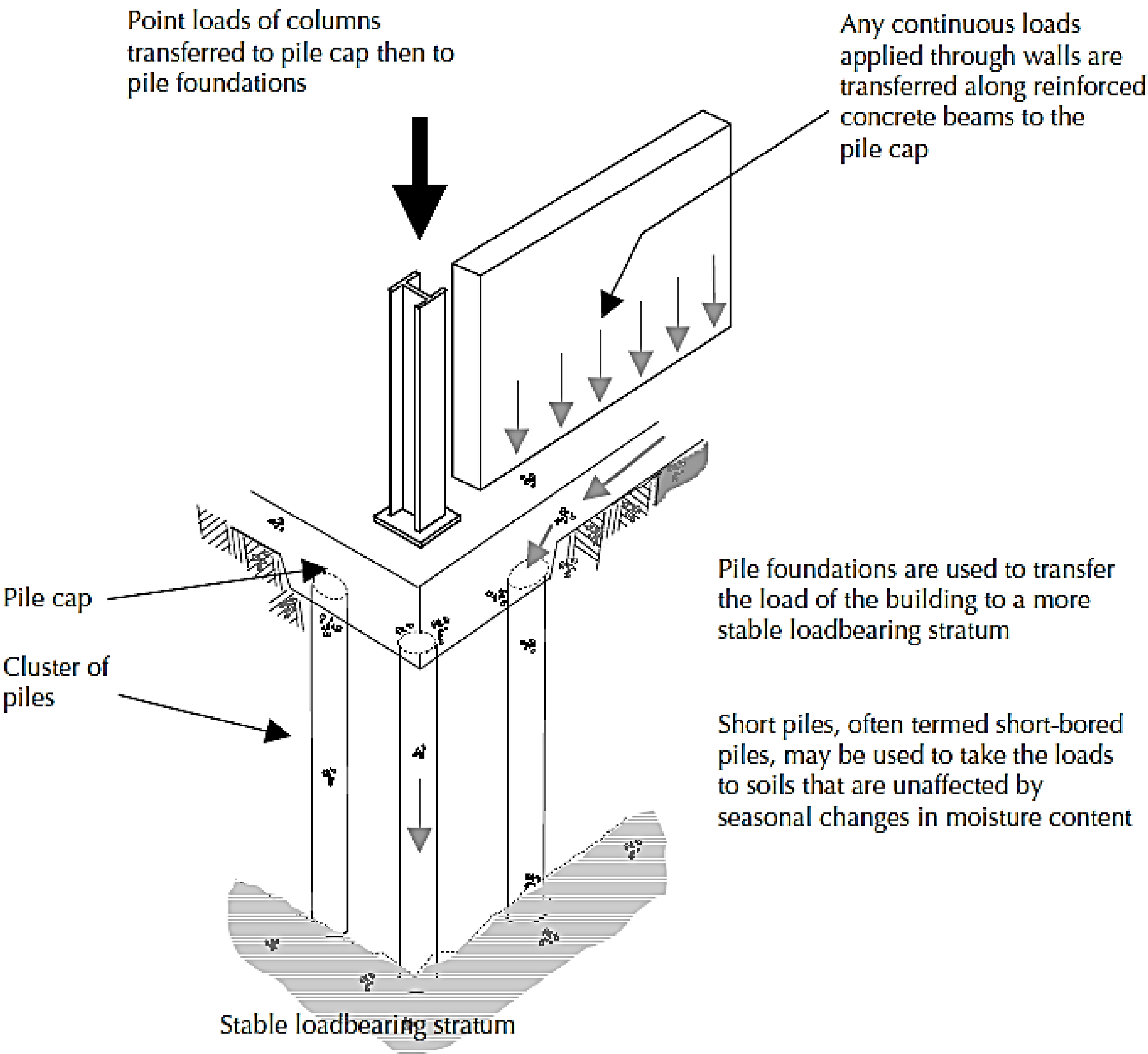


Figure 5.0 Pile foundations.

