الجــــمهورية الجـــزائرية الديمـــقراطية الشــــعبية
People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research
University Mohamed Boudiaf of M'sila
Faculty of Technology
Civil Engineering Department

وزارة التعليم العالي والبحث العلـمي
جـامـعة محمد بوضياف- المـسيلة
كـليـة التكنـولــــوجيـا
قسم الهندسـة المدنيـــة

1985
جامعة محمد بوضياف - المسيلة
Université Mohamed Boudiaf - M'sila

الرقم: 242 /ق هـ م/2026

المسيلة في: 2026/06/30

# شهادة إدارية

## بخصوص تقييم المطبوعة البيداغوجية المنجزة من طرف الأستاذة: بوعلاق سعيدة

بعد الاطلاع على تقارير الخبراء المعينين من طرف أعضاء اللجنة العلمية لقسم الهندسة المدنية ضمن اجتماعها المنعقد في يوم الاثنين السابع والعشرون من شهر أفريل عام ألفين وستة وعشرون ميلادي، بهدف إنجاز خبرة حول المطبوعة البيداغوجية المقدمة من طرف الاستاذة **بوعلاق سعيدة**، أستاذ محاضر "أ" بقسم الهندسة المدنية بجامعة محمد بوضياف، والمعنونة ب:

**Construction Techniques and Regulations**

(Support pédagogique destiné aux étudiants de 3ème année Licence spécialité: Génie Civil)

وحيث أن جميع تقارير الخبراء كانت إيجابية، فقد تمت المصادقة على المطبوعة واعتمادها لطلبة السنة الثالثة ليسانس في تخصص الهندسة المدنية.

وتتكون لجنة الخبراء المعينة من طرف أعضاء اللجنة العلمية للقسم من السادة الآتية أسماءهم:

الأستاذ: عمريو عبد الرشيد أستاذ محاضر أ بجامعة محمد بوضياف بالمسيلة

الأستاذ: بعلي العيد أستاذ محاضر أ بجامعة محمد بوضياف بالمسيلة

الأستاذ: عمران محمد أستاذ محاضر أ بجامعة الجلفة

تستعمـــل هذه الشهـــادة فيما يسمـــح به القانـــون

**رئيس اللجنة العلمية للقسم** — **رئيس القسم**

براج فؤاد
جامعة محمد بوضياف المسيلة
رئيس
اللجنة العلمية
لقسم الهندسة المدنية
كلية التكنولوجيا

عمريو عبد الرشيد
جامعة محمد بوضياف - المسيلة
رئيس قسم
الهندسة المدنية
كلية التكنولوجيا

MINISTERE DE L’ENSEIGNEMENT SUPERIEUR ET DE LA RECHERCHE SCIENTIFIQUE

**Université Mohamed Boudiaf - M'SILA**
**Faculty of Technology**
**Civil Engineering Department**

1985

جامعة محمد بوضياف - المسيلة
Université Mohamed Boudiaf - M'sila

**Course**

# Construction Techniques and Regulations

## (techniques et règles de construction)

## 3rd Year Bachelor's Degree in Civil Engineering

***Prepared by : Dr. BOUALLEG. SAIDA***

**2025/2026**

## SUMMARY

- PREFACE

## CHAPITRE I : PROJECT DEVELOPMENT TECHNIQUES

## CHAPTER II. SITE PREPARATION TECHNIQUES



## CHAPTER III. TECHNIQUES FOR CONSTRUCTING REINFORCED CONCRETE STRUCTURES

## CHAPTER IV. METAL AND COMPOSITE STRUCTURES

## CHAPTER V. INTRODUCTION TO THE DIFFERENT REGULATIONS



## CHAPTER VI. ALGERIAN SEISMIC REGULATIONS RPA 2024 (GENERAL DESIGN RULES FOR SEISMIC ZONES, CRITERIA FOR CLASSIFICATION OF STRUCTURES)

## CHAPTER VII. JUSTIFICATION OF REINFORCED CONCRETE STRUCTURES



## CHAPTER VIII. SPECIFICATION OF STRUCTURAL ELEMENTS

## *PREFACE*

This document is intended for third-year Civil Engineering students under the new LMD system; This subject is composed of two parts. The first part aims to introduce students to the technical and technological aspects of the construction operation. The second part introduces students to the basic concepts of the various regulations applied in the design of civil and industrial constructions, with an application of the rules for justifying reinforced concrete structures according to the RPA.

For better understanding, a fairly simple scientific language has been used and numerous illustrations, images, and tables have been included to help the student understand the course and to provide a clear idea of the techniques and technological rules.

**The subjects taught in the semester**

**Content of the subject :**

**Chapter 1. Project Development Techniques.**

Process of carrying out a construction project, design and Preparatory arrangements for the execution of the works, site selection and placement of structures, geotechnical investigations.

**Chapter 2. Site Preparation Techniques**

Preparation of work and techniques for organizing construction sites, staking and delimitation of the site, earthworks and backfilling, techniques for soil removal, well excavations, compaction, topsoil replacement, trenches and shoring, sloping.

**Chapter 3. Techniques for Constructing Reinforced Concrete Structures**

Execution techniques for shallow foundations and deep foundations. Formwork and reinforcement techniques for building structures

**Chapter 4. Metal and Composite Structures Welding and bolting,** Assemblies of metal structures in buildings and industrial halls.

**Chapter 5. Introduction to the different regulations.** Generalities and Necessity of Regulation, Introduction to the different construction standards, BAEL standards, and Eurocodes.

**Chapter 6. Seismic Rules RPA 99 version 2003**

(General design rules for seismic zones, criteria for the classification of structures). **Chapter 7. Justification of Reinforced Concrete Structures** (Load Combinations, Justification Regarding Resistance, Overall Equilibrium, and Foundation Stability, Definition and Justification of Joints).

## Chapter 8. Specification of Structural Elements

Specifications for the main elements (columns, beams, floors, slabs, walls, and partitions).

Specifications for secondary elements, Specifications regarding materials.

**Semester : 5**

**Teaching Unit :** UET 3.1

**Subject :** Construction Techniques and Rules

**VHS: 10:30 PM (Class: 1 hour 30 minutes)**

**Crédits** : **1**

**Coefficient** : **1**

**Objectives of the teaching :**

This subject is composed of two parts.

**The first part** aims to introduce students to the technical and technological aspects of the construction operation.

**The second part** introduces students to the basic concepts of the various regulations applied in the design of civil and industrial constructions, with an application of the rules for justifying reinforced concrete structures according to the RPA.

**Recommended prerequisites :**

The subjects taught in the semester

**4. Course Content :**

**Chapter 1. Project Development Techniques.**

Process of executing a construction project, design and preparatory arrangements for the execution of the works, site selection and placement of structures, geotechnical investigations.

**Chapter 2. Site Preparation Techniques**

Preparation of work and techniques for organizing building sites, staking and delimitation of the site, earthworks and backfilling, techniques for earth removal, well excavations, compaction, topsoil replacement, trenches and shoring, sloping.

**Chapter 3. Techniques for Constructing Reinforced Concrete Structures**

Techniques for executing shallow foundations and deep foundations. Formwork and reinforcement techniques for building structures.

**Chapter 4. Metal and Composite Structures**

Welding and bolting, Assemblies of metal structures in buildings and industrial halls.

**Chapter 5. Introduction to the different regulations**

Generalities and Necessity of Regulation, Introduction to the different construction standards, BAEL standards, and Eurocodes.

**Chapter 6. Algerian Seismic Rules RPA 2024**

(General design rules for seismic zones, criteria for classification of structures).

**Chapter 7. Justification of Reinforced Concrete Structures**

(Action combinations, Justification regarding resistance, overall equilibrium, and foundation stability, Definition and justification of joints).

**Chapter 8. Specification of Structural Elements**

Specifications for the main elements (columns, beams, floors, slabs, walls, and partitions). Specifications for secondary elements, Specifications concerning materials. Mode of assessment : Exam : 100%.

# CHAPTER.I :

# PROJECT DEVELOPMENT TECHNIQUES

# CHAPTER. I PROJECT DEVELOPMENT TECHNIQUES

## I.1INTRODUCTION

The execution of a civil engineering project (building, road, structure, etc.) requires preliminary studies, in-depth technical studies, and a coherent legal and administrative setup. In the case of public interest projects, the regulation of this field is governed by the law known as the public procurement code. Before listing the various steps that precede the implementation of a project and getting an idea of Algerian regulations and the terms of public contracts, it is important to know the main actors that can exist for the implementation of a project.

## I.2 The stakeholders in a civil engineering project:

A contract is concluded between two parties, namely:

a contracting service acting as the client on one side, and the co-contracting partner, company, or supplier on the other side. In the field of civil engineering projects, the stakeholders who can intervene are:

- On the contracting authority's side (the administration): the project owner, or the individuals acting on their behalf, such as the delegated project owner.
- On the side of the contracting partner: the company or the group of companies.
- Third parties, the project manager, the control services, etc.

As a general rule, the main stakeholders that one will regularly encounter on a municipal construction site number four (4); they are:

- the project owner;
- the delegated project owner, or the project owner's assistant; - the project manager;
- the contractor (and/or their subcontractors).

The presence of other stakeholders (administration, consortium, and even subcontractors) is not always effective. It is clear that the importance of the project can more or less dictate their presence.

### I.2.1 The project owner:

Is the individual or legal entity on behalf of whom the work is carried out. As the principal responsible party, they are tasked with ensuring the sufficient maturation of the project and the establishment of the necessary funding for its realization. In general, the responsibility of the project owner extends to the development of the terms of reference for the creation of the work, its implementation, its design, its financing, as well as the conditions for its management and maintenance. His responsibility is also engaged in the removal of land-related constraints and obtaining regulatory urban planning permits. As the project owner, we mention:

- Local administrations (central, decentralized…).
- Local authorities (wilaya, commune).
- Public institutions with an administrative nature (national or local).
- Autonomous institutions (APN, the Constitutional Council…)

**I.2.2 the delegated project owner;**

Or the person responsible for the contract is a legal or natural person. It is the legal representative of the Project Owner in the execution of the contract. He ensures the management of the execution of the works from the project design to the final acceptance of the works. He is the sole intermediary between the Project Owner and the other stakeholders. The decision to carry out the project, the budget assembly of the operation, the approval of the choice of the project manager and the contractor. As delegated project owner, examples include:

- ANA, National Highway Agency: delegated project owner at the Ministry of Public Works.
- AADL, National Agency for Housing Improvement and Development: delegated project owner at the Ministry of Housing.
- ONA, National Sanitation Office: delegated project owner at the Ministry of Water Resources.

**I.2.3 The project manager's assistant** :

is a legal or physical entity co-responsible with the project owner for the contract and the execution of the works. It provides technical support to the Project Owner in the execution of the contract, from the project design to the final acceptance of the works.

**I.2.4 The project manager:**

is the individual or legal entity who, due to their technical expertise, is appointed by the project owner or the person responsible for the contract to oversee and control the technical execution of the works and to propose their acceptance and payment; if the project manager is a legal entity, they designate an individual who is solely qualified to represent them.

The project manager: is the natural or legal person who, due to their technical expertise, is appointed by the Project Owner or the person responsible for the contract to direct and oversee the technical execution of the work and to propose their acceptance and payment; if the Project Manager is a legal entity, they designate a natural person who is solely qualified to represent them.

The subject of legal proceedings. In his role as project manager, the project manager must:

- Ensure that the project program is feasible and compatible with the land provided, both technically and administratively or regulatory-wise.

-Ensure that the available budget is adequate for the operation.

-Design, represent, describe, and evaluate the work (plans, drawings, technical specifications, etc.) in compliance with current regulations.

-Coordinate the additional technical studies necessary for the completion of the work. Submit requests for administrative permits (such as building permits) in compliance with current regulations.

-Prepare the contract(s) to be awarded by the project owner.

-Direct the work in accordance with the contract documents, the regulations in force, and within the budget and deadlines.

-Control the compliance of the work with the project.

-Control the quality and quantity of materials and their implementation.

-Control the cost of the work.

-Prepare the attachments with the co-contracting partner.

-Assist the project owner during the acceptance operations. However, one must distinguish between the role of the project manager and that of the technical control establishments (CTC), whose main missions are:

-Approval, correction if necessary, of the plans and studies presented by the project manager.

-Acceptance of the foundations.

-Analysis of materials and aggregates before their implementation and proposal of a concrete formulation based on this analysis.

-Verify the mechanical characteristics of the concrete with crushing tests, monitoring, etc., and consult these results if the tests are conducted in accredited construction laboratories.

- Acceptance of waterproofing, electrical work, and all operations that put the safety of users and the stability of the structure at risk.

**I.2.5 The contractor**;

Is the natural or legal person responsible for the execution of the work in accordance with the contractual and regulatory documents. He is responsible for the organization of the site and the safety of the personnel during the execution period of the works.

**I.2.6 The co-contracting partner**:

It is the natural or legal person designated by the term entrepreneur, responsible for carrying out the project according to the conditions defined in the contract (the market). The contractor can act as a sole partner (general contractor) or in a consortium of companies. The contractor can also entrust the partial execution of the contract to another person (legal or natural) known as a subcontractor, after obtaining the agreement of the project owner.

To have the status of an entrepreneur, one must:

- Meet administrative obligations, such as business registration, premises, etc.
- Meet fiscal, parafiscal, and social obligations.
- Fulfilll technical obligations (professional qualification and classification for the work and approval for the studies).

The main tasks of the contractor in the context of carrying out a civil engineering project are:

-Provide the specialized equipment necessary for the completion of the project.

-Recruit a qualified and properly supervised project manager.

-Provide construction materials from known sources with standardized performance and characteristics.

**I.3 Preliminary Studies of a Project :**

Before starting the implementation of a project, the project owner must conduct certain preliminary studies to clearly specify the needs to be met and avoid subsequent errors. These studies are of various types; they allow for an objective assessment of the project cost estimate, ensure quality and speed of execution, and minimize the likelihood of unforeseen events and disputes.

**- Feasibility Study:** It allows for a clear definition of the project in terms of cost, quality, timeline, site and environmental constraints, etc. To establish it, the project owner must answer these questions :

- Is the proposed project feasible?
- Under what technical and financial conditions?
- Are these conditions reasonable?
- At what pace is the project feasible?

**- Feasibility Study**:

It allows measuring the usefulness and profitability of the project from a socio-economic perspective.

**I.3.1 Environmental Impact Study**:

This study ensures that the project does not harm the environment. It involves:

-Analyzing the initial state of the site and the project's effects on the environment.

-Define the measures envisaged to eliminate or reduce the harmful consequences of the project on the environment, the corresponding expenses, as well as the reasons for proceeding with the project.

-This study is subject to a public inquiry where the results are subject to a decision of approval or rejection.

**I.3.2 The sketch:**

Specific to construction work, it is a volumetric representation of the project, accompanied by an approximate cost estimate.

**I.4. Preliminary project studies**

It involves the preliminary draft (APS) and the detailed preliminary draft (APD). The APS allows for outlining the main lines of the functional, technical, and economic design of the project. The project owner must have several technical solutions (APS) to cover all eventualities. The APD allows for a deeper exploration of the chosen solution among these APS variants.

**I.4.1 Geotechnical Study:**

It addresses the mechanical characteristics of the soil.

**I.4.2 The execution project:**

It consists of the study including the technical file of the work.

**I.4.3 Multi-network studies:**

It allows for the inventory of existing networks in the project and the definition of necessary deviations and protections. Indeed, an omitted network leads to very costly construction site immobilizations. The actions to be taken during this phase must be meticulously coordinated with the relevant services (ADE, PTT, Sonelgaz, ONA, etc.).

**I.4.5 The legal setup:**

It consists of ensuring:

- That the proposed contract complies with the forms prescribed by the public procurement code.
- The existence of the necessary authorizations (deliberation of the APC or APW, building permit, etc.).
- That the necessary credits for the realization of the project are put in place.
- The acquisition of the land.

**I.4.6 The acquisition of land :**

The urban planning regulations require the project owner to be the owner of the project land. If not, he is required to complete the regulatory acquisition formalities, such as:

- Amicable acquisition (purchase, exchange).
- Or, expropriation after compensation.

The buildability of the land must comply with urban planning regulations (PDAU, POS).

**I.5. Public contracts :**

The implementation of a public project is an important act that is repeated in each annual state budget. It is part of the equipment in the overall budget under different forms of programs such as PCD (communal development programs), PSD (decentralized sectoral programs), and PSC (centralized sectoral programs). Other projects can be registered and financed by national funds such as the southern fund, the highlands fund, etc.

Every registered project must be executed in the form of a contract or a market, this execution is governed by the law known as the public procurement code (currently it is presidential decree No. 15-247 of September 16, 2015, regulating public procurement). As a result, a public contract is a written agreement, entered into for a fee with economic operators under well-defined conditions, to meet the needs of the contracting service in terms of works, supplies, services, and studies. Article 2 of DP No. 15-247 of September 16, 2015, regulating public procurement. This contract must preserve all the rights of the contracting parties, both moral and material. The role of public procurement is to give every company the same chances to access public contracts offered by public buyers. This competition is regulated by the Public Procurement Code (CMP).

**I.5.1 Categories of Public Contracts:**

Public contracts can be classified into two main categories, according to their purpose and according to their nature.

**-According to their purpose:**

- **The works contract**: it is a contract whose services involve the construction of a work, its maintenance, or its rehabilitation.
- **The supply contract**: it concerns the acquisition of a supply.
- **The service contract:** the service contract involves material or intellectual services. Material services can involve the repair or maintenance of equipment, their cleaning, gardening, etc. Intellectual services are those that require specific knowledge that the project owner cannot provide on their own. We distinguish:
- The study contract: preliminary study, geotechnical study, economic study, sociological study, etc.
- The project management contract: its purpose is to assist the project owner in certain phases of design, control, and execution of the works. Regarding buildings, project management

includes the following tasks: sketches, execution project (study and plans), assistance in preparing specifications, monitoring and controlling the execution of the works, etc.

**- According to their nature:**

**- Simple (single) contracts:**

it involves entrusting a service to a single person thru a contract. This mode involves the execution of precise and quantified services with pre-established values.

**- Customer market:**

its purpose is to satisfy an unpredictable need (e.g., streetlight repair). The client market is a market that involves the execution of certain services requested as needed over a specified period, according to unit prices set in the market. In this type, the quantities and the overall value of the contract are not initially identified, which limits the use of this type when the available financial envelope is likely to be insufficient to cover the service to be performed.

**- Framework agreement:**

resorting to this type is necessary when the volume of the service and its deadline cannot be determined precisely. The framework agreement is concluded for a renewable period of one year, without the total duration exceeding five years. This limit helps preserve competition and avoid monopolies (e.g., supply contracts, transportation, leasing...)

**- Staged contract**:

in this category of public contracts, the service to be performed is fully defined in advance. It is recommended to resort to this type of contract when financial conditions do not allow the contracting service to commit immediately to the entire program, such as in cases of insufficient payment credits. The contract in this case includes a firm tranche concluded within the limits of the available budget, and one or more conditional tranches executable upon the removal of financial obstacles.