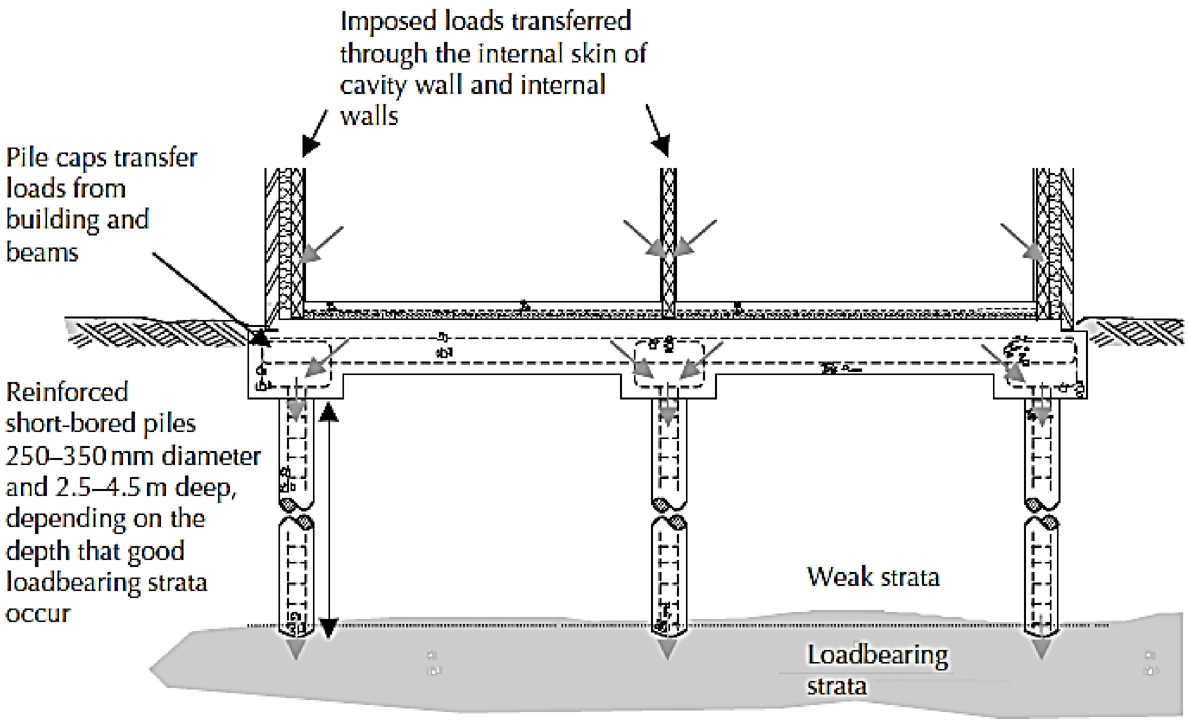


Figure 6.0 Section illustrating pile foundations.

Pad foundations

Pad foundations can be used to carry point loads. They can also be designed so that the loads of the walls and the buildings are transferred through ground beams that rest on the pad foundations. Pad foundations transfer the loads to a lower level where soil of sufficient loadbearing strata exists. The width of a pad foundation can be increased to distribute the loads over a greater area, thus reducing the pressure on the ground. Photographs in Figure 8.0 show the excavation sequence of pad foundations and ground beams. On made up ground and ground with poor bearing capacity where a firm, natural bed of strata, for example, gravel or sand, is a few meters below the surface, it may be economic to excavate for isolated piers of brick or concrete to support the load of buildings. The piers will be built at the intersection of the walls and under the more heavily loaded sections of wall, such as that between windows up the height of the building.

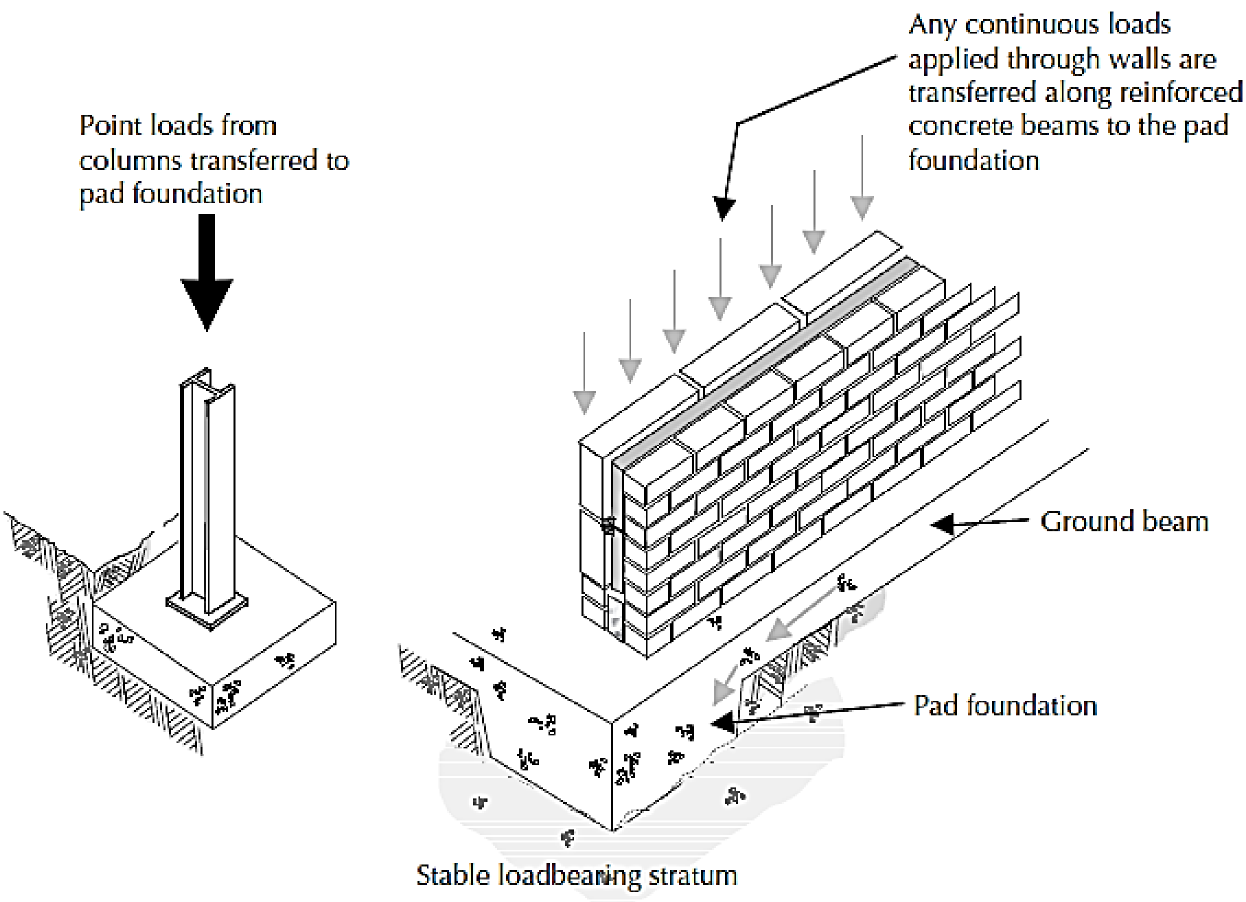