**I.5.2 Financing of Public Contracts:**

The principle is that the funds necessary for the implementation of public equipment projects must be planned and included in the annual finance law. These expenses are recorded in the state general budget in the form of program authorizations (PA) and are executed thru payment credits (PC). The AP is the upper limit of the project, its duration is unlimited unless it is canceled or closed. The classification of public equipment programs introduces a distinction between two categories of expenditures:

- The first category concerns centralized public equipment, known as centralized sectoral programs (PSC), which are subject to decisions established by the sectoral minister, the specialized administration, or the institution with financial autonomy. The decisions of the

latter two can be established by the Minister of Finance.
- The second category concerns decentralized public facilities, which are subject to decisions established by the Wali in accordance with the program decision of the annual plan notified by the minister in charge of finance (for PSD and PCD programs).

**Centralized sectoral programs**:

When the PSC has reached sufficient maturity, a file is prepared for registration:

- A statement of reasons.
- A technical sheet.
- The feasibility and impact study.
- The implementation strategy.
- The necessary intersectoral coordinations.
- An evaluation report comparing the different options.
- An evaluation of the cost in Currency and its financing method.
- The results of the call for tenders (if it has been done).

The study of the file by the competent minister allows him to accept the launch of the project, or to postpone it in order to further develop its maturation.

**-Decentralized Sectoral Programs of the State (PSD):**

The projects related to the decentralized sectoral programs (PSD) are registered under the Wali's indicator by a program decision from the minister in charge of finance in the form of an AP. The CPs are also allocated annually and concern all PSDs.

**-Projects related to the communal development programs (PCD):**

At the local level, expenditures related to the PCD are financed by the state equipment budget, so as not to burden the municipal treasury. The public equipment programs under the PCD are subject to a global AP notified by the minister in charge of finance for each wilaya after consultation with the minister in charge of local authorities, then sent by the Wali to the P/APC for execution. The CPs related to the PCD are notified globally by means of a decision and then distributed by chapter and by the Wali in accordance with the orientations and priorities of the national plan.

The program related to the PCD is established by the wilaya following needs expressed by the commune after consultation with local technical services. It particularly concerns the following actions:

- Drinking water supply.
- Sanitation.
- Roadworks.

- Networks and unblocking... etc.

In addition to the PCD, municipalities can finance public equipment projects thru:

- Self-financing using the APC's own resources (communal budget).
- Grants (common fund for local authorities, etc.).

**I.5.3 Prices in public contracts:**

The prices of public contracts include all expenses resulting from the execution of the work. The determination of the price is an essential element, as the remuneration of the contracting partner mainly depends on the accurate recognition of the price of the work or services provided.

This remuneration is provided according to the following terms:

- At a global and lump-sum price.
- On a unit price schedule.
- At mixed price.

Fixed-price and lump-sum contract:

It is a contract where the service required from the co-contracting partner is precisely determined in advance for a non-modifiable global price. Furthermore, when the contract is concluded at a global and fixed price, the contractor generally provides a breakdown of this price in the form of a quantitative and estimated quote. Errors that may be detected in the calculations cannot lead to any modification of the fixed global price of the contract. Indeed, in the field of construction, particularly for the superstructure part, the work is generally treated at a fixed price, in order to:

- Protect the project owner against uncertainties, by preventing them from paying for work done at prices that could increase the initially planned amount.
- To require the contracting partner to thoroughly understand the consultation file and to take into account all the project's specificities in their decision-making.

**- Unit price contract:**

This type applies in the case of a work or a work element whose quantities are only indicated in the contract as provisional. The payment in this case is made based on the quantities executed and regularly verified by applying the unit prices from the schedule, modified if necessary by the application of price variation clauses.

- **Mixed-price contract**:

-Prices are mixed when part of the service is paid for at a fixed rate and another part at a unit price. This type is generally used in construction contracts (lump sum for the superstructure where quantities are manageable in advance, and unit price for the infrastructure which cannot be sufficiently managed in advance).

**Note:**

Another classification of market prices concerns the possibility or not of having a variation in prices. The markets in this case can be in one of the following forms:

**- Fixed-price contract:** Fixed prices are prices that do not vary during the duration of the contract, neither due to technical contingencies nor due to economic conditions.

**- Market with adjustable prices**: When prices are likely to experience economic fluctuations, the market provides a price revision formula as well as the implementation procedures.

**- Market with adjustable prices:** Prices can also be adjustable if economic circumstances require it. The adjustment allows for the transformation of an initial fixed price into a new price thru either a global lump sum or a formula inserted into the contract. This method is primarily intended for cases where there is a delay between the offer's expiration date and the notification of the service order by the administration.

**I. 5.4 Methods of Public Procurement:**

The conclusion of public contracts must guaranty the following principles:

- The widest possible competition.
- The equality of candidates in public procurement.
- The best management of public funds.
- The preservation of the balance of interests of both parties.

In this regard, public procurement regulations have provided for two methods of awarding for any order:

-The call for competition (in various forms), the general rule.

-Direct negotiation (simple or after consultation).

The choice of the procurement method falls under the competence of the contracting service; this prerogative is not without limits, and the choice of method must be aligned with the objectives assigned to the contracting service within the framework of its submission (nature of the project, quantity, guaranties, product characteristics, etc.).

**-Call for competition (Tender):**

This procedure aims to qualify several candidates and then award the contract to the bidder presenting the most favorable offer. It is characterized, regardless of its form, by the mandatory use of publicity. The call for tenders can take four forms:

**- Open tender:** This is the procedure by which any qualified candidate can submit a bid. It is suitable for any service for which the number of potential bidders is sufficient to create competition. (example: building maintenance, construction of works, infrastructures, or buildings that do not require specialized expertise or rare resources, supply of materials, equipment, or raw materials, transport services, security services, cleaning services, training services, etc.).

- **The open tender with minimum capacity requirements**:

This is the procedure whereby all candidates meeting certain minimum eligibility conditions, previously defined by the contracting service before the launch of the procedure, can submit a bid. The contracting authority does not carry out a preliminary selection of candidates. The eligibility conditions must be limited to what is essential for the execution of the contract; they pertain to the technical, financial, and professional capacities indispensable for the execution of the contract. They must be proportionate to the nature, complexity, and importance of the project. The minimum conditions that candidates must meet, in terms of professional, financial, and technical capabilities, must be clearly defined in the call for tenders notice and in the tender specifications.

- **Restricted tender:**

It is a selective consultation procedure, according to which only the candidates pre-selected in advance are invited to submit a bid. The preselection of candidates is carried out by the contracting service for the selection of candidates to be put in competition for study contracts or complex and/or particularly important operations. This method is suitable for projects such as dams, desalination or purification plants, civil engineering works, etc. Before opting for this procurement method, the contracting authority ensures that the object of the contract cannot be satisfied thru an open tender or a tender with minimum capacity requirements.

- **Competition :**

It is the procedure of putting craftsmen in competition for the selection of a plan or project, designed in response to a program established by the project owner, with a view to carrying out an operation involving specific technical, economic, esthetic, or artistic aspects, before awarding the contract to one of the competition winners. The contract is awarded, after negotiation, to the winner who presented the most economically advantageous offer. The contracting authority resorts to the competition procedure particularly in the fields of land use planning, urban planning, architecture, engineering, or data processing. It should be noted that the project management contract is not necessarily awarded thru the competition procedure.

- **The negotiated procedure :**

It is the process that allows the contracting service to engage in negotiations with companies without a call for tenders and freely award the contract to the candidate they have selected.

**- The negotiated procedure after consultation :**

It is a procedure for awarding a public contract, after possible negotiations, without a public call for competition, which puts candidates in competition based on a specifications document. According to DP No. 15-247 related to public procurement, the contracting service can resort to negotiated procedures after consultation in the following cases:

**I.5.5. Public procurement procedures:**

**-The specifications:**

Before any call for competition (even in a negotiated procedure), a specifications document must be meticulously prepared by the contracting service to inform interested candidates about the nature and scope of the project. This specifications document must indicate the services to be performed, the goods to be provided, the installation site (construction site), the warranty requirements, it must define the tests, standards, and methods for judging the conformity of the works to be carried out and the technical specifications, the bond, the indemnity and insurance, the penalties, the termination, the advances, the payment method for the services, etc.

**-The call for tenders notice:**

The contracting service must publish an announcement about the project it wants to undertake. The use of press advertising is mandatory in cases of calls for competition and negotiated procedures after consultation. This announcement, called the "call for tenders notice," must include: the method of the call for tenders, the pre-selection conditions, the purpose of the operation, a summary list of the required documents, the duration for preparing the offers and the location for submitting the offers, the validity period of the offers, the bid security, if applicable, the submission of offers in a sealed envelope marked "to be opened only by the bid opening and evaluation committee," and the references of the call for tenders, the cost of the documentation.

**- Submission of bids:**

The bids must be submitted by the date specified in the call for tenders notice. They must include a bid dossier, a technical offer, and a financial offer.

These elements are placed in separate and sealed envelopes, indicating the name of the company, the reference and the subject of the call for tenders, as well as the mention "application file," "technical offer," or "financial offer," as applicable. These envelopes are placed in another sealed and anonymous envelope, bearing the mention "to be opened only by the bid opening and offer evaluation committee

- tender no. ... - subject of the tender."
- The application file contains:
- A declaration of candidacy.
- A declaration of integrity.
- The statutes for companies;
- The documents allowing the evaluation of the company's capabilities, namely: Professional capabilities: qualification and classification certificate; Financial capabilities: financial means justified by balance sheets and bank references; Technical capabilities: human and material resources and professional references.

The technical offer includes:
- A declaration to be signed.
- A bid bond, if applicable.
- The specifications document bearing on the last page the handwritten mention "read and accepted."
- The financial offer includes: - The submission letter.
- The unit price schedule (UPS).
- The quantitative and estimated breakdown (DQE).
- The breakdown of the global and lump-sum price (DPGF).
- The contracting authority may, depending on the nature of the contract and its amount, request in the financial offer a detailed breakdown of unit prices (DBUP) and a detailed descriptive and estimated quote (DDEQ). I.5.5.4 Opening and evaluation of bids:

The opening of the bids is carried out by the bid opening and evaluation commission, which mainly performs the following tasks:
- Verify the regularity of the registration of the bids.
- Draw up the list of candidates in the order of arrival of the bids, indicating the content, the amounts of the proposals, and any discounts.
- Inviter, par écrit et par le biais du service contractant, les candidats à compléter leurs offres techniques, dans un délai maximum de dix (10) jours à compter de la date d'ouverture des plis, sous peine de rejet de leurs offres, par les documents manquants ou incomplets exigés.
- Proposer au service contractant, dans le procès-verbal, de déclarer l'infructuosité de la procédure.
- Draw up the minutes signed by all the members present at the commission.

The evaluation of the bids is carried out by the bid opening and evaluation committee.

This commission is mainly responsible for:

- Eliminate offers that do not comply with the content of the specifications.
- Proceed with the analysis of the remaining offers in two phases based on the criteria specified in the specifications document. It establishes, in the first phase, the technical ranking of the offers by eliminating those that did not achieve the minimum score. She examines in a second phase the financial offers of the technically pre-qualified bidders.
- Deduce, in accordance with the specifications, the most advantageous offer, which is:

* The least distant, among the financial offers of the selected candidates, when the nature of the contract allows it. In this case, the evaluation of the bids is based solely on the price criterion.
* The least distant, among the technically pre-qualified offers. In this case, the evaluation of the offers is based on several criteria, among which is the price criterion.
* Who obtains the highest total score based on the weighting of several criteria, among which the price criterion is included, when the choice is essentially based on the technical aspect of the services.

- Propose to the contracting service to reject the financial offer of the temporarily selected economic operator, deemed excessive compared to a price benchmark.

**-Deadlines related to administrative procedures:**

The contracting service must provide in its call for tenders a period (of validity of the offers) sufficient to:

- Compare and evaluate all the offers.
- Award the project.
- Develop the market project.
- Obtain all necessary approvals.
- Notify the market.

**-The deadlines for the different stages could be set, for example, as follows:**

- Call for tenders notice (for publication in the press) (15 days).
-Deadline for submitting bids (21 to 60 days).
-Opening of bids (1 day).
-Analysis and evaluation of offers (15 to 30 days).
-Non-objection agreement from the funder (financial service) (15 days).
-Preparation of the market project (7 days).
-Approval of the contract (21 days).
-Commitment and notification of the contract (15 days).

**I.5.6 Provisional award, appeal, and definitive award of the contract:** The criteria for selecting the co-contracting partner must be explicitly mentioned in the tender specifications. To choose the most advantageous offer, the contracting service must rely either on the price criterion only when the nature of the contract allows it, or on several criteria, including: price, technical value (rating), deadline, quality, esthetic and functional characteristics, social performance to promote the professional integration of people excluded from the labor market and the disabled, and performance in terms of sustainable development, after-sales service, and technical assistance, etc.

**I.6 Design and Preparatory Arrangements for the Execution of the Works** The construction site The design office prepares the implementation of the site and organizes the participation of different specialties to ensure compliance with the rules of the trade (current rules and standards), everyone's commitments, and the proper execution of the plans. The management of the construction site The project manager intervenes on-site with the various companies to ensure the proper execution of the different phases of the building construction:

•**Earthworks and road and utility network (VRD) works**

•**Structural work:** stability and solidity of the building (foundations, structure)

•**Finishing work:** waterproofing, esthetics, and comfort The project manager leads the site meetings, for which he prepares and distributes the minutes to all concerned parties. He also supervises the payment of the contractors and the completion of the corresponding services within the scheduled times.

**I.6.1 Scheduling, coordination, and site management:**

The analysis of the elementary tasks that make up the execution studies and the works, their sequence, and the critical points of this series of interventions constitute the mission of scheduling and planning, which is complementary to project management. Its purpose is to carefully plan the optimal integration of the various interventions by the companies for the fastest and least expensive construction possible.

Project Closure:

**I.6.2 Assistance with the reception and delivery operations of the building to the project owner**:

The engineering office oversees all the work carried out and the execution of services down to the finest details. It is also responsible for the general accounting of invoices from various service providers and settles the construction site accounts. The design office then closes the file of the completed works and thus confirms the conformity of the work to meet the terms of the warranty contracts. Penalties may be imposed on companies that exceed the scheduled duration for their intervention. Once all the work has been validated by the project manager and the project owner, they agree on the provisional acceptance of the building and the complete transfer of responsibility for the building(s) to the project owner. The final acceptance will be pronounced twelve months after the commissioning or the start of operation of the building.

**I.6.3 Criteria for Site Selection**

The choice of the site for the installation of an infrastructure is motivated by several parameters, including:

-Topography A terrain with significant elevation changes will incur high costs for development (retaining walls, embankments, etc.) and for stormwater protection systems, so choosing a flat terrain would be ideal.

-The geotechnical nature The choice of a site with geotechnical characteristics of soils with more or less acceptable bearing capacities is the most interesting option because it leads to the adoption of the least expensive foundation methods possible. Sites characterized by rather poor geotechnical formations in terms of mechanics (bearing capacity) require the adaptation of special foundations that are financially costly, difficult to implement, and necessitate a significant execution time. Knowing that the vast majority of the issues observed in various infrastructures are of a geotechnical nature, this requires us to pay particular attention to the nature and soil studies. I.6.3.3 Natural risks: It would be more prudent to avoid sites presenting natural risks such as: Flood-prone areas, Areas with slope instabilities (risk of landslides).

**I.7 Location of structures:**

The implantation is the operation that consists of transferring onto the ground, according to the indications of a plan, the position of buildings, axes, or isolated points for the purpose of construction or marking. Most layout plans consist of straight lines, curves, and isolated points.

The instruments used must allow for the positioning of alignments or points: theodolites, optical squares, tapes, levels, etc. The chosen instrument depends on the required precision, which in turn depends on the type of structure to be installed: millimeter precision for special foundations, centimeter precision for common structures, decimeter precision for earthworks, etc.

**I.7.1 General Layout Plan of the Structures**

The general layout plan of the structures is an oriented plan that specifies the position of the structures, in planimetry, in relation to fixed reference points.

**I.7.2 General Staking** :

The general staking consists of marking on the ground the position of the structures defined by the general layout plan, using numbered stakes firmly fixed to the ground, whose heads are connected in plan and altitude to the fixed benchmarks mentioned in the layout plan.

**I.8 Geotechnical Investigations** :

**I.8.1 General Concepts on Geotechnics** :

**- Soil:** construction material Used to build dams, earth dikes, roads, highways, embankments,

-**The soil supporting foundations** : The foundations bear the loads and surcharges or, more generally, the stresses transmitted by the structure (superstructure), and then transfer them to the ground capable of ensuring the stability of the work.

- **Stability and Settlement**: The stability conditions must lead to respecting the fundamental principle of the equality of actions transmitted by the structure with the reactions transmitted by the ground. The foundation soil must not settle. Although in reality, settlements do exist and are tolerated up to certain thresholds, except on rocky soils.

• **Instantaneous settlement:** without change over time

• **Delayed settlement:** evolves over time Choice of foundation type

•Considering the loads of the superstructure

•Properties of the existing soils

•Groundwater level

• Adjacent structures I

•Soil reconnaissance

**-In situ tests ;**

(cored drilling, penetrometers, pressure meters, geophysical studies) In situ geotechnical tests aim to assess the soils intended for construction projects. They provide information on the condition of the in-situ soil, specify the organization of the different layers, and identify the mechanical parameters to be assigned to them in order to proceed with the design calculations.

**I.8.3 Laboratory tests** ; (identification of different layers, determination of the physical and mechanical characteristics of in-situ soils, calculation of settlements, calculation of bearing capacity, etc.) In order to know the physical and mechanical characteristics of the soil as well as its behavior in situ under stress conditions, tests simulating these conditions must be conducted. The role of laboratory tests is, first of all, to identify the material from a physicochemical perspective, and then to determine its mechanical characteristics and behavior when subjected to the actual mechanical conditions imposed by the structure.

.

| | | |
|---|---|---|
|  | Essai pénétromètrique | Donne une idée sur la portance des sols sans prélèvement de carottes. |
|   | Carottes prélevées et mises dans des caissons. | Pour le transport au laboratoire et leurs protections. |

**Figure 1.** Two examples of in situ geotechnical tests + box with cores

# CHAPTER II.

# SITE PREPARATION TECHNIQUES

# CHAPTER II. SITE PREPARATION TECHNIQUES

## II.1. INTRODUCTION

The study and execution of a construction project require a large number of tasks of very diverse natures, involving a great number of participants. Moreover, the tasks of one and the other are most often interconnected, or even conditioned by one another.
It is therefore imperative to organize everyone's actions and to materialize in appropriate language the decisions made and the consequences that ensue.

## II.2 Preparation of work and techniques for organizing construction sites

A site installation plan (P.I.C.) is generally established based on a site layout plan and defines the "fixed" equipment necessary for the execution of the works and To accommodate the Construction site personnel.

It is also used to obtain:

- the permits for crane installations, crane overflights over neighboring lands or buildings, public roadworks, road diversions, etc., issued by the Technical Services of the town halls or police prefectures.

- the permits to set up the construction site in accordance with hygiene and safety regulations from labor inspection services.

## II.3 Role of the construction site setup

### II. 3.1. Organize the progress of the construction site

To be studied during the preparation at the methods office,

• Plan the different phases of execution by moving men, equipment, and materials as little as possible (including during the dismantling of the site),

• Facilitate coexistence and dialog between the different trades,

• Make the best possible use of the available space, especially on urban construction sites

### II. 3.2 Organize the site

-Time savings: reduces unit times (U.T.),

-Avoids losses (materials) and double handling (equipment),

-Improves safety: human + material (fence + guarding + alarm),

-Improves quality (succeeding on the first try at the lowest cost),

-Showcase for project management and companies

### II. 3.3 Position the elements

•human: appointment, accident,

•equipment: delivery, movements,

•networks: leaks, breakdowns, connections

Use of warning meshes and standardized color tubes

| | |
|---|---|
| Bleu | Eau |
| Jaune | Gaz |
| Rouge | Electricité |
| Vert | Courants faibles et téléphone |
| Ocre jaune | Assainissement |
| Marron | Télédistribution |
| Blanc | Eclairage public |

**Table.1** Location and functions of the different positions

| Rep. | Désignation | Localisation | Fonctions |
|---|---|---|---|
| 1 | Engins de levage (grue à tour, grue à tour à montage rapide, grue automotrice…) | L'aire de balayage doit couvrir les bâtiments, le poste de bétonnage, les aires de préfabrication, armatures et stockage<br>Eviter le survol des riverains | Manutentionner les matériaux, les matériels, des divers postes aux lieux de mise en œuvre |
| 2 | Poste de bétonnage (centrale à béton, malaxeur de mortier…) | Proche de l'accès principal, accessible aux camions de livraison (granulats, ciment, silos, trémies) | Fabriquer le mortier et le béton |
| 3 | Aire de préfabrication | Près des bâtiments à construire | Préfabriquer des ouvrages élémentaires (acrotères, poteaux, poutres, prédalles non précontraintes…)<br>Fabrication de coffrages (bois) |
| 4 | Aire de ferraillage | Proche des bâtiments à construire et de l'aire de préfabrication | Découper et façonner les armatures |
| 5 | Aire de stockage | Proche des accès<br>Aire protégée (vols de matériaux)<br>Sur le bâtiment | Stocker les matériaux, éléments préfabriqués et matériels avant leur utilisation.<br>Stocker la terre végétale. |
| 6 | Cantonnements (bureaux, réfectoire, sanitaires, hébergements, magasin, caravanes) | A proximité d'un accès du chantier<br>Si possible hors de l'aire de balayage de la grue<br>Les éléments peuvent être superposables ou se trouver dans le bâtiment réalisé | Accueillir le personnel du chantier et les intervenants (réunion de chantier) dans des conditions d'hygiène et de sécurité<br>Favoriser les communications entre les |

| | | | |
|---|---|---|---|
| | | | intervenants<br>Stocker les matériaux et matériels sensibles |
| 7 | Réseaux: eau, gaz, électricité, téléphone, air comprimé, égout | Enterrés ou aériens, à la périphérie des bâtiments.<br>Stockage eau. | Alimenter les postes de travail (armoires de distribution)<br>Evacuer les eaux |
| 8 | Clôture ou palissade (éventuellement balises et TS proscrit) | A la périphérie du chantier | Isoler le chantier de la voie publique<br>(intrusion, vols, accidents) |

## II.4 The technical file for the works to be carried out

The project designer is directly responsible for the preparation of the technical file, in accordance with the terms of the technical studies contract. The technical file consists of the project's graphic and written documents, developed in collaboration with the municipal technical services (if the municipality has them), or with representatives of the municipality. The project designer is specifically responsible for preparing the following documents for the tender:

- Plan of the works to be carried out;
- Descriptive specifications;
- Price schedule .
- Estimated Bill of Quantities and annexd documents such as measurements, schedule, standard plans, etc.
- Draft Contract with the Contractor
- Terms of Reference for the Call for Tenders ;
- Particular Technical Specifications.

### II.4.1 Development of the Site Installation Plan (S.I.P) :

| Phases | Démarches / Règles |
|---|---|
| Positionner le ou les engins de levage | Schématiser les grues et indiquer les informations suivantes:<br>longueur de flèche et contre flèche, zone d'interférence, longueur et largeur des voies de grue, marque, type et caractéristiques, cotes par rapport aux bâtiments, niveau du support (rails), HSC, $N_{HSC}$, charge maxi soulevée, charge en bout de flèche…<br>Penser au démontage et à l'emprise de l'embase et/ou des pieds stabilisateurs |

| | |
|---|---|
| Placer le poste de bétonnage ou les aires de stationnement des camions toupies (bennes à béton) | Suivant l'importance du chantier le béton sera soit du B.F.C. (Béton Fabriqué sur Chantier): on place la centrale à béton et on représente les parcs à granulats, le silo à ciment ; soit du B.P.E. (Béton Prêt à l'Emploi): on prévoit l'aire de stationnement des camions toupies |
| Définir les aires de coffrage, de ferraillage et de préfabrication | Selon le mode constructif retenu, il y a lieu ou non de prévoir ces aires (ouvrages élémentaires coulés en place, préfabriqués sur site, préfabriqués en usine), on indiquera la destination de chaque aire et les dispositions particulières à prévoir (dimension, sécurité) |
| Représenter les bureaux et les cantonnements | Le nombre de bureau à installer est indiqué par la maîtrise d'œuvre dans les pièces écrites.<br>Les dimensions et le nombre de baraques destinées au personnel est fonction de l'effectif et de la durée du chantier.<br>Le magasin doit se situer prêt du bureau du chef de chantier. |
| Représenter les réseaux | A partir du transformateur, on positionne les armoires de distribution électrique puis on trace les réseaux pour approvisionner les postes (ou groupe électrogène).<br>Idem pour l'adduction en eau et les lignes téléphoniques.<br>L'évacuation des eaux se fait des sanitaires jusqu'à l'égout.<br>Prévoir un local de confinement pour le compresseur. |
| Représenter les aires de stockage et les voies de circulation | Le plan est complété par les aires de stockage (matériels du gros œuvre, matériaux du second œuvre, terres pour remblais) et les voies de circulation (sens de circulation, entrée, sortie, parking des personnels et des intervenants extérieurs) |
| Représenter les équipements divers | Clôture de chantier, panneau de chantier, éclairage, poste de lavage, benne à gravas |

### II.4.2 Marking and Delimitation of the Site

A site installation plan must also show, in addition to the main positions defined above, the location of:

Natural obstacles (vegetation, rock) and industrial obstacles (poles, manholes), From the construction site sign (building permit number, names of the project managers and owners, names and qualifications of the companies, deadlines, costs...), access and circulation routes, the debris bin, the potential truck washing station...

**Note:** The Site Installation Plan must be complete but must above all remain legible (Think of printing plans in black and white).

General staking General staking consists of marking the position of the structures defined by the general layout plan on the ground, using numbered stakes firmly fixed to the ground, whose heads are connected in plan and elevation to the fixed benchmarks mentioned in the layout plan.

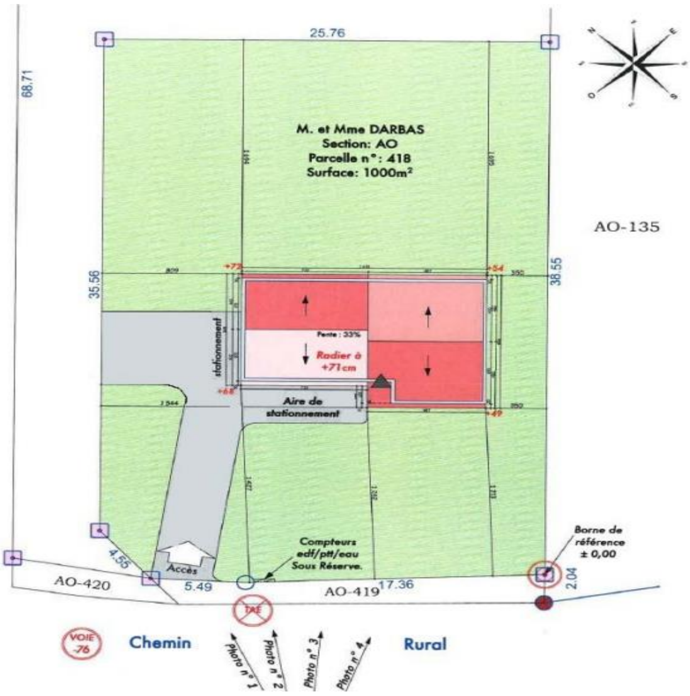


**Figure 1 .** Example of a layout plan.

The implantation is the physical representation on the ground of the footprint of a structure as outlined in the work file. It is the projection on the ground of all the major lines of the construction using layout chairs and strings. Indeed, mastering the layout is crucial for the orthogonality and parallelism of the structure. If the construction is not square or not level, major difficulties and big problems are to be expected. To carry out an installation, it is necessary to have a site plan, a layout plan, and a foundation plan (Figure III.1).

- **The site plan**: provides information about the location of the project site in relation to a known reference point (street, establishment, etc.).

- **The site plan:** is used to locate the project site and its immediate surroundings in relation to its neighborhood (adjacent buildings, party walls, etc.).

- **The foundation plan**: allows for the materialization of the different elements of the foundation.

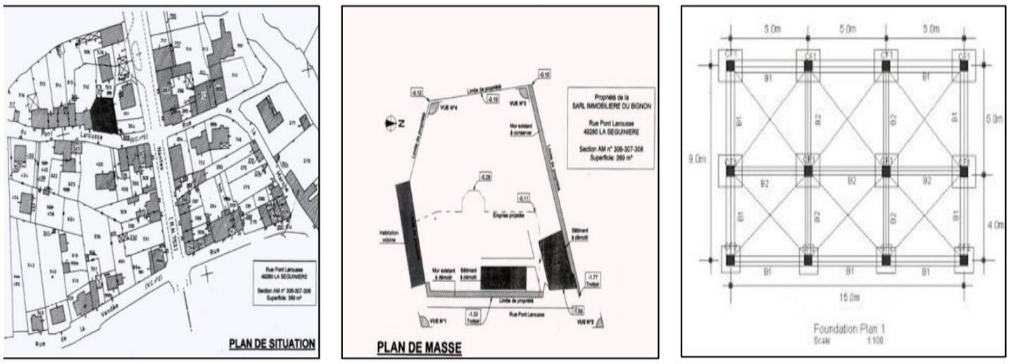


**Figure 2.** Graphic layout documents.

To set up, we need a certain number of materials such as:

- **Markers (or stakes):** are 2m long wooden or metal rods, painted alternately in white and red. Their role is to determine or extend an alignment.
- **Chalk line:** it allows for the representation of guidelines.
- **Tape measure:** it allows measuring lengths.
- **Spirit level:** it allows determining and verifying horizontality.
- **Layout chairs:** they consist of metal or wooden stakes driven into the ground, equipped with horizontal beams with markers for fixing the cords.

Their role is to allow the fixing of alignment cords for guideline lines.

- How to carry out the layout? How to perform the implantation?
- Example of implementation execution

After stripping the topsoil, the following points should be followed (Figure III.2):

- Marking the first line by stakes M and N.
- Obtaining the director No. 2 and point E from the station in B.
- Setting up the chairs to position the alignment cords.
- The station at A allows obtaining point F, placing chair No. 4, and checking the diagonals (AE=FB).
- Lead the parallels to the guidelines (marking by nailing on the chairs, excavations, footings, starts) using the cumulative dimensions.

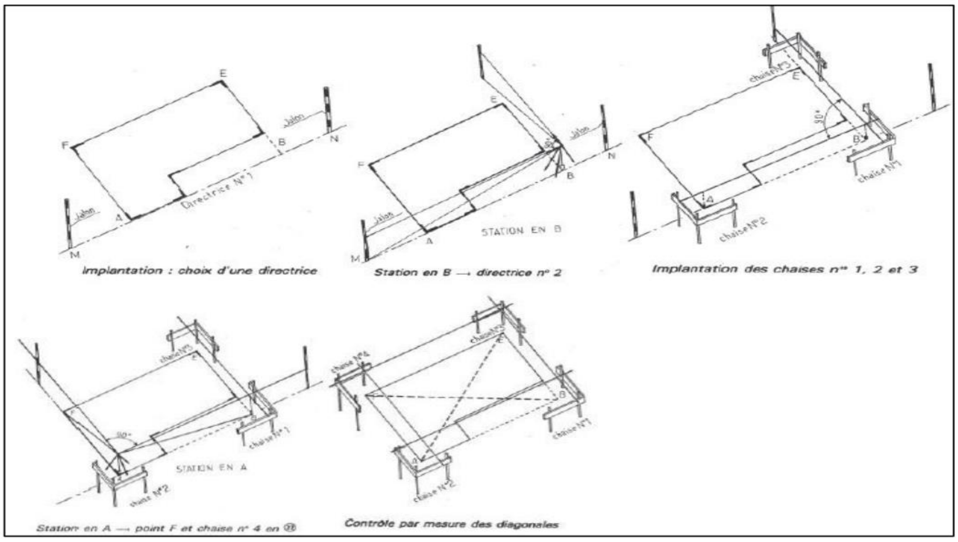


**Figure 3.** Example of an implantation.

**- The implantation technique:**

**-The implantation technique** : To correctly perform an implantation, you will need to follow these steps :

-Set up the first two markers.

-Create and set up the chairs as well as the stakes or remaining markers.

-Transfer and secure the strings on the stakes with nails.

-Check the squareness and take the plumb of the intersection points of the cords.

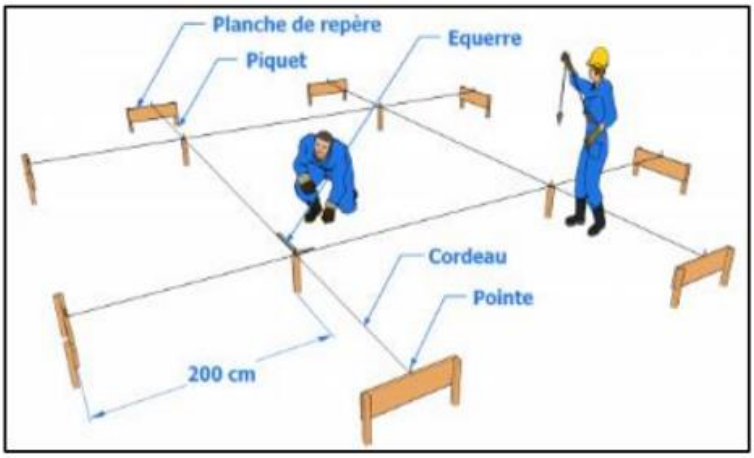


**Figure 4 .** Exemple de mise en place de chaises d'implantation

### II.4.3 The square method :

It is an excellent method for perfecting a layout in the absence of professional surveying equipment (construction level, theodolite, etc.).

You can choose between:

-Squaring with the mason's square.

-the 3-4-5 method (the triangle method).

- the equality of the diagonals.

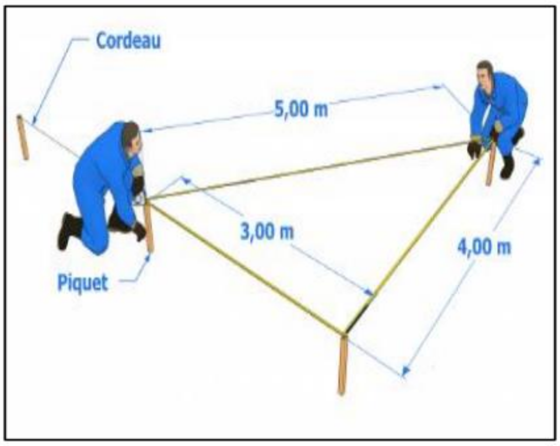


**Figure 5.** Squaring.

### II.5 Earthworks

In civil engineering, the realization of a project consists of transforming a study and plans into a real-sized structure, which is based on the natural terrain. However, to construct a structure, whatever it may be (building, road, bridge, dam, etc.), it is necessary to modify the natural terrain that will support it. This terrain can be sloped, uneven, it can contain topsoil, etc. Earthworks aim to shape the surface of the land so that it can support the weight of the structure and incorporate its form. But before starting the earthworks, it is essential to carry out a layout so that the structure is orthogonal, parallel, and built in the correct location on one hand, and to facilitate the implementation on the other hand.

Earthworks are the set of operations aimed at making the natural soil conform to the profiles planned for a project and suitable for receiving a structure. It is a procedure for modifying the relief of a terrain thru several operations such as the extraction of soil from the surface, the stripping of topsoil, backfilling, compaction, etc. (Figure III.6). These operations can be grouped into three categories, namely: excavations or earthworks (removed soil), embankments (soil brought in to fill cavities and level up), and the removal of excavated soil to a disposal site. There is not just one type of material to excavate but several possible kinds: rocks, sand, silt, clay, etc.

**Figure 6.** Examples of earthworks.

After the layout, excavation is carried out in accordance with the excavation plan. The nature of the soil is crucial, the earthmovers distinguish three types of soil:

**Table 2**. Types of Soil.

| Sun | Properties |
|---|---|
| Furniture | Attackable by a loader or a hydraulic excavator |
| Rocheux | Attackable by a loader after breaking the rock with a hydraulic hammer (BRH). |
| Roc | Requires blasting |

The earthworks begin with the staking, which involves setting up reference stakes indicating the level to be reached. These stakes can be aligned in the case of trenches or placed in a grid pattern in the case of excavation earthworks.

- **The embankments** consist of bringing in soil to raise the level, also called backfilling. Embankments consist of bringing in soil to raise the level, also known as filling. We distinguish several types of earthworks, notably:

• Stripping

• Large-scale excavation or full-scale excavation

• Trench or trench excavation • Shaft excavation

• Gallery excavation

**II.5.1 Techniques for carrying out earth removals:**

We begin the excavation operation, which is an extraction of the earth. The resulting cavities are called excavations. These can be dug manually or mechanically, depending on the layout made during the installation. The level or depth of the excavation is indicated by the reference stakes.

**We distinguish**: excavation trenches, trench excavations, and ditch excavations (Figure III.7).

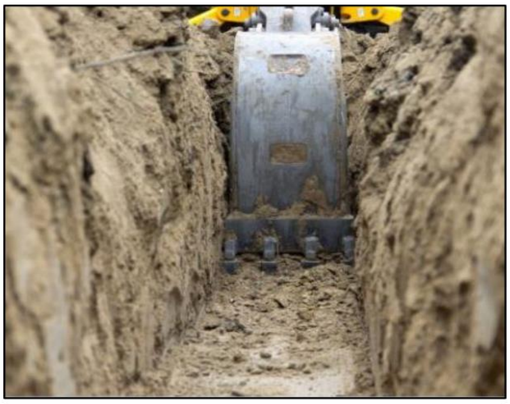

**Figure 7** . A search.

### II.5.2 Stripping :

Involves the removal, prior to any earthworks, of the top layer (topsoil), unsuitable or unfit land for receiving the foundations of the construction. The excess soil or rock extracted from the stripping and earthworks will be removed ; they constitute the excavated materials. The topsoil will be stored at the periphery of the site to be reused for exterior developments (green spaces, etc.). You need to choose a storage location that does not hinder any progress of the work or get crossed by future pipelines. It is also important to ensure that the topsoil is not contaminated by debris or other materials. Work is generally counted per square meter, but if the depth is not consistent, it will be counted per cubic meter.