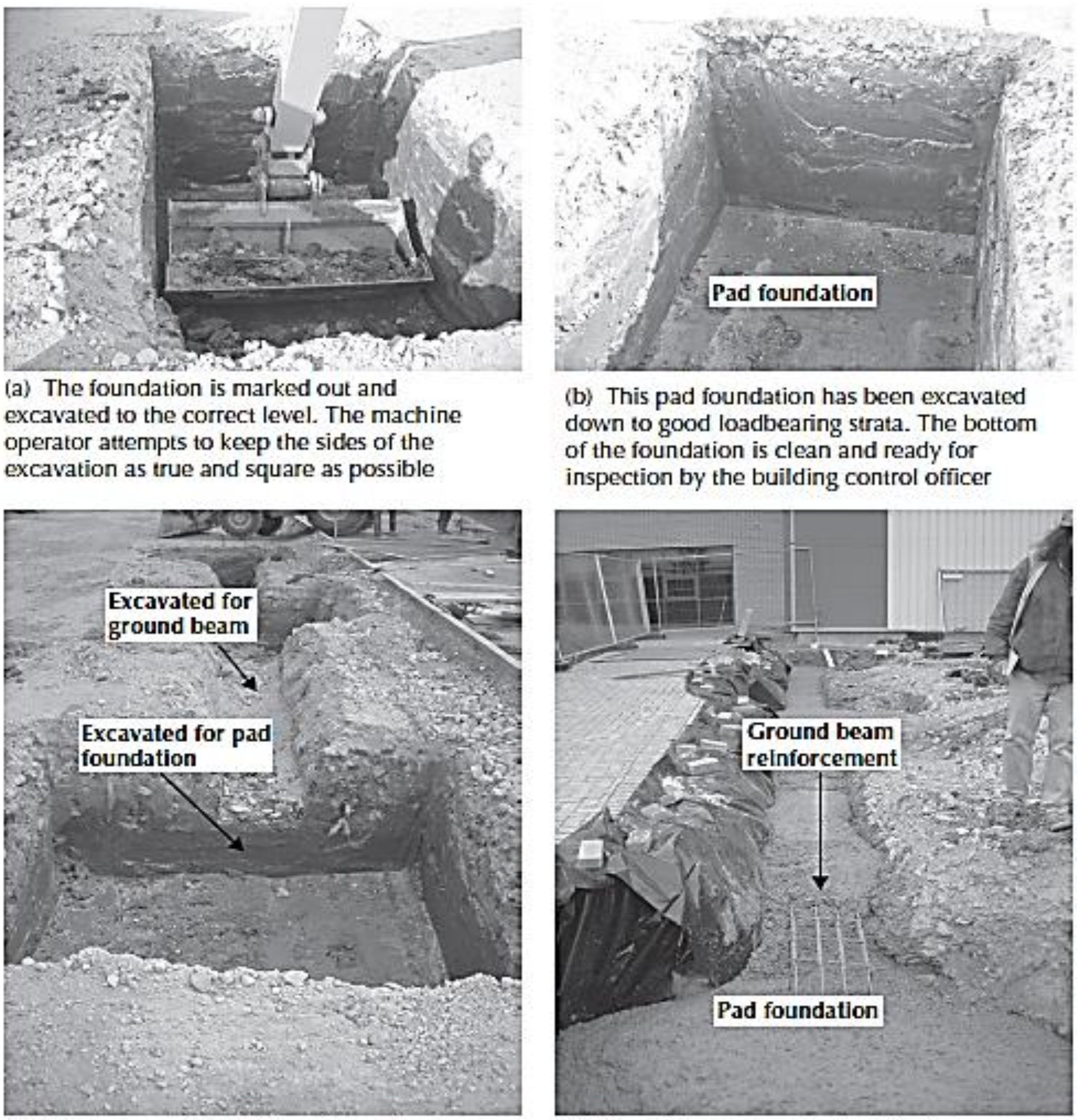