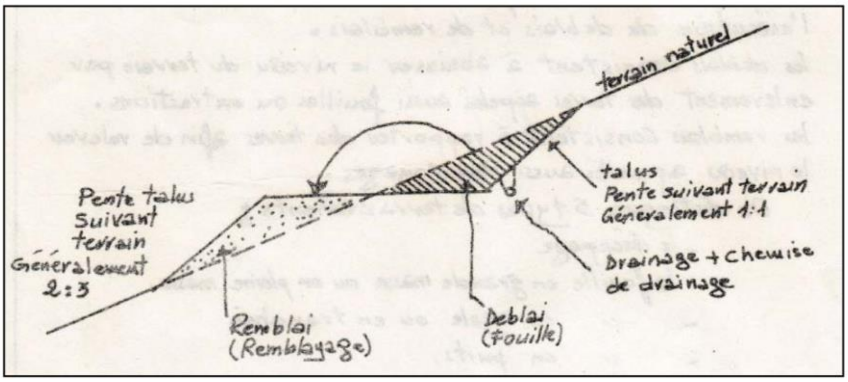


**Figure 8.** Cross-section diagram of embankment and excavation

**II.5.3 The full mass excavation** : It is the main excavation of a construction. The depth depends on the importance of the structure. At the bottom of the excavation, the distance between the wall and the earth will be at least 50cm, to allow for the execution of waterproofing, drainage, etc. Excess soil must be immediately removed, and only the soil necessary for the various backfill operations will be kept on site. The work is measured in cubic meters.

**Figure 9**. Full mass excavation.

**II.5.4 The well excavation :** It is an excavation of small surface area and great depth intendedto receive: pole foundations, elevator shaft, In this type of excavation, the shoring is called bracing.

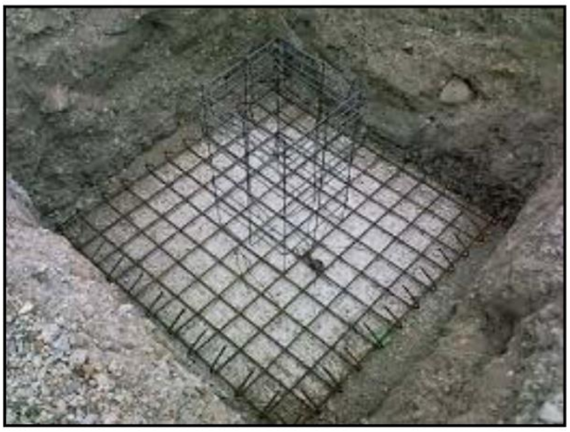

**Figure 10.** Well excavation

**- The well excavation** It is a small-surface, deep-excavation intended to receive: pole foundations, elevator shaft,…. In this type of excavation, the shoring is called bracing.

**Figure 11**. Well excavation

### II.5.5 The sloped excavation

The sloping prevents the collapse of a trench by eliminating the pressure of the soil. The sloping, and especially the stepped sloping, requires a significant footprint. The embankments are characterized by their slope angle (embankment slopes) which depend on the nature of the soil (physical characteristics of the soil).

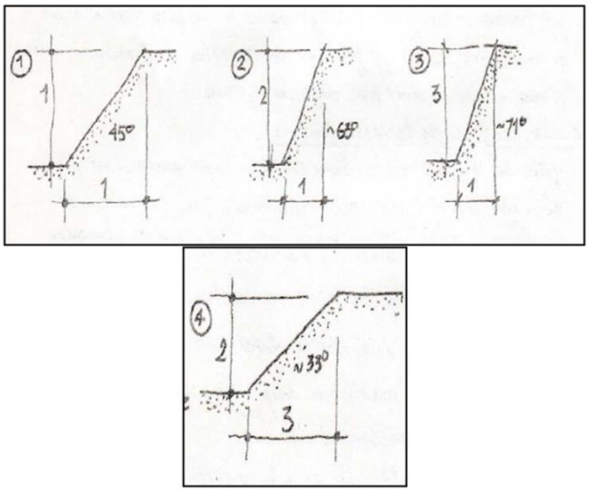


**Figure 12.** Some examples of slope inclinations.

Maximum slope angles

Figure 7 (1): scree slope 1:1

Figure 7 (2): resistant soft terrain 2:1

Figure 7 (3): very compact terrain 3:1

### II.5.6 Excavations in holes or trenches:

These are excavations intended to receive isolated footings (in the case of hole excavations) or strip footings under slabs (in the case of trench excavations). It is noted that if the depth of the isolated footings is significant, we will refer to well excavations.

### II.6 Shoring of excavation walls:

In the case of wide or full-mass excavations, stability must be ensured either from the inside using a series of struts, or from the outside to avoid clutter inside the excavation by installing sheet piles anchored at the top of the anchored diaphragm walls. The walls to prevent collapses of the walls are constructed from the ground surface even before the excavation begins to ensure high safety. We can also proceed with the opening and shoring as the work progresses. In some cases (excavation and trenching), there is a risk of the walls collapsing. In this case, shoring of the excavations is carried out as the digging progresses. This operation involves temporarily supporting the walls of a slope or trench to ensure safety throughout the work. The principle consists of placing continuous or discontinuous walls made of wood or metal inside the excavations, as illustrated in the cases shown in Figure III.8.

**Figure 13**. The shielding.

### II.7 Shielding by panels or boxes:

The shoring with wooden/concrete panels or wooden or metal boxes is carried out as the excavation progresses. Shoring using wooden or concrete panels is often employed during manual excavation due to the inconvenience caused by struts (screw jacks). In some cases, the shoring is of the "lost" type. When the technique involves metal casings, excavation using an excavator is possible. The widths of the excavations can then be larger. For the de-blinding, the lower elements are dismantled or reassembled as the backfilling progresses.

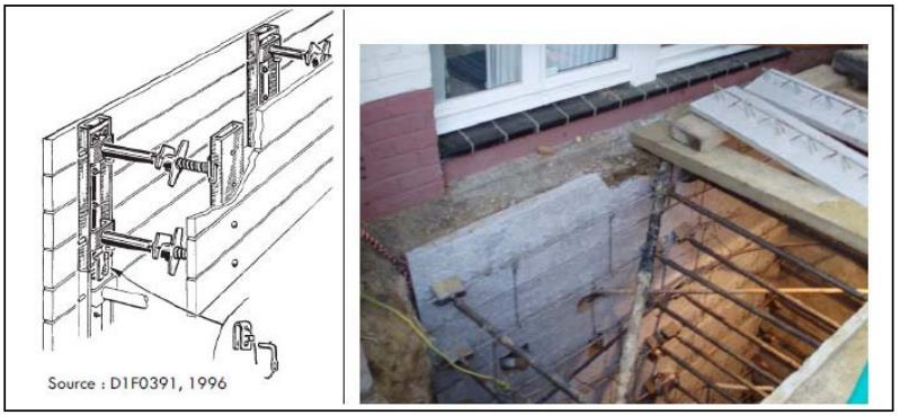


**Figure 14.** Excavation in shielded digging

### II.9. Problems posed by earthworks :

| **Type** | Problems | **Propositions/ indications** |
| --- | --- | --- |
| Digging the ground | Bad weather.<br>- Soil type. | Geotechnical soil studies<br>- Choose the appropriate equipment<br>- Weather information<br>- Planning |
| | | Appropriate tools |

| | | |
|---|---|---|
| Excavation of the spoil | Inclement weather.<br>- Accessibility of equipment on the site. | Appropriate tools |
| Transport and removal of debris | -Clutter in the excavation area.<br>- Accessibility to the site.<br>- Distance from the approved dumping area.<br>- Insufficient means. | Better site preparation.<br>- Optimize earthworks.<br>- Choose the equipment wisely. |
| Deposit of excavated materials | Reduced discharge area (urban zone) | Know the proliferation<br>. |
| Construction of embankments | Embankment stability. | Natural terrain angle. |
| Stability of slopes and walls | Field angle | Provide a shielding device for excavations (critical height) |
| Excavation costs | Poorly conducted studies.<br>- Exceeding projected costs<br>- Poor project management | -Good cost forecasting.<br>-Conduct the studies well (equipment performance).<br>- Better monitoring.<br>- Price studies. |
| Choice of earthmoving tools | The condition of the equipment.<br>- Type of terrain. | Appropriate materials. |

### II.7.1 Earthmoving Methods:

In earthworks, the following methods are used:

**-The manual method:**

The work is done using shovels and picks in soft and loose terrains. This method is mainly used for small projects, particularly for foundations and trenches.

**-The blasting method:**

The choice of the blasting method is generally guided by the hardness of the rocks to be excavated. In semi-hard and hard rocks, blasting is essential.

All blasting operations must meet several requirements imposed by the specific characteristics of open-pit mining, particularly the particle size of the blasted products, the safety opersonnel, and the safety of the equipment.

**- Mechanized earthworks:**

For significant projects, regardless of their nature (road, building, hydraulic works, etc.), the site must be equipped with the necessary equipment to ensure the success of the earthmoving operation.

The main equipment used in earthworks are as follows (Table.4):

| Engin | Tipos | Equipment | Photo | Usage |
|---|---|---|---|---|
| Bulldozer | Tracked - On tires | Blade at the front Ripper at the back |  | Excavation and extraction. Leveling of the land. Demolition and cleaning. Earthmoving. |
| Hydraulic excavator | Tracked On tires | Fixed chassis - A 360° rotating top equipped with: - Rear bucket - Stop bucket - Rock breaker |  | Excavation and execution of the trenches. Loading of excavated materials. |
| Grader | On tires | Variable angle and adjustable steel blade -A scarifier (Ripper) at the rear |  | Excavation on a thin layer. - Movement of earth. Flattening (leveling) of the surface . |
| Paint stripper | On tires | Reinforced bucket for floor scraping |  | Excavation on significant thicknesses. -Transport of soil over short distances. |
| Charger | On tires | Godé. |  | Clearing and leveling of surfaces after excavation. Backfilling of hollow spaces (holes, trenches) -Handling activities (loading and unloading) |

| | | | | |
|---|---|---|---|---|
| Compact<br>or | With tires.<br>Single cylinder.<br>Foo<br>t-operated vibrator<br>Manual vibrating roller | Weight (cylinder)<br>Weight (tires)<br>Vibrator. |  | Surface leveling.<br>Compaction and smoothing of surface materials.<br>Soil compaction. |
| Retro charger | On tires | Godé.<br>Shovel in reverse<br>. |  | Small excavation (trenches).<br>Loading/unloading small quantities of materials<br>. |
| Camions | On tires (6, 10, 12 wheels or more) | Dump truck |  | Transport the materials<br>. |

# CHAPTER III.

# TECHNIQUES FOR CONSTRUCTING REINFORCED CONCRETE STRUCTURES

# CHAPTER III. TECHNIQUES FOR CONSTRUCTING REINFORCED CONCRETE STRUCTURES

## III.1 Introduction :

The determination of the dimensions of building structures aims to maintain a state of stable equilibrium. Like any solid, constructions obey the general laws of equilibrium. The construction-foundation system must allow us to state that the sum of the forces along the two main axs is equal to 0, as well as the sum of the moments.

The foundation must, in this context, ensure the balance between the pressure generated by the load (load descent of the construction) and the soil resistance (admissible stress).

### III.1.2 Definition

A structure, regardless of its shape and purpose, always rests on a foundation soil. The elements that serve as an interface between the structure and the ground are called foundations. Thus, regardless of the material used, under each vertical load-bearing element, wall, shear wall, or column, there is a foundation.

## III.2. Main Role

The load-bearing structure of a building supports various loads such as:

- Vertical loads:

Like permanent loads such as the weight of load-bearing elements, the weight of non-load-bearing elements.

-such as variable loads like the weight of furniture, the weight of people. The weight of the snow.

- **Horizontal (or inclined) loads:**

-like permanent loads such as earth pressure.

-like variable loads such as water or wind pressure.

It is not about calculating the overall load that the structure bears but the load taken by each foundation. Indeed, each foundation does not receive the same load.

- It depends on the supporting elements included. It depends on the load-bearing elements being considered. The load taken by a foundation is calculated using a load transfer method.

- The main role of a foundation is therefore to ensure the transmission of the loads applied to the structure to the ground. The main role of a foundation is therefore to ensure the transmission of loads applied to the structure to the ground.

The criteria influencing the choice of a foundation are there fore:

-the quality of the soil.

-The charges brought by the construction.

-The cost of excursions.

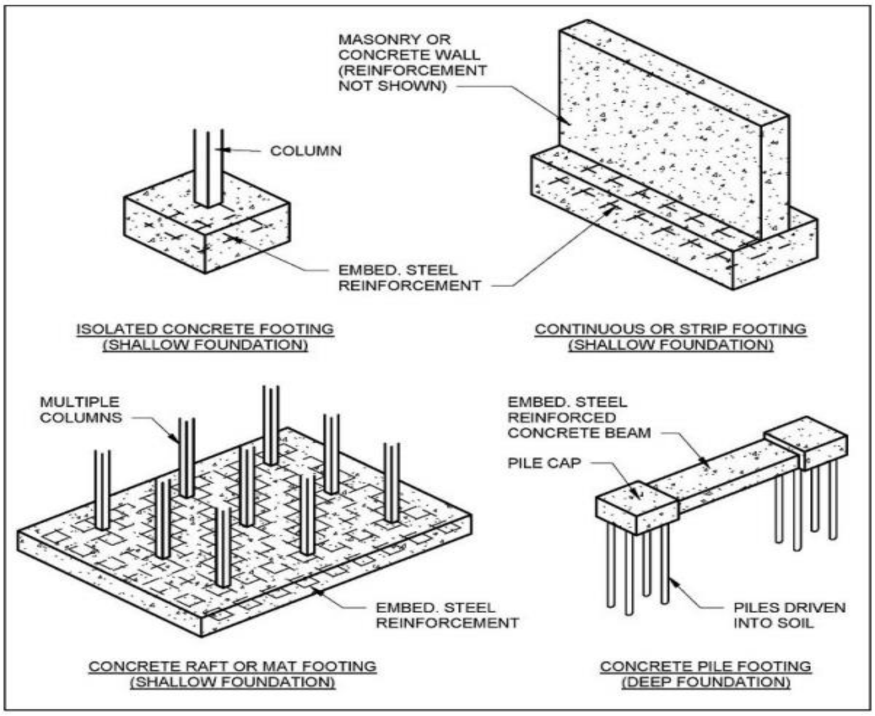


**Figure 1.** Superficial and deep foundation.

The foundation must transfer the loads it receives from the superstructure to the chosen bearing soil. It may happen that the loads transmitted to the foundation by the superstructure have a horizontal component (wind load, seismic origin loads...). The foundation must also transmit these loads to the ground and allow for their balancing by the ground. The forces are then transmitted thru friction on the ground or by implementing a stop along the vertical walls of the foundation elements.

**III.3 Roles of foundations :**

-Distribute the load of the structure over a large surface.

-Load the bearing surface at a uniform rate.

-Prevent lateral movement of the supporting material.

-Ensure a level and firm bedding for construction operations.

-Increase the stability of the structure.

**III.4 Types of foundations :**

**III.4.1 Shallow foundations :**

Foundation placed immediately under the lowest part of the superstructure. Used to distribute the structural load over a large surface at a shallow depth. Also called Open Foundation.

**Various types available:**

-Widened footing / isolated footing

- Combined footing

-Cantilever footing / strip footing

- Continuous footing / wall / strip

- Raft foundation

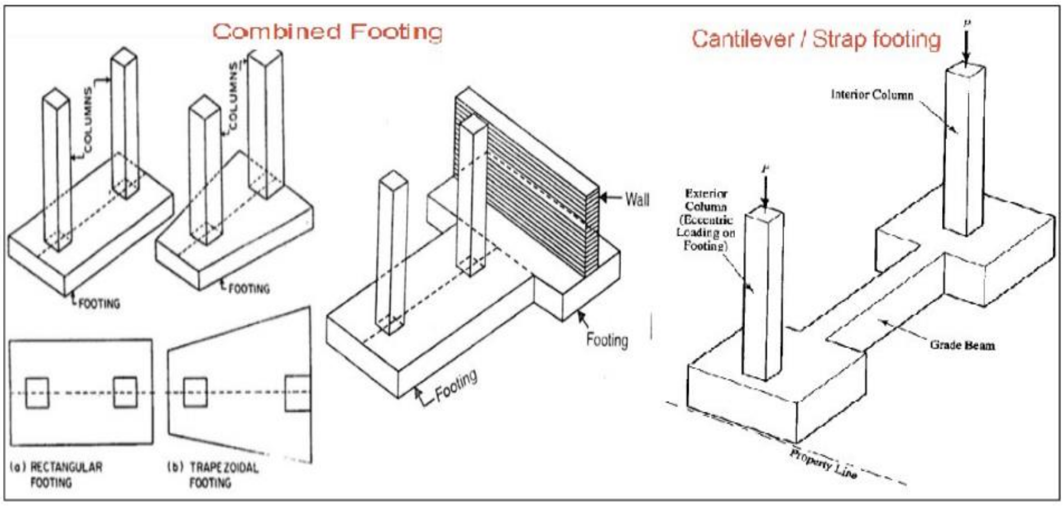


**Figure 2.** Types of shallow foundations.

A shallow foundation is defined as any foundation where the ratio D/B ≤ 6 or the depth D ≤ 3 m. Example: isolated footing, strip footing, and raft foundation (Figure 2).

**Figure 3**. Shallow foundations : Isolated Footing, Continuous Footing, Raft Foundation.

A shallow foundation is defined by geometric characteristics.

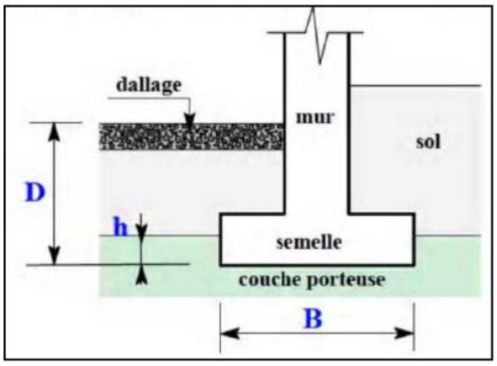


**Figure 4.** Vertical section on shallow footing.

-L: length of the sole or longer side of a sole.

- B: width of the sole or shorter side of the sole.

-circular footing B = 2 R

- square footing B = L

- rectangular footing B < L < 5 R

- continuous or sliding sole:... L > 5 B

- D: embedment depth of the footing.

Minimum height above the foundation level. If a slab or pavement overlaps the foundation, they are taken into account in the embedment depth.

- h: anchorage of the footing. It corresponds to the penetration depth of the footing into the bearing layer. It is also defined by the B/D ratio. Beyond a ratio of 1/6, we are in the realm of deep foundations.

### III. 4.2 Isolated footings:

They can be square, rectangular, or circular in shape. The isolated footings are constructed under the columns. Their surface dimensions are similar to those of the column they support.

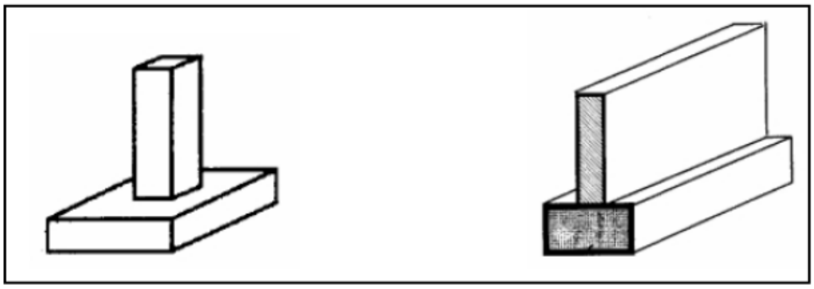

**Figure 5.** Isolated footing, and continuous footing under wall.

- Dimensions of isolated footings:

-Isolated footings are the foundations of the poles. Their surface dimensions are similar to those of the pole that the foundation supports

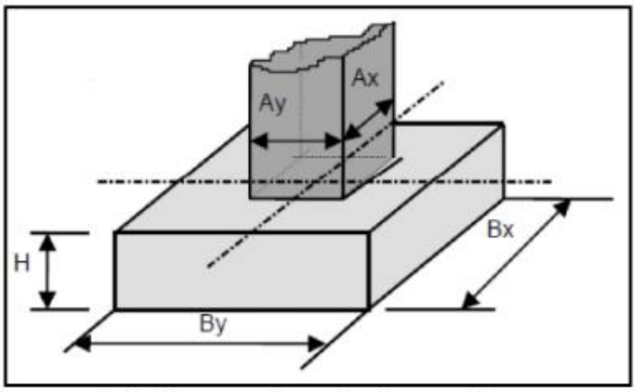


**Figure 6**. Geometric characteristics of isolated footings.

Rectangular footings:

- Homothety

$$\frac{\mathbf{B_x}}{\mathbf{B_y}} = \frac{\mathbf{A_x}}{\mathbf{A_y}}$$

- Height H

$$\frac{\mathbf{B_x - A_x}}{\mathbf{4}} \leq \mathbf{H}$$

**III.4.3 The continuous footings:**

They have a length L greater than the width B (L/B>10). The strip foundations are constructed under walls or a row of columns. Their surface dimensions are homothetic to those of the wall they support.

**III.4.4 The general raft:**

When the surface of all the footings becomes too large (more than 50% of the total surface area of the building), or when excavations are difficult to carry out, it is advisable to construct a general raft foundation. This flat slab consists of a general footing covering the entire ground surface of the building and sometimes includes overhangs (external cantilevers). Several types of raft foundations are known, including: flat raft with constant thickness, ribbed raft, mushroom raft, vaulted raft, etc. The raft foundation is justified if the surface area of isolated or continuous footings is very large (greater than or equal to 50% of the building's footprint) due to:

-The low bearing capacity of the soil.

-High loads of the building (high-rise building).

-Of the closer spacing of the columns.

-Difficulties in establishing piles (cost, harmful vibrations).

-Of the existence of eccentric loads at the edge of the building.

-Of the use of the ground-ground (parking, garage, cellar, etc.).

**Figure 7**. General raft.

**III .4.5 Methods for Constructing shallow foundations**:

The foundation excavations generally have uniform geometric shapes. On their base and before the execution of the foundations, pouring a low-cement-content concrete (150 kg/m$^3$) to a thickness of about 10 cm makes the site cleaner, facilitates the marking of the foundations, and ensures the stability of the formwork. This is the blinding concrete (Figure 8). Generally, for the successful execution of the foundation work, the following points must be ensured.

-The layout of the structure must be carried out in the best possible way.

-The earthworks are done with a mechanical shovel (the manual process is rarely used).

-Excavation work should be avoided during rainy weather.

-Before proceeding with the construction of the foundations, the excavation bottoms must be cleaned out.

-The bottom of the excavation and thus the base of the foundation must be horizontal.

-The top surface of the foundation must also be horizontal.

-Implementation of a cleanliness concrete under the foundation.

-You must ensure the positioning of the rebar to maintain the cover distances

**Figure 8.** Clean concrete at the bottom of the foundation.

**III.4.6 Deep foundations :**

Deep foundations are said to be "deep" when the ratio D/B > 6 or if its depth D > 3m. Deep foundations allow loads to be transferred beyond the surface layers when they are incompetent, by engaging deeper layers. They can be slender (piles) or massive (caissons).

**-The piles :**

The pile is the oldest type of deep foundation. Originally, it consisted of a tree trunk driven vertically into soil too soft to support a shallow foundation. The piles are used to transfer loads to resistant layers located at depth, like columns. We then talk about end-bearing piles. They can also, if the point resistance is very low, mainly rely on the effect of lateral friction. We then refer to floating piles (Figure 9).

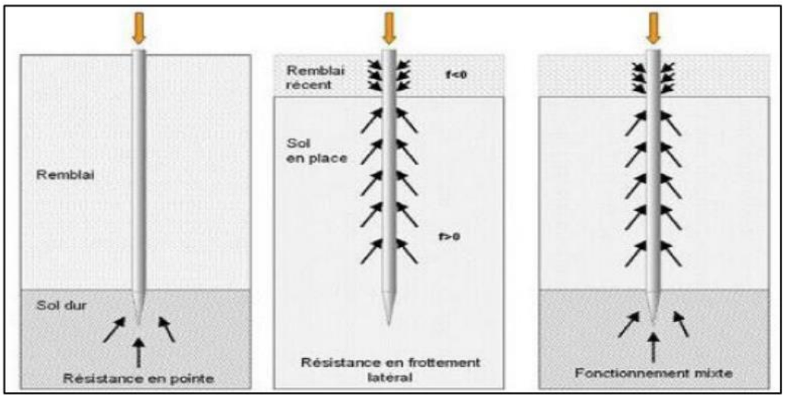


**Figure 9.** Operation of the piles.

Reinforced concrete piles are the appropriate technical solution when the good soil is located at a significant depth (20 m or more), and the construction site is only of medium size. They are grouped in sets of 2, 3, 4, 5, and more, and connected by a very thick footing on the ground. They must generally withstand the effect of vertical loads as well as horizontal or oblique thrusts. Their method of implementation may allow for the consideration of lateral friction. There are two main categories of piles: driven piles and bored piles. However, regardless of the type of pile, its minimum anchorage must be in the layer of good soil; care should be taken to anchor the pile 3 times its diameter in the recommended layer if it primarily functions in point bearing.

Driven piles are prefabricated elements made of wood, reinforced concrete, or metal that are driven into the ground by hammering with a pile driver until a pair of values (penetration, energy) corresponding to the desired mechanical resistance is achieved. The load capacities are around 100 tons for diameters ranging from 50 cm to 80 cm. At the end of the driving process, the cutting of the pile is carried out, which corresponds to the demolition of the concrete located at the upper part (head) of the pile, and their cutting exposes the reinforcements for reworking in the head mass (Figure 10).

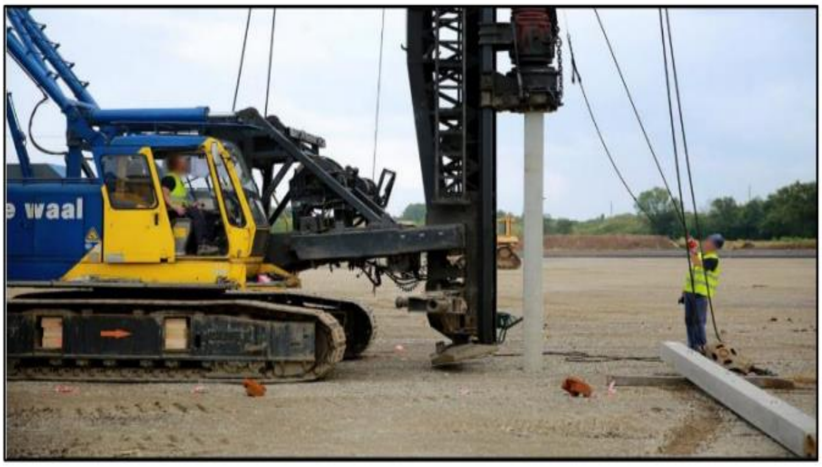


**Figure 10.** Driven pile.

Bored piles are reinforced concrete elements placed inside a pre-drilled hole. Drilling can be done with an auger for loose soils, or with rotary percussion for rocky terrains...) (figure 11).

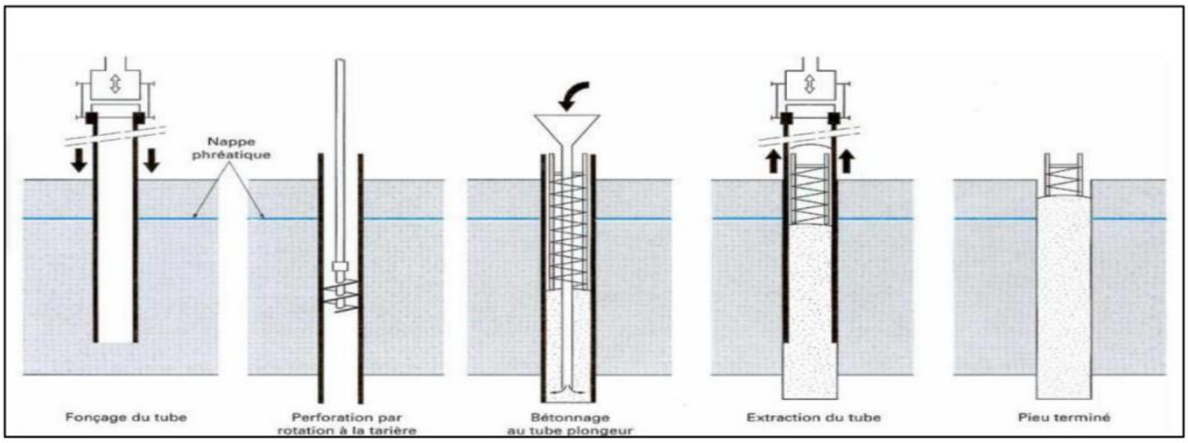


**Figure 11**. Bored pile.

**- The wells:**

A foundation well is similar to a large pillar, which bears heavy loads while resting on the soil resistant at a depth greater than 2 meters. The well foundation is characterized by a diameter larger than that of the pile (around 80 cm at a minimum). During its construction, the well is often supported by a metal casing that will be removed after the reinforcement and concreting. Due to their shallow depth compared to that of piles, wells are sometimes classified as semi-deep foundations (Figure 12). The well foundation solution is chosen if:

- The superficial layer provides insufficient resistance to balance the loads of the superstructure.
- The loads are significant and concentrated.

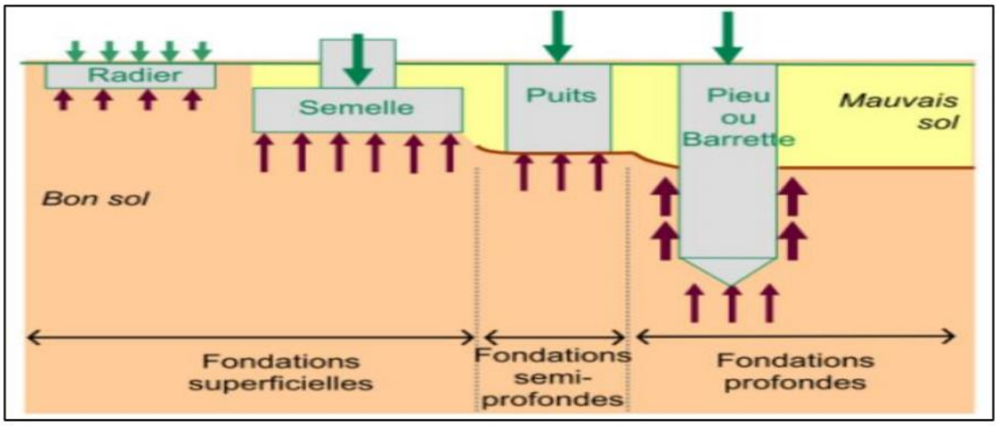


**Figure 12.** Depth of wells compared to other types of foundations.

**III.5 Formwork and reinforcement techniques for building structures :**

**III 5.1 Definition**

Formwork is a temporary construction structure whose shape is used to mold concrete. It can be single-use or reusable (the number of reuse cycles influences the choice of materials and cost).The type of formwork, its shape, and its rigidity are designed according to the structure to be built. At the end of the cycle, the formwork is dismantled and reused.

A detailed study is necessary to design the formwork structure so that its deformation during use remains within acceptable tolerances, and to produce the corresponding drawings (called operating procedures or formwork plans).

**-Role and function of formwork** :

A formwork, whatever it may be, must take into account certain construction provisions and must meet requirements in terms of quality and safety.

-Role

**A formwork must:**

• mold the concrete to give it its final shape,

• provide clean, smooth, and/or architectured surfaces.

**-Function**

Its main functions are:

• Rigidity: Its structure must be able to withstand the pressure of fresh concrete without deforming in order to maintain the desired shape.

• Stability: The formwork must remain in position without the risk of overturning.

• Safety: The workstation must be accessible and protected (guardrails...).

• Sealing: The junction between the different panels must be carefully done to avoid loss of laitance.

• Simplicity: It is designed so that its manufacturing, installation, assembly, and even the formwork removal are as simple and quick as possible in order to reduce implementation costs.

• Durability: Depending on the number of reuses, it will be designed to be more or less robust.

**III.5.2 Different Types of Formwork**

**-Wooden formwork** :Wood is the most commonly used material for formwork. It is economical, easy to saw and nail, which allows for the creation of formwork in various shapes. For slab formwork, thick and rigid boards (beams with a thickness of 27 to 40 mm) are generally used to avoid deformation.

The wood used must be dry, stabilized, and free of tannins. Given that the properties of wood change over time (moisture, wear, porosity), the number of reuse cycles is limited.

For large flat surfaces (walls, slabs), plywood panels covered with a phenolic film (film-faced plywood, waterproof plywood) with a thickness of 16 to 19 mm are used. These panels are ideal for concrete formwork because their smooth surface produces high-quality finishes, and their waterproof coating ensures long durability.

**Figure 13.** Wooden Formwork.

**-Metal Formwork**

Steel formwork is widely used in building construction, suitable for repetitive tasks (walls, slabs, columns, beams, retaining walls, etc.). This allows for efficient concrete placement and optimized formwork/removal cycles.

Although more expensive than wood, metal formwork can be reused many more times. The addition of stiffeners (ribs) makes it suitable for tall and large structures.

**Figure 14.** Metal Formwork.

**-Plastic Formwork :**

Plastic is used to manufacture small modular formwork components for walls, columns, beams, etc. Easy to assemble, these elements are ideal for small construction sites as they can be handled manually without lifting equipment.

For outdoor slabs, an ultra-flexible plastic formwork is available to create slabs with curved edges.

**Figure 15.** Plastic formwork.

### III .5.3 The wall formwork equipment -collapsible formwork

It is a metal formwork tool particularly suited for wall formwork in buildings, as all the equipment is attached to the formwork panel (stabilizers, access ladder, walkway, guardrail, etc.).

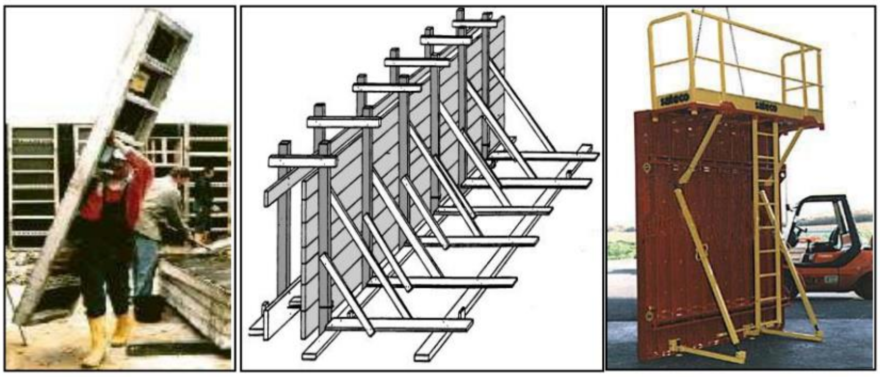

**Figure 16.** Collapsible and portable scaffolding.

**- Public works formwork**

With more varied dimensions, these formwork-tools are mainly used for art structures, as they are modular and more robust.

**Figure 17.** Public Works Scaffolding.

### III.5.4 The formwork material for the columns

**- Metal formwork tools :**

For square or rectangular sections, they can be made up of panels assembled in a windmill wing or in two half-shells. For circular sections, they consist of two half-shells. Each mold corresponds to a single diameter.

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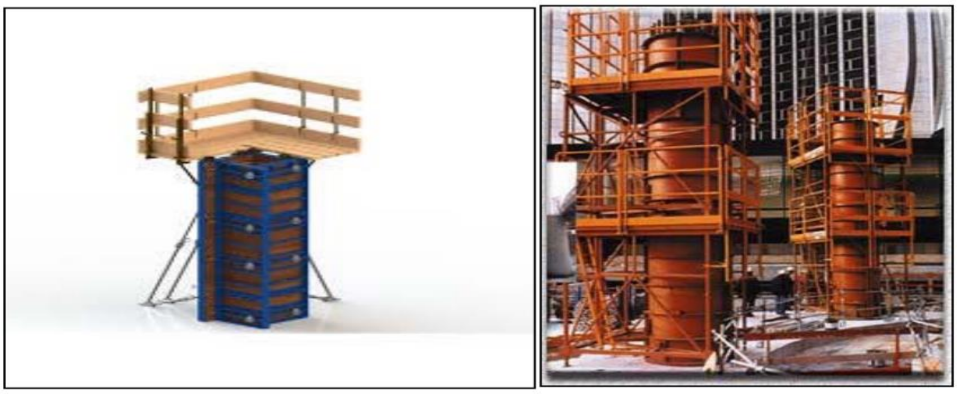

**Figure 18.** Formwork for circular and square columns.

**- The lost cardboard formworks:**

Mainly for circular sections, they are made of a spiraled strip of cardboard. Each mold corresponds to a single diameter.

**Figure 19.** Cardboard formwork.

**- Traditional formworks**

On site, their use is reserved for standard sections (lintels, soffits 20 x 20).