Figure 7.0 Pad foundations.

Pits are excavated down to the necessary level and the sides of the excavation are temporarily supported. Isolated pads of concrete are then cast in the bottom of the pits. Brick piers or reinforced concrete piers are built or cast on the pad foundations up to the underside of the reinforced concrete beams that support walls as illustrated in Figure 7.0. The ground beams or foundation beams may be just below or at ground level, the walls being raised off the beams.



(a) The foundation is marked out and excavated to the correct level. The machine operator attempts to keep the sides of the excavation as true and square as possible

(b) This pad foundation has been excavated down to good loadbearing strata. The bottom of the foundation is clean and ready for inspection by the building control officer

(c) Once one pad foundation is complete, the ground beam, which spans between the pad foundations, is excavated, then the next pad foundation is dug out

(d) The reinforcement is placed in the ground beam foundation, positioned correctly and then the concrete is poured to the correct level. The concrete should be vibrated to remove air bubbles

Figure 8.0 Excavation and casting of pad foundation and ground beam.

Raft foundations

A raft foundation consists of a raft of reinforced concrete under the whole of a building or a structure. Raft foundations may be used for structures on compressible ground such as very soft clay, alluvial deposits and compressible fill material where strip, pad or pile foundations would not provide a stable foundation without excessive excavation. The reinforced concrete raft is designed to transmit the load of the building and distribute the load over the whole area under the raft, reducing the load per unit area placed on the ground (Figure 9.0).

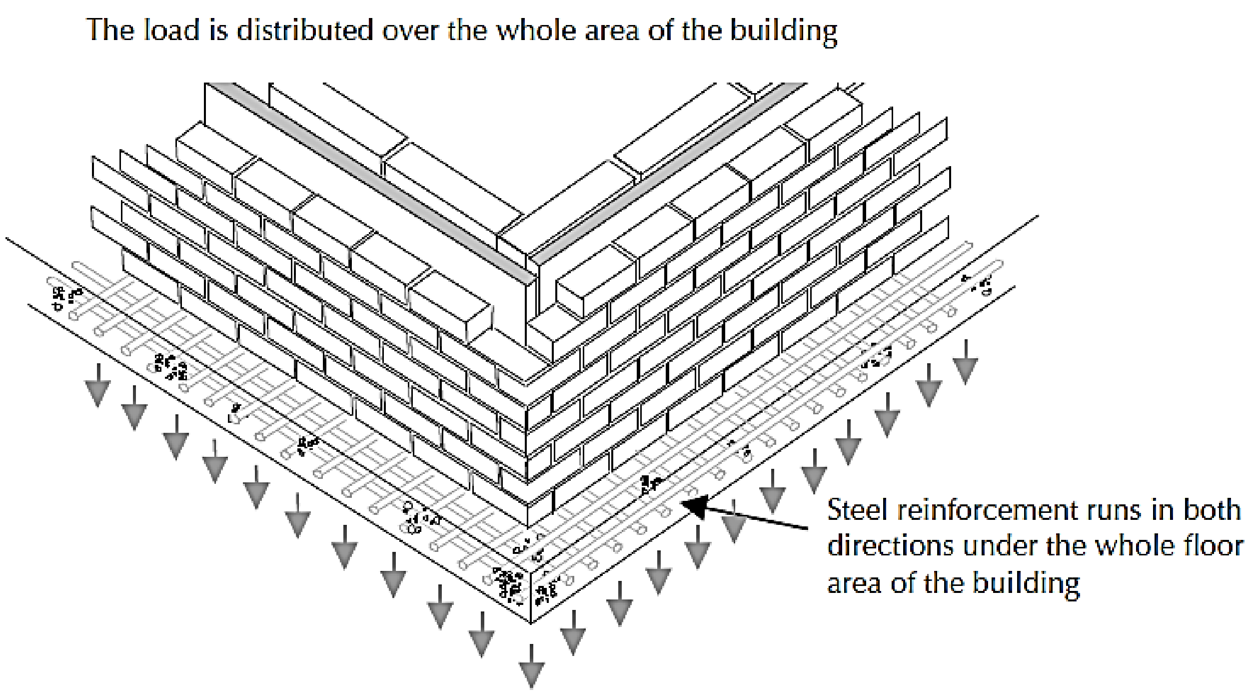


Figure 9.0 Raft foundation.

Distributing the loads in this way causes little, if any, appreciable settlement. The two types of raft foundation commonly used are the flat raft and the wide toe raft. The flat slab raft foundation may be used under small buildings such as bungalows and two storey houses where the comparatively small loads on the foundations can be spread safely and economically under the raft. The concrete raft is of uniform thickness and reinforced top and bottom against both upward and downward bending. The construction sequence is as follows:

i. Vegetable topsoil is removed.
ii. A blinding layer of concrete 50mm thick is spread and levelled to provide a level base so that the steel reinforcement cage can be constructed.
iii. Where the raft is not cast directly against the ground, formwork may be required to contain any concrete up-stands.
iv. Once the reinforcement is correctly spaced and tied together in position, the concrete can be poured, vibrated and levelled.
v. A waterproof membrane can be positioned either underneath the structural concrete or on top of it, beneath the insulation. Traditionally the damp-proof membrane (dpm) was placed on top of the blinding or on top the insulation
vi. Rigid insulation boards are placed on top of the structural concrete.
vii. Finally a 40mm sand/cement screed finish is spread and levelled on top of the raft.