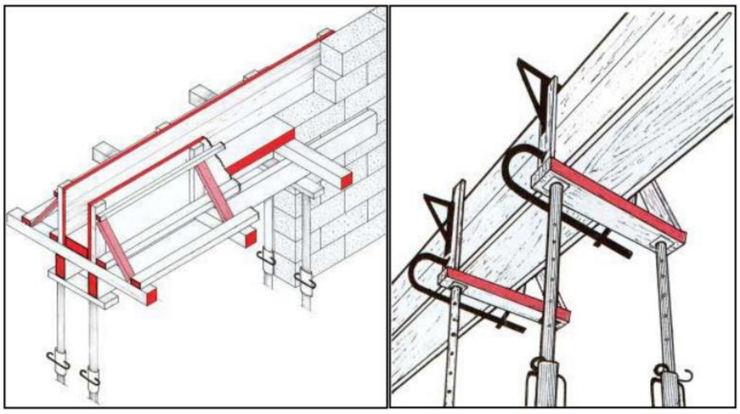

**Figure 20.** Wooden formwork for beams.

**-Traditional formwork**

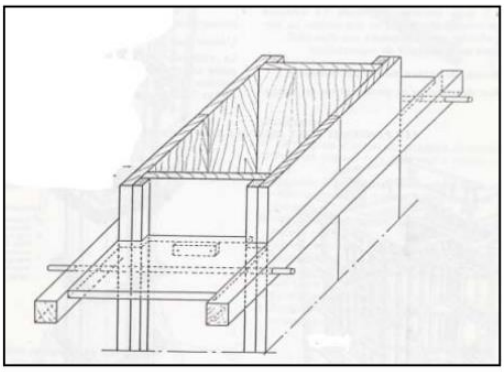

**Figure 21.** Wooden formwork for a medium-sized column.

**III.5.5 The reinforcement:**

The reinforcement refers to the assembly of steel bars or mesh integrated into the concrete to improve its tensile, shear, and flexural strength. Concrete alone is strong in compression but weak in tension, so reinforcement is essential to prevent cracking, bending, or breaking under loads.

The key aspects of reinforcement t include:

**III .5.6 Types of reinforcement:**

Reinforcement bars (Reinforcing bars): Standard steel rods of various diameters, used in beams, slabs, columns, and walls.

**Figure 22**. Reinforcement bars under construction.

-**Metal mesh (mesh reinforcement):** Welded steel grids often used in floor slabs and walls to evenly distribute loads.

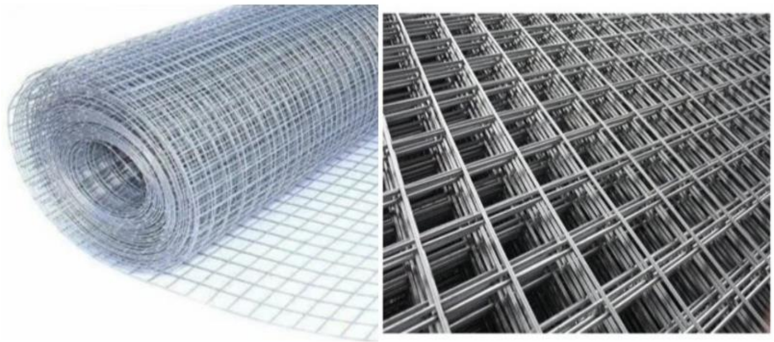

**Figure 23**. Metal lattice (Lattice reinforcement)

**-Prestressing tendons:** High-strength steel cables or bars used in prestressed concrete structures to counteract tensile forces.

**III.5.7 Functions of the reinforcement:**

· Increase the tensile strength of the concrete.

· Control and limit cracks caused by shrinkage or loads.

· Improve ductility, allowing structures to deform without sudden failure.

· Distribute loads safely to prevent structural collapse.

**- Placement principles:**

The reinforcement must be positioned precisely according to the design plans. · An appropriate concrete cover (distance between the reinforcement and the surface) is necessary to prevent corrosion. · The bars can be tied, welded, or supported using spacers and chairs to maintain correct alignment during the pouring of the concrete.

**-Structural Applications Current:**

**Beams:** The reinforcement resists bending and shear forces.

**Slabs:** The reinforcement distributes the loads and controls the cracks.

**Columns:** The reinforcement ensures axial load capacity and stability.

**Walls:** Reinforcement provides lateral strength and prevents cracks.

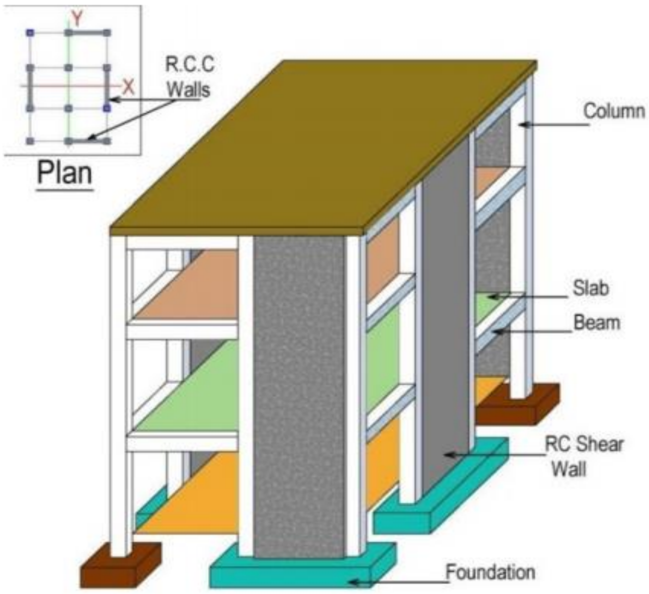


**Figure 24**. Structural Elements.

**-For horizontal structures :**

· The longitudinal tensile reinforcement strengthens the tensile zone.

· The longitudinal compression reinforcement strengthens the compression zone.

· The transverse reinforcement (stirrups and ties) connects the longitudinal bars and resists shear forces.

· Additional bars are added to the longitudinal reinforcement for long-span beams or those supporting heavy loads.

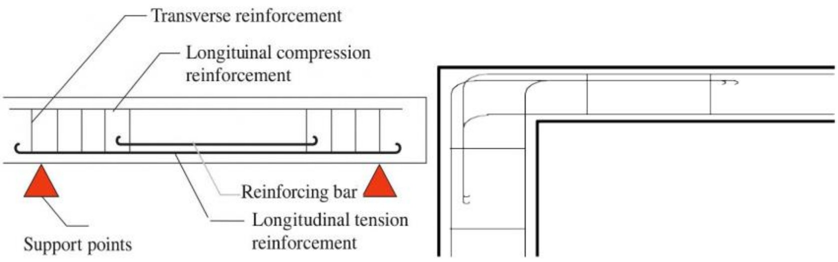


**Figure 25**. Reinforcement of the beam.

**At corners :** The reinforcement should never be placed along the inner face of an inward corner. The bars must extend to the reinforcement of the outer face.

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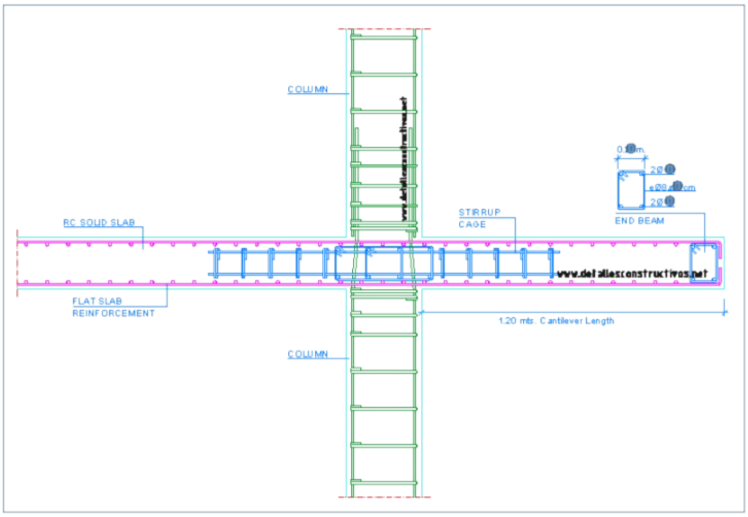


**Figure 26.** Reinforcement of the solid slab and columns For the columns.

·The columns support vertical loads and transfer them to the foundation. ·The continuity of load transfer is ensured by longitudinal reinforcement connecting the different structural elements.

· The longitudinal bars placed at the corners resist tension on each face.

· The transverse reinforcement maintains the spacing of the bars and prevents lateral expansion.

· The starter bars left at the top of the columns or the dowels placed during the pouring of the foundations or level beams allow for the connection and ensure the linkage with the reinforcement of the upper element.

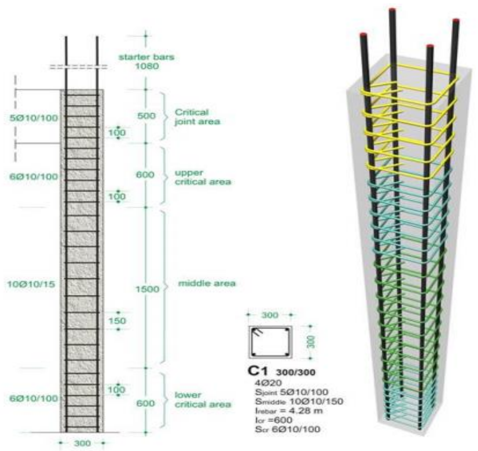


**Figure 27.** Reinforcement of the column.

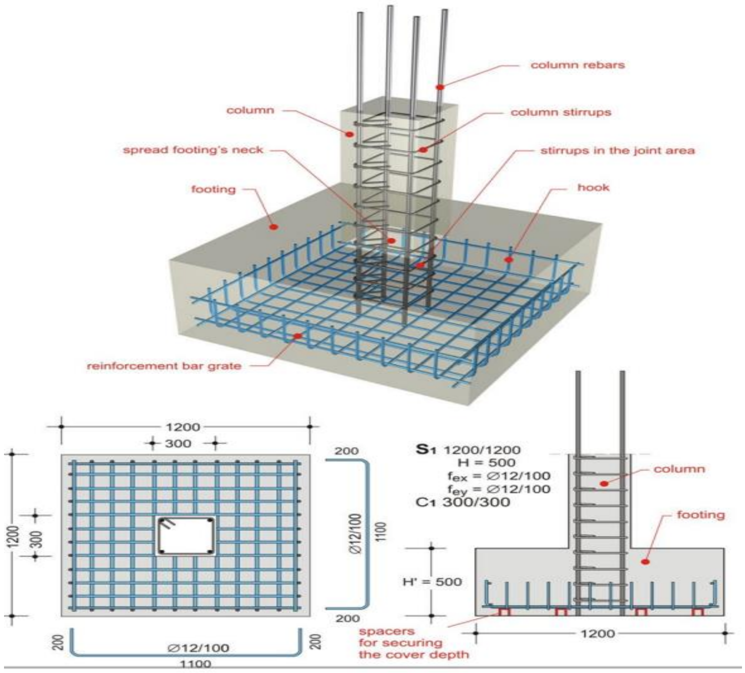


**Figure 28.** Foundation reinforcement.

# CHAPTER IIII.

# METAL AND COMPOSITE STRUCTURES

# CHAPTER IV. METAL AND COMPOSITE STRUCTURES

## IV.1 Choice of the metallic solution:

Two traditions coexist in construction:

• the frame solution (wooden frames, then iron and steel, then reinforced concrete);

• the wall solution (masonry, then formwork concrete and load-bearing panels). The metallic solution presents the characteristics related to the first: freeing the plane and concentrating the loads. This first fundamental choice, once made, should not be forgotten in the subsequent stages of the study, in order to retain its advantages while reducing its disadvantages. The framework provides bracing without using weight (the infill may not be permanent); the loads transmitted at specific points must be distributed more or less widely depending on the soil's resistance.

The partitions (facades, partitions, roofs, floors) must be provided by the finishing work. These characteristics being common to all frame solutions, let's review the advantages and disadvantages of the metallic solution.

## IV.2 Connection in Steel Building Structures :

Steel structures of buildings are composed of different types of structural elements that must each be properly connected to the surrounding parts of the structure. This requires the use of various types of connections. The main classes of connections are:

- Connections involving a change of direction: beam-to-column connections, beam-to-beam connections, and connections between truss elements.
- Connections required due to transportation and erection limits: the lengths of structural elements are limited for transportation and assembly; columns, for example, are generally assembled every two or three floors.
- Connections between different types of elements, including connections between the steel structure and other building components such as column bases, connections to concrete cores, panels, floors, and roofs.

Figure 1 shows examples of connections found in a multi-story building.

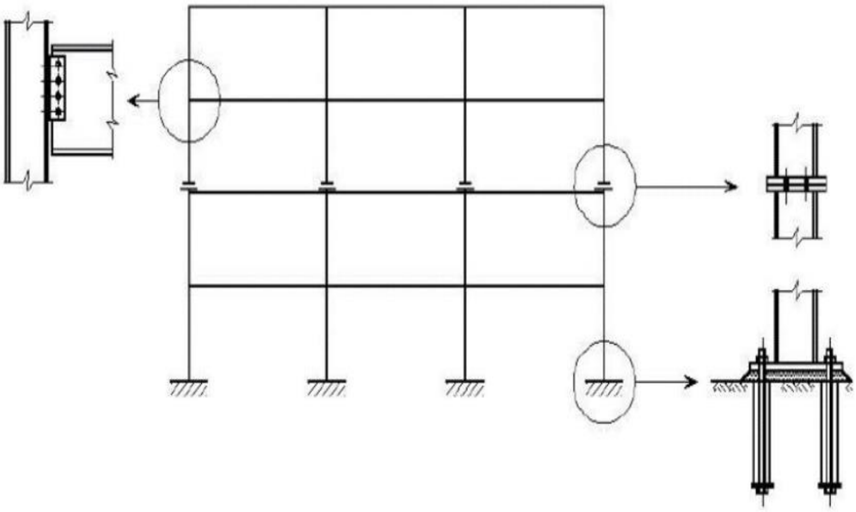

**Figure 1.** Connections found in a multi-story building.

### IV.3 Advantages of metal construction

**IV.3.1 Prefabrication Factory prefabrication (common in metal construction)** leads to significant time savings on the construction site. However, this gain is not as significant in the overall schedule unless the other parts of the work follow a similar pace, which implies:

• extensive preliminary studies, avoiding improvisations on the site;

• coordination of the choices and final adjustments of the secondary work and equipment elements, in relation to the framework.

**IV.3.2 Lightness**:

The self-weight of metal frameworks has little impact on strength calculations, but this advantage is only significant to the extent that the other parts of the structure are themselves quite weight-efficient. Traditional heavy masonry and concrete solutions for infill are not always very suitable for the metal solution. Lightness provides a definite advantage in cases of difficult soils (by avoiding or reducing deep foundations), or when the infrastructure (often in concrete) must undergo local flexing, or finally in the case of large spans, where weight becomes the main enemy.

**IV .3.3 Architecture Structural**

Expression is favored by frame structures, particularly those made of steel, whose great variety of solutions and forms (both overall and detailed) is a preferred tool for the architect. Among the frameworks, those made of steel are characterized by their great lightness of appearance (to the point that it can sometimes

Necessary to enlarge certain sections that might cause concern, without necessarily increasing the amount of steel).

**IV.3.4 Wide variety of solutions Numerous solutions** :

Both in general structural components and in details, are always available in metal construction, some of which take advantage of the combination of steel with other materials (especially concrete). This variety, which allows for a close adaptation to the specific requirements of the functional program and the economy, is immediately reflected in architectural terms to the extent that the structure remains visible or at least is indicated in the finished building.

**IV.3.5 Ease of transformations**

Metal frames lend themselves well to transformations:

• thru the standardization of spaces allowed by the frame solution;

• thru the possibilities of transforming the frame itself, which can be cut and welded in position, albeit with precautions.

This advantage is well known to industrialists, whose buildings constitute the vast majority of metallic construction manufacturing.

It can be noted that the demolition cost of a metal-framed building is often entirely offset by the residual value of the recovered materials, which is quite exceptional.

- Low bulkiness

The thin sections of steel frames (due to the high strength characteristics of this material) offer several advantages:

• maximum openings to daylight and views, in facades and roofs;

• minimal clutter inside the premises (the gain in free surface has been calculated, which in certain situations leads to a considerable number of heavy francs);

**IV.4 Disadvantages of metal construction**

As is customary, the disadvantages corresponding to the advantages of any solution are found.

**IV.4.1 Prefabrication**

This method requires a high level of organizational rigor, with preliminary studies (before manufacturing, allowing a certain lead time before any element arrives on site) that are important and carefully organized, in coordination among all trades. The regrets of the project manager during site meetings are to be avoided here, or at least must to be carefully considered (this then involves transformations after construction and no longer adjustments).

**IV.4.2 Lightness**

In the case of tall buildings, overturning forces due to wind can cause, at the base of certain columns, uplift values greater than the minimum dead loads due to the lightness of the structures and the accompanying works.

### IV.4.3 Wide Variety of Solutions

It is often difficult to know in advance, among several solutions to the same problem, which one will be the most economical. It indeed depends on the specific working conditions unique to each manufacturer: equipment, machines, methods, techniques, etc.

### IV.4.4 Insulations

Acoustic and thermal insulation can be ensured in a metal-framed building, despite drawbacks such as lightness (mass law) and thermal conductivity (facade frames), provided that specific solutions are sought and that one does not strictly adhere to traditional methods that are relatively better suited to other construction types.

## IV.5 Classic Beams

The section of these beams, also called a double T profile, consists of two flanges or webs whose outer faces, which are parallel, connect in the middle to a perpendicular web thru two filets (connections). These profiles come in several types: IPN, IP, and HE.

The height of commercial profiles generally ranges between 80mm and 600mm. These profiles are designated by their name followed by an integer equal to or close to their height in mm, e.g., IPE 300 (h=290mm). The delivery lengths for profiles less than 300mm are from 8m to 18m. For profiles of 300mm and above, they range from 8m to 22m.

### IV.5.1 IPN Profiles

The inner face of the flanges is inclined at 14% relative to the outer face. Their heights range from 160 to 600mm. These profiles are no longer manufactured.

### IV.5.2 IP Profiles

The inner faces of the flanges of these profiles are parallel to the outer faces. The most commonly used IPE profiles, the IPE-A (lightweight) profiles, and the IPE-O (reinforced) profiles are distinguished.

### IV.5.3 HE Profiles (European wide-flange beams)

These profiles have very wide parallel flanges compared to I-beams. They come in several categories according to the increasing thickness of the flanges: HEA, HEB, and Hem. We now manufacture HHD profiles that have very large web and flange thicknesses.

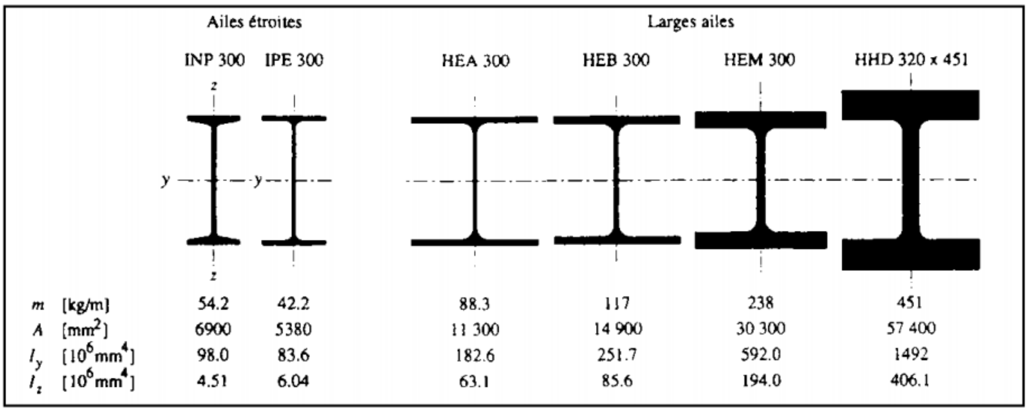


**Figure 2.** Example of double T profiles Tee.

**-Usage**

IPN and IPE profiles are primarily used as flexural elements (floor beams, roof purlins) because their moment of inertia Iy is large compared to the moment of inertia Iz. H-beams are mainly used as elements that are both compressed and bent (columns) because the ratio between the moments of inertia is less unfavorable than with I-beams. They can also be used as flexural elements.

**IV.5.4 U-Profiles**

They are composed of a web and two flanges connected to the web at one end. They come in two types: UPN, which are no longer manufactured, and UAP. Their height ranges between 80mm and 300mm. They are designated by their name followed by an integer indicating the height of their section: UAP 300, UPN 100. The inner faces of the flanges of UPNs are inclined at 8% relative to the outer faces, while the flanges of UAPs have parallel faces. UAP profiles are used as roof purlins, cladding battens, bracing bars, and components of trusses and posts.

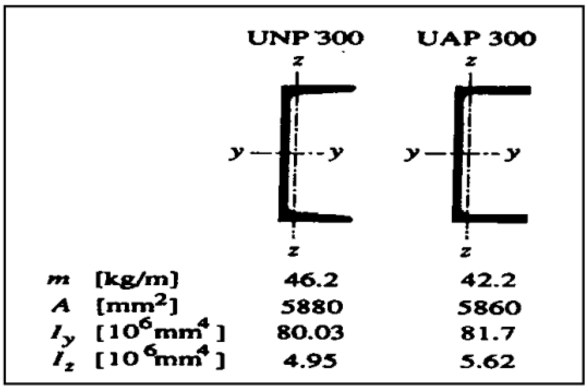


**Figure 3.** Examples of U-profiles

**IV.6 Merchant bars**

**- Les cornières** Ce sont des laminés à deux branches perpendiculaires. Elles se désignent par la largeur des deux ailes et leur épaisseur. Les cornières sont de deux types.

• À branches ou à ailes égales

• A branches ou à ailes inégales

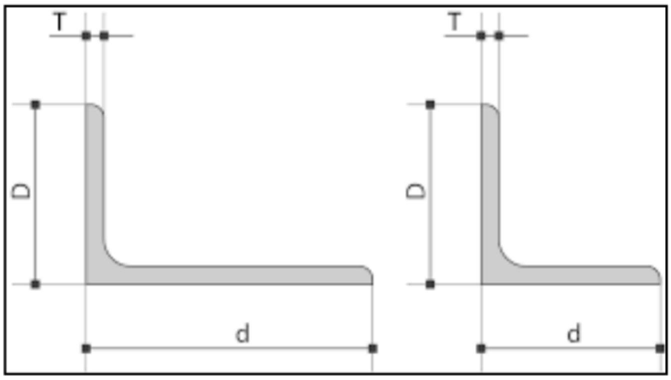


Figure 4. Examples of angles.

**Angles are generally used as:**

• Beam bars or truss girders, truss columns,

• Structural elements such as assembly supports,

• Connecting elements in old riveted constructions

**-Other products**

- Half-beams These are IP or HE profiles cut in the web at its midpoint (h/2). These half profiles are sometimes used as web members of truss beams or elements of composite columns.

-Special profiles They come in a very large number of shapes and dimensions and are used in very diverse fields. They are most often of small section and include:

• Equal leg or unequal leg angle brackets.

• The T-sections with sharp angles, either equal-winged or unequal-winged.

**- The circles**

They have a circular section and are designated by the diameter of this section. They can be used as truss bars, bracing, and ties.

**- The tubes**

These include round hollow profiles with diameters ranging from 21.3mm to 406.4mm, square hollow profiles with an outer dimension C ranging from 22mm to 300mm, and rectangular hollow profiles with dimensions ranging from 50x25 to 400x250mm.

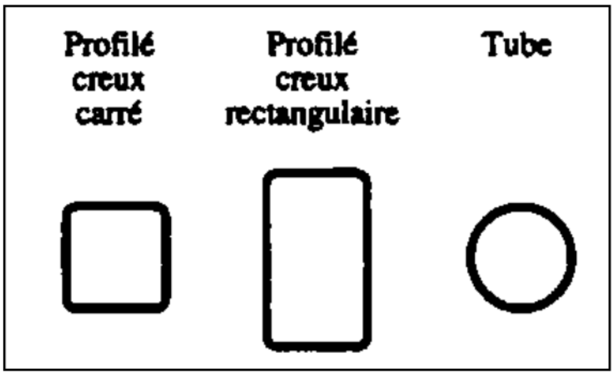


**Figure 5.** Examples of tubular profiles.

## IV.7 CONNECTION COMPONENTS

The connections of steel structures are generally made by welding and/or bolting.

### IV.7.1 Welding

Although different types of welds are possible, normally preferred over flat welds (Figure 6) because they require minimal preparation of the parts to be assembled, can generally be performed with relatively simple equipment, and do not require any particular skill from the welder.

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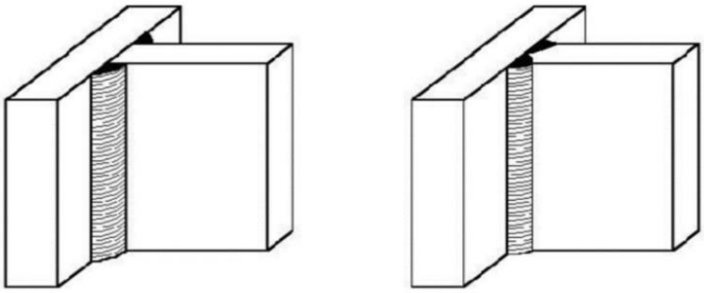


**Figure 6**. Different types of welds.

### IV.7.2 Bolting

Bolting is a mechanical assembly method that can be disassembled. Bolts are used to create continuity between elements or to ensure the complete transfer of forces from one part of a structure to another.Structural steel bolts are commonly used for lightly loaded connections in halls and buildings. High-strength bolts are generally used for bridge connections, heavily loaded connections, or connections subjected to dynamic effects. Only high-strength bolts can be pre-tensioned.

For any type of bolt, the normal clearance between the bolt shaft and the hole in the parts to be assembled is:

- $d_0 = d + 1$ mm for $d \leq 14$

- $d_0 = d + 2$ mm for $d \leq 24$ mm
- $d_0 = d + 3$ mm for $d \leq 27$ mm

In some cases, a smaller clearance may be necessary. Bolts with only 0.3 mm of play are called fitted bolts.

They offer connections with minimal relative movement, creating structures with very low deformability. However, the manufacturing of the holes must be extremely precise, which significantly increases the cost.Therefore, fitted bolts are only used when absolutely necessary.

The following figure shows the different components of a structural bolt and a high-strength bolt. High-strength bolts are distinguished from ordinary structural bolts by the quality mark stamped on their heads and washcloths. A washer must always be placed under the part that will turn during tightening (usually the nut, sometimes the head, often both).

The following figure shows the different components of a structural bolt and a high-strength bolt. High-strength bolts are distinguished from ordinary structural bolts by the quality mark stamped on their heads and washcloths. A washer must always be placed under the part that will turn during tightening (usually the nut, sometimes the head, often both).

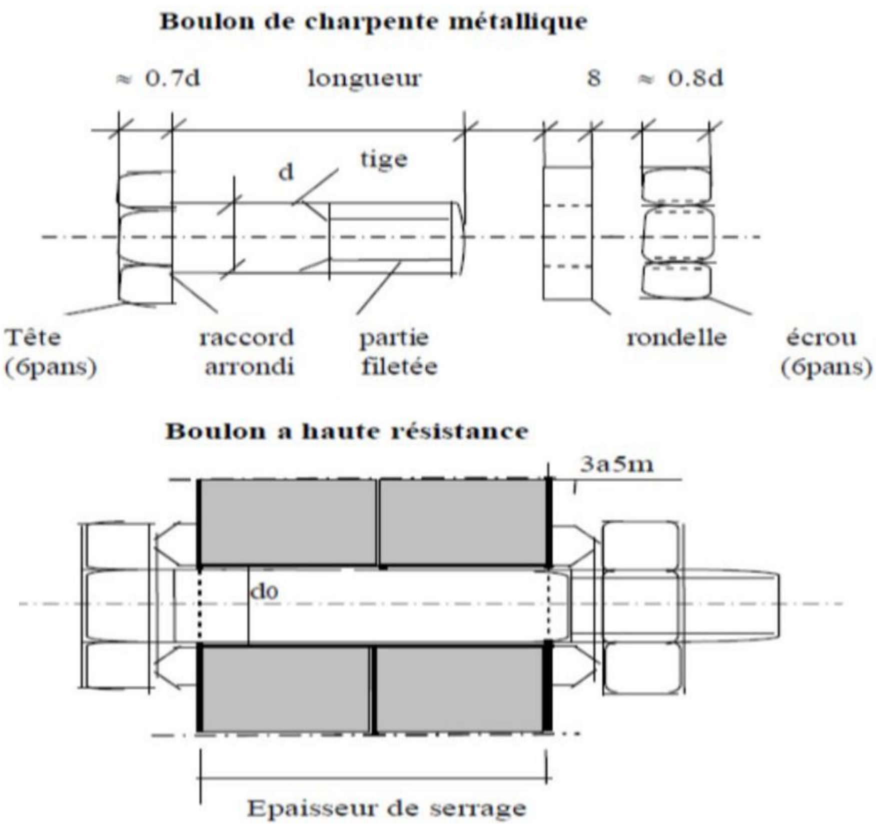



**Figure 7.** Structural bolt and high-strength bolt.

## IV.8 Types of connections

In multi-story structures, the connections between the main elements can be practically classified as follows:

· beam-to-beam connections

· beam-to-column connections

· column splices

· column bases

· bracing connections

**- Simple beam-column connections**

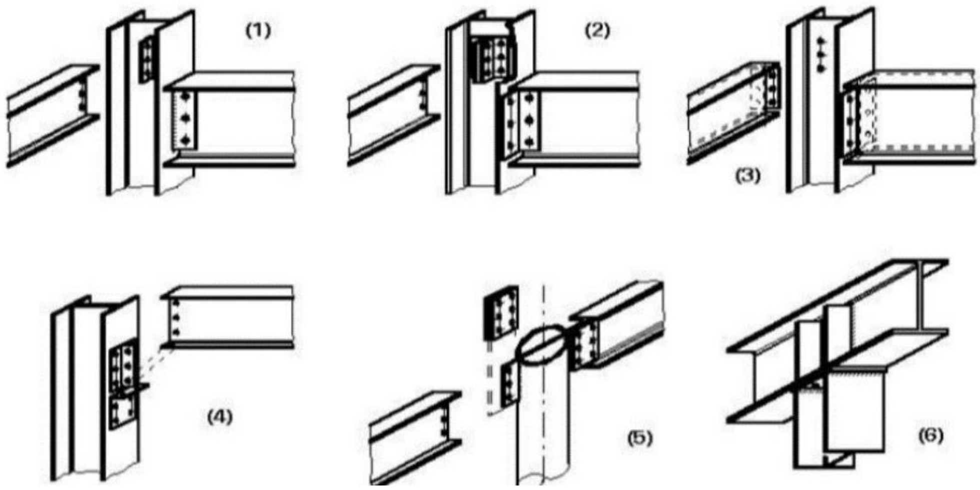



**Figure 8**. Simple beam-to-column connections.

**Figure IV .8.1**: Connection using a thin plate welded to the column; the beam is connected on one side only.

**Figure IV .8.2**: Bolted angle connection. Alternatively, the angles can be welded to either of the flanges.

**Figure IV. 8.3:** Short flexible end plate welded to the beam.

**Figure IV. 8.4**: Bolted angle connection. The horizontal angle provides additional support.

**Figure IV .8.5:** If the wall of the tube is thick, the plates can be welded directly without notching the tube.

**Figure IV. 8.6:** The rigidity largely depends on the thickness of the terminal plate of the column and the web of the beam. Stiffeners can be omitted in many cases.

**-Connections resistant to beam-column moment:**

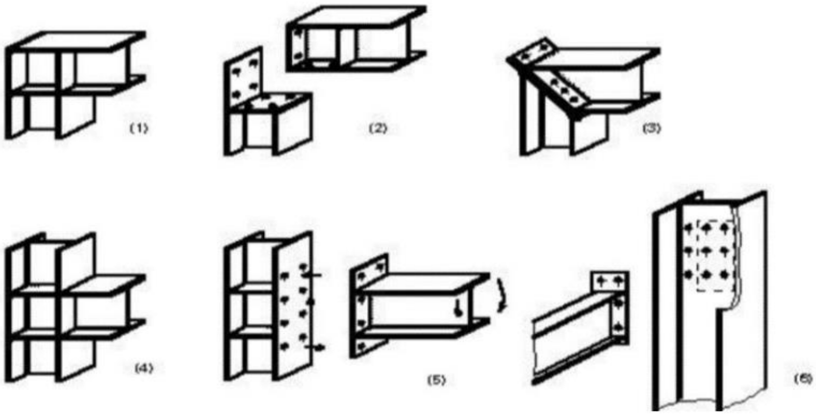


**Figure 9.** Moment-resistant beam-column connections

**Figure IV.9.1 :** Fully welded connection.

**Figure IV.9.2 :** Bolted angle connection.

**Figure IV.9.3 :** Bolted connection with welded end plate.

**Figure IV.9.4 :** Welded T connection.

**Figure IV.9.5 :** Bolted T Connection.

**Figure IV.9.6 :** Bolted end plate connection. Another beam is supposed to be connected on the other side of the column web.

**- Simple beam-to-beam connections**

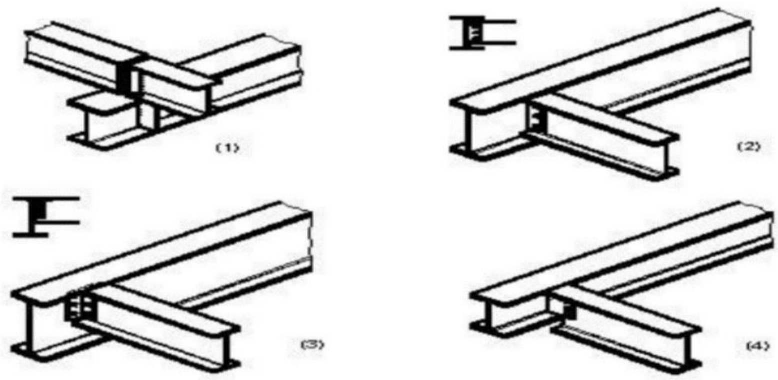


**Figure 10**. Simple beam-to-beam connection.

**-Figure IV.10.1**: Depending on the geometry and loads, stiffeners may or may not be necessary. This connection is inexpensive but has a greater depth compared to the other solutions in Figure 10.

- Does not require cutting the secondary beam, making it cheaper than Figure **IV**.10.3. Does not require cutting the secondary beam, which makes it cheaper than Figure **IV** 10.3.

**Figure IV.10.3**: Upper flanges aligned. The bevel makes it more expensive than Figure **IV**.10.2. **IV**.10.4 The connection beam has a greater depth than the main beam. Economical to manufacture; the hinge is located at the weld between the plate and the web.
- Moment-Resistant Connections between Beams Moment-Resistant Connections between Beams

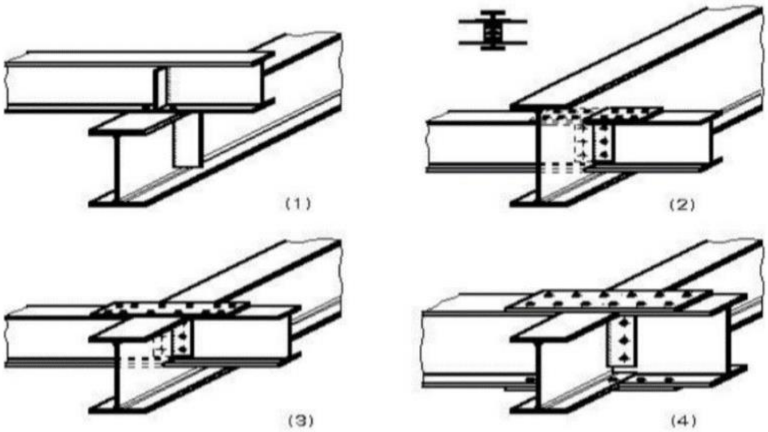



**Figure 11.** Moment-resistant beam-to-beam connection.

**Figure IV.11.1**: Similar to Figure 11.1, Stiffeners should be avoided as much as possible. **Figure IV.11.2**: The tension in the top flange is transferred thru a cover plate passing thru an opening in the web of the main beam. Small blocks can help transmit compression in the compressed zone.
**Figure IV.11.3**: Requires a fixed support, similar to the Figure. **Figure IV.11.4**: The two beams have identical depths.
- Jonctions de colonnes

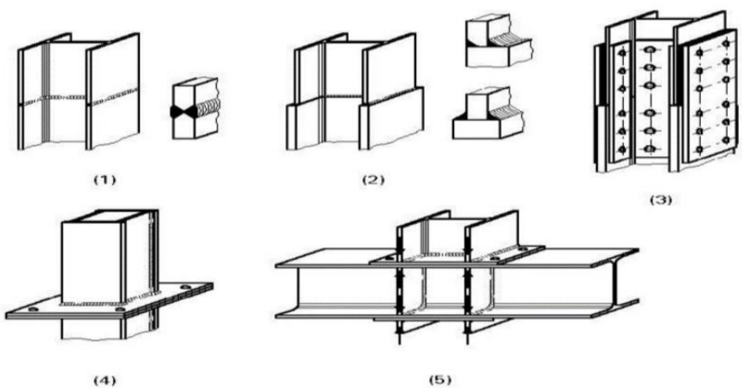



**Figure 12**. Column nuts.

**Figures IV.12.1 IV.12.2:** Welded joints. When the plate thicknesses differ, corner welds are more economical. Welding is not ideal for on-site assembly.

**Figure IV.12.3:** Bolted connection plates. Vertical loads can be transferred by direct contact and/or thru the connection plates. These plates also transfer bending moments and shear forces. The shims are used for different flange/web thicknesses.

**Figure IV.12.4:** A commonly used type of joint. After workshop welding, the plates may not be perfectly flat but generally do not need to be straightened.

**Figure IV.12.5:** In certain situations, it is desirable to make the beam continuous. Reinforcement at the base of the column is necessary for force transfer and stability.