When the reinforced concrete raft has dried and developed sufficient strength the walls are raised. The concrete raft is usually at least 150mm thick. Where the ground has poor compressibility and the loads on the foundations would require a thick, uneconomic flat slab, it is usual to cast the raft as a wide toe raft foundation. The raft is cast with a reinforced concrete stiffening edge beam, from which a reinforced concrete toe extends as a base for the external leaf of a cavity wall, as shown in Figure 10.0.

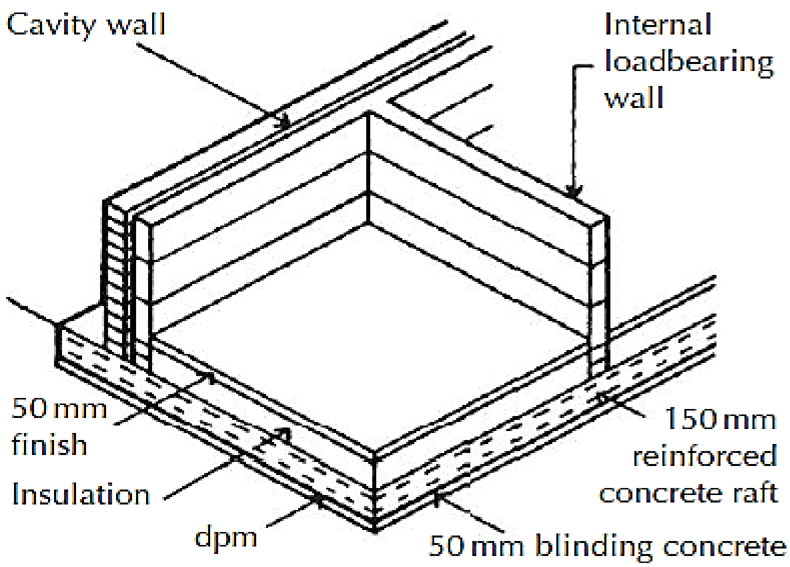


Figure 10.0 Flat slab raft.

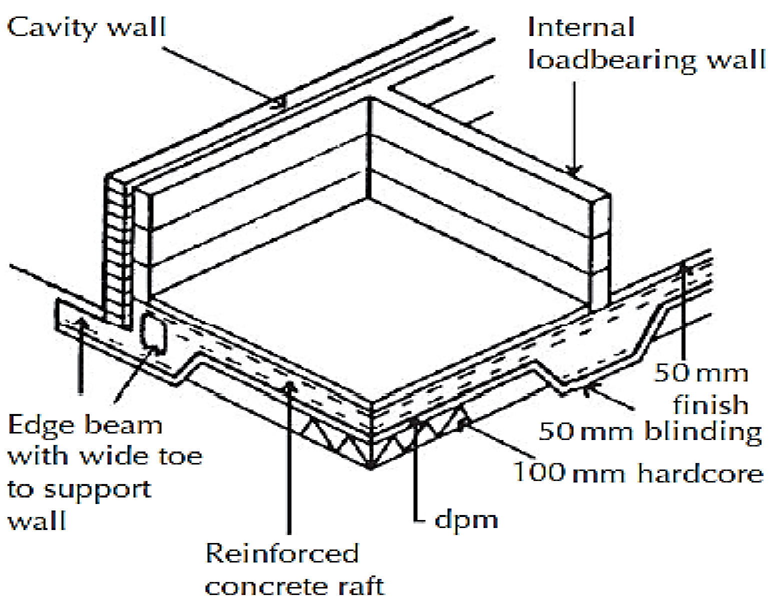


Figure 10a Edge beam raft.