**- Column Bases**

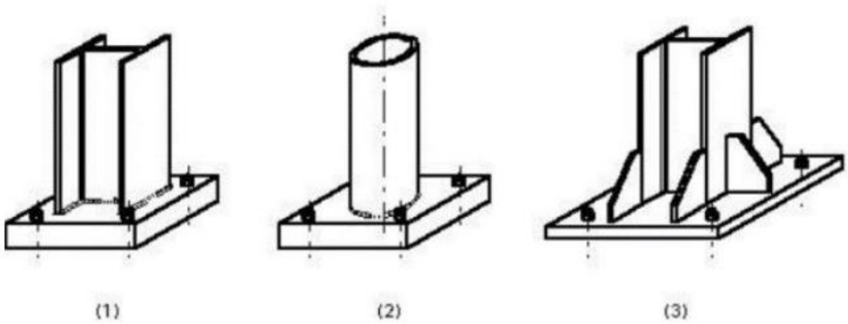



**Figure 13**. Bases de colonnes.

**Figures IV.13.1 & IV.13.2 :** For thick base plates, no stiffeners are required. Usually the most economical solution.

**Figure IV.12.3** : Thin stiffened plates used in the past.

**-Connexions de Contreventement Horizontal.**

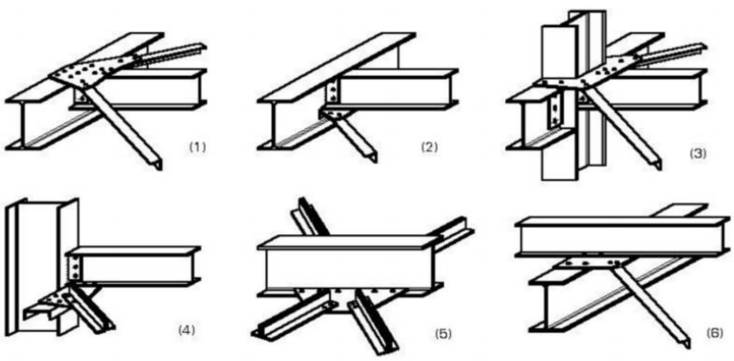



**Figure 14.** Horizontal bracing connections.

**Figures IV.10.1, IV.10.2, IV.10.3:** The assembly plates located on the upper flanges can pose problems when using metal roofs or floors.

**Figures IV.10.4, IV.10.5, IV.10.6:** The U-profile in IV.10.4 is required as a chord member of the horizontal truss.

**- Conexiones de Arriostramiento Vertical**

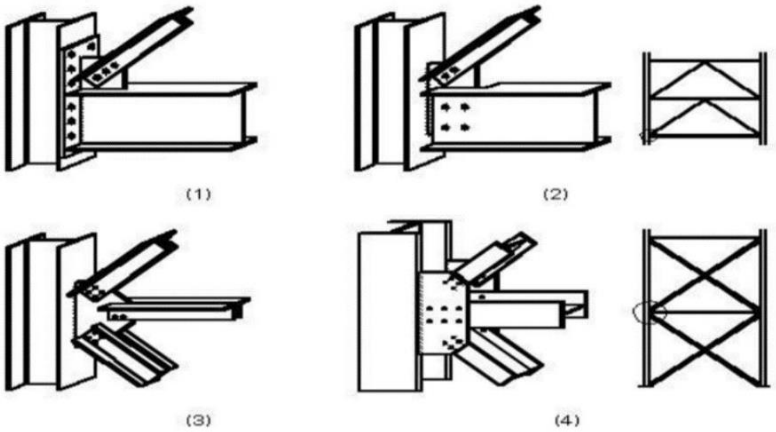



**Figure 15**. Vertical Bracing Connections

# Chapter V.

# Introduction to the Different Regulations

# Chapter V. Introduction to the Different Regulations

## V.1 Introduction

The calculation rules are designed to ensure the safety and longevity of structures. They specify the maximum level of actions that can be exerted on a structure during its period of use. This level is achieved by taking into account in the calculations the characteristic values of the actions and safety coefficients that increase the stresses resulting from these actions. Moreover, the actions applied to the structure lead to effects on the structure: forces and deformations, which result in stresses (bending moment, normal force, shear force, etc.), to which the materials composing the structure must resist. For each limit state, for each section of the studied structure, it must be shown, for the most unfavorable load case under the considered action combination, that the acting solicitation does not exceed the material's resistance. The general objective of the design of structures is to:

- know the principles of regulation based on limit state design,
- know the existing regulations,
- be able to calculate the main actions exerted on Civil Engineering structures, permanent loads, operational loads, snow loads, and wind loads, etc.
- know how to evaluate the loads acting on the different elements of a structure.

## V.2 NOTIONS ON THE DESIGN AND EXECUTION REGULATIONS FOR CONSTRUCTIONS IN ALGERIA

### V.2.1 Concepts on Building Design Regulations in Algeria

**V.2.1.1 Permanent loads and operational loads (DTR-BC 2.2)** This document addresses the "permanent loads" and "operational loads" of buildings, their evaluation methods, and the values of these loads to be included in the calculations.

**V.2.1.2 Algerian Seismic Rules "R.P.A 99 / version 2003"** (DTR-BC 2.48) The technical document "DTR BC 2.48" concerning the "ALGERIAN SEISMIC RULES RPA 99" which was approved by the permanent technical commission for technical construction control (CTP). This regulation is organized as follows:

- More precisely define the purpose of the RPA
- Further specify the scope of application of the RPA
- Specify the objectives and levels of seismic protection sought for the different categories of constructions that fall within the scope of application of the RPA.
- Describe the seismic design principles to be followed prior to any calculations (site selection, layout, etc.).

• Review the different classifications (seismic zoning, sites and soils, categories of structures).
• Further specify the criteria for plan and elevation regularity of constructions.
• Identify the structural systems commonly used in Algeria.
Specify the criteria for choosing the method of calculating seismic forces (equivalent static method, spectral modal analysis method).
• Describe the equivalent static method with the modifications made to the different parameters.
• Describe the spectral modal dynamic method.
• Describe the safety criteria to be justified for the structure to be considered earthquake-resistant (bracing system, secondary elements, and non-structural elements).
• provides the construction provisions related to reinforced concrete, steel, and load-bearing masonry structures.
• Consider a chapter on foundations and retaining walls (foundations, liquefaction, slope stability, retaining walls)

**V.2.1.3 The design and calculation rules for reinforced concrete structures C.B.A 93 (DTRBC 2.41)**

The design and calculation rules for reinforced concrete structures, abbreviated as "C.B.A 93," aim to specify the most current principles and methods to govern and serve the design and verification calculations of reinforced concrete structures and works, and they specifically apply to common buildings.

**V.2.1.4 Design and Calculation Rule for Steel Structures "CCM 97":** (DTR-BC 2.44)

This regulatory technical document aims to codify the design calculations and verifications of steel-framed building structures. The regulation only defines the requirements related to mechanical resistance, serviceability, and durability of the structures.

**V.2.1.5 Design and sizing of steel-concrete composite structures :** General rules and rules for buildings (DTR-BC 2-4.10)

This regulatory technical document constitutes a general basis for the design and calculation of mixed structures and structural elements for buildings and civil engineering works. Mixed structures and structural elements are composed of construction steel and reinforced concrete bonded together to withstand loads.

**V.2.1.6 The design and calculation rules for cast-in-place concrete walls and panels (DTR-BC 2.42)** The document defines the calculation rules applicable to cast-in-place concrete walls and partitions of all buildings, regardless of their purpose: residential, office, school, hospital, industrial, commercial, etc. It also provides guidance on the design of certain cast-in-place concrete walls and partitions so that the various functions these walls and partitions must fulfilll in a typical building can be adequately and durably ensured.

**V.2.1.7 Rules for calculating shallow foundations (DTR-BC 2.331)** This document provides the loads to be considered, depending on the case studied, and the checks to be carried out to ensure the stability of shallow foundations and the safety of the structures.

## V.3. THE BAEL CODE

### V.3.1 Definition and Historical Context

BAEL stands for "Béton Armé aux États Limites" (Reinforced Concrete at Limit States). It is a French design code developed for the calculation of reinforced concrete structures based on the limit state design philosophy.

Several versions of BAEL have been published, with the BAEL 91 version (revised in 1999) being the most widely used at the end of the 20th century. BAEL has been mainly applied in France and in French-speaking countries for: · Buildings (beams, slabs, columns, walls).

· Certain types of civil engineering works (foundations, retaining walls, etc.), often in combination with other specific recommendations.

### V.3.2 Scope and Main Principles

BAEL provides, in particular:

· Rules for material properties

· Characteristic compressive strength of concrete.

· Characteristic yield strength of the reinforcement steel.

· Design values of material strengths, obtained by dividing the characteristic values by the appropriate partial safety factors.

· Design situations and load combinations, generally with reference to distinct standards for actions.

· Ultimate limit state checks for bending, shear, torsion, and the combination of bending and axial force.

· Serviceability limit state criteria for cracks, deflection, and stress limitations.

The design procedure according to the BAEL generally involves:

1) Define the geometry and the structural system.

2) Evaluate the design actions (bending moments, shear forces, axial forces).

3) Choose the materials and preliminary sections.

4) Verification of ULS and SLS according to BAEL formulas and detail rules

### V.3.3 Transition to Eurocode 2

With the development of the Eurocodes, the BAEL is gradually being replaced by Eurocode 2 (EN 1992), which serves the same function but within a harmonized European framework. Although the general design philosophy (limit states and partial coefficients) remains similar, Eurocode 2:

· Introduces a more comprehensive treatment of durability and environmental exposure classes.

· Harmonizes the notations and partial coefficients with the other Eurocodes.

· Provides more detailed rules for specific structural elements and advanced topics.

In teaching, the BAEL is always useful for illustrating traditional French practice and for comparing it with the modern approach of the Eurocode.

## V.4 THE EUROCODES

### V.4.1 Objectives and Philosophy

The Eurocodes are a set of European standards for the structural design of buildings and civil engineering works. Their main objectives are:

· To provide a common technical basis for design across Europe.

· To eliminate technical barriers to trade and support a single European market for construction products and services.

· Ensure a uniform level of structural safety and reliability. · Facilitate innovation and performance-based design.

The Eurocodes adopt a limit state design and a partial coefficient format, in accordance with modern reliability theory. They distinguish between:

· Ultimate limit states (ULS): safety against collapse, instability, fatigue failure, etc.

· Serviceability limit states (SLS): comfort, appearance, and proper functioning.

## V.5 Structure of the Eurocodes

The Eurocodes are organized into ten main standards:

· EN 1990 – Eurocode 0: Basis of Structural Design EN 1991 – Eurocode 1: Actions on structures

· EN 1992 – Eurocode 2: Design of concrete structures

· EN 1993 – Eurocode 3: Design of steel structures

· EN 1994 – Eurocode 4: Composite steel and concrete structures

EN 1995 – Eurocode 5: Design of timber structures

· EN 1996 – Eurocode 6: Design of masonry structures

EN 1997 – Eurocode 7: Geotechnical design

EN 1998 – Eurocode 8: Design of structures for earthquake resistance

EN 1999 – Eurocode 9: Design of Aluminum Structures

Each Eurocode is divided into parts (for example, EN 1992-1-1 for general rules and buildings, EN 1992-2 for bridges, etc.).

A key feature is the presence of Nationally Determined Parameters (NDP), which allow each country to adapt certain numerical values (such as partial coefficients or climatic data) thru a National Annex, while maintaining the common general rules.

**V.6 Eurocode 2 and comparison with the BAEL**

Eurocode 2 (EN 1992) covers the design of reinforced concrete and prestressed concrete structures, including buildings, bridges, and certain other types of works.

Compared to the BAEL, Eurocode 2:

· Uses similar fundamental concepts:

· Characteristic strengths of concrete and steel

Design values obtained using partial coefficients (for example, gammaC for concrete and gammaS for steel).

· Verification of the ULS and SLS.

· Provides more explicit rules for: · Durability (coating, crack width limits, exposure classes).

· Minimum reinforcement for ductility and crack control.

· Shear and punching design in slabs.

· Long-term effects such as creep and shrinkage.

Eurocode 2 is intended to be consistent with the other Eurocodes (for actions, geotechnics, seismic design), allowing for a comprehensive and coherent design of complex projects.

For students and young engineers, learning the Eurocodes means acquiring a transferable skill recognized in many European and international contexts.

**V.7 CONCLUSION**

Structural design codes and standards are at the heart of civil engineering practice.

They are essential for:

· Ensuring the safety, functionality, and durability of structures.

· Providing rules and a common language among all actors in the construction sector.

· Ensuring that lessons learned from past failures are not forgotten. In the French and European context:

· The BAEL represents the traditional national code for reinforced concrete design based on limit states.

· The Eurocodes, and in particular Eurocode 2, represent the modern and harmonized framework used today and in the future.

A solid understanding of the general principles of the regulations, as well as the logic and structure of the BAEL and Eurocodes, is essential for any civil engineer who wishes to design safe and efficient structures in a professional environment.

# Chapter VI.
# Algerian Seismic Regulations RPA 2024
# (General design rules for seismic zones, criteria for classification of structures)

# Chapter VI. Algerian Seismic Regulations RPA 2024 (General design rules for seismic zones, criteria for classification of structures)

## VI.1 INTRODUCTION :

Earthquakes are among the most critical natural hazards for the built environment. In a matter of seconds, a strong earthquake can cause the collapse of buildings, bridges, and essential service networks, with severe human and economic consequences. Unlike gravity or wind, seismic actions are highly dynamic, cyclical, and uncertain.

Their effects depend heavily on local soil conditions and the dynamic properties of the structures. For these reasons, the design of buildings and civil engineering structures in seismic regions must follow seismic design regulations based on scientific knowledge, lessons from past earthquakes, and an acceptable level of risk agreed upon by society.

The Regulatory Technical Document "D.T.R-BC 2.48" on the "ALGERIAN SEISMIC STANDARDS RPA 2024," which was approved by the Permanent Technical Commission for Technical Control of Construction (CTP) during its meeting on May 15, 2024, represents an evolution and continues the lineage of previous documents: "RPA 81, version 1983," "RPA 88," "RPA 99 and its 2003 version."

In fact, it aims to be an update that has become necessary after nearly two decades of rich and diverse practices by national scientists and technicians from study and control offices, companies, and higher education institutions.

This update also takes into account the lessons learned from recent earthquakes in Algeria, such as those in Béjaïa (2021 and 2022), Mila (2020), Algiers (2014), Médéa (2016), or abroad, such as Sichuan/China (2008), Maule off the coast of Chile (2010), Tohoku/Japan (2011), Christchurch/New Zealand (2011), and Turkey and Syria in 2023.

In Algeria, this role is played by the "Algerian Seismic Regulations" (ASR). The latest version, referred to here as RPA 2024, provides the current national reference for seismic design. It defines

· Seismic risk thru zoning and design spectra.

· The general design rules for structures in seismic zones.

· The classification of structures according to their importance and function.

· The analysis methods and detail requirements necessary to ensure adequate seismic performance.

According to the RPA 2024 document, the objectives are as follows:

The main objective of these regulations is to define the rules for the design and calculation of structures in seismic zones in order to ensure:

**VI.2 Objective of no-collapse:** The structure must be designed and constructed to withstand design seismic actions without local or global collapse, thereby preserving life safety. It must maintain its integrity and a residual load-bearing capacity after the earthquake.

**VI.3 Damage Limitation Objective:** The structure must be designed and constructed to limit material damage during seismic actions that are relatively frequent over the building's lifespan.

These objectives aim to protect human lives and reduce socio-economic impacts while maintaining a balance between safety requirements and construction costs.

**VI.4 General seismic design rules**

Based on the RPA 2024 document, the general rules for seismic design are based on fundamental principles aimed at ensuring human safety and limiting material damage.

**VI.4.1 Site Selection and Implementation**

· **Soil investigation:** A geotechnical study is mandatory to classify the site (from S1 to S4 or SS) and detect risks of liquefaction or instability.

· **Topography:** It is advisable to avoid building on ridges, cliff edges, or very rugged terrain, as these features amplify seismic waves.

· **Discontinuities:** A structure must be built on only one side of a geological discontinuity (fault, contact between different formations). If this is not possible, the structure must be divided using shrinkage joints.

**VI.4.2 Structural Configuration**

· **Regularity:** The building must have a simple and symmetrical configuration, both in plan and elevation, to ensure a uniform distribution of mass and rigidity.

· **Seismic joints:** These are used to separate blocks with complex geometries (L, T, U shapes) or significant lengths (maximum 200 m) to prevent impacts (collisions between structures).

**Ductility:** The structure must be capable of dissipating seismic energy thru inelastic deformations without collapsing. The "plastic hinges" should ideally form in the beams rather than in the columns or shear walls (principle of "strong column-weak beam").

**VI.5 Bracing Systems**

The frame must possess a system capable of resisting horizontal forces in at least two directions.

The 2024 RPA defines several systems, including:

· **Reinforced Concrete or Steel Frames (Frames)**: Height limits apply depending on the seismic zone.

· **Reinforced Concrete Walls:** These must be arranged to ensure overall stability. The document also introduces "large-scale walls."

· **Confined masonry:** Must be properly surrounded horizontally and vertically by reinforced concrete elements (bond beams and columns).

**VI.6 Infrastructure and Foundations**

· **Connection (Solidarization):** The support points (footings, piles) must be connected by beams or equivalent devices to prevent relative horizontal movement.

· **Homogeneity**: Unless a specific study is conducted, the foundation system must be identical for the same construction block.

· **Fill support:** Construction on fill is strictly prohibited, except for reconstructed soils after thorough studies.

**VI.7 Materials and Techniques**

· **Fragile Materials**: The use of unreinforced concrete or unconfined masonry is prohibited for bracing elements.

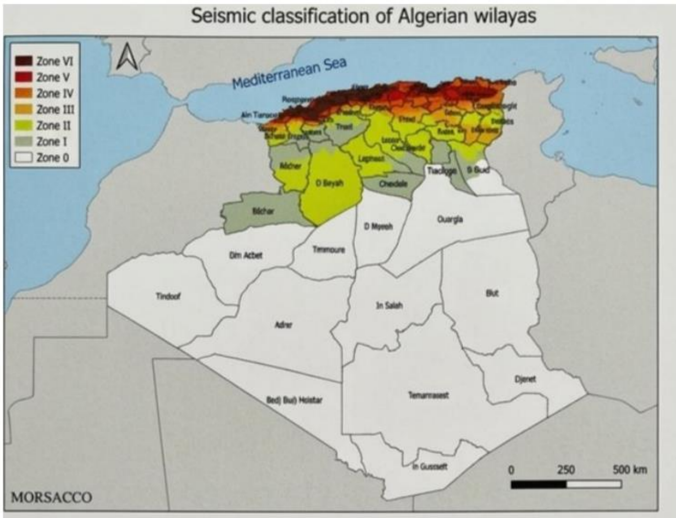
· **Mechanical Continuity**: The connections must ensure the transmission of forces, favoring cast-in-place concrete or steel.

· **Base Isolation**: The RPA 2024 introduces new rules for the use of seismic isolation devices to reduce structural response.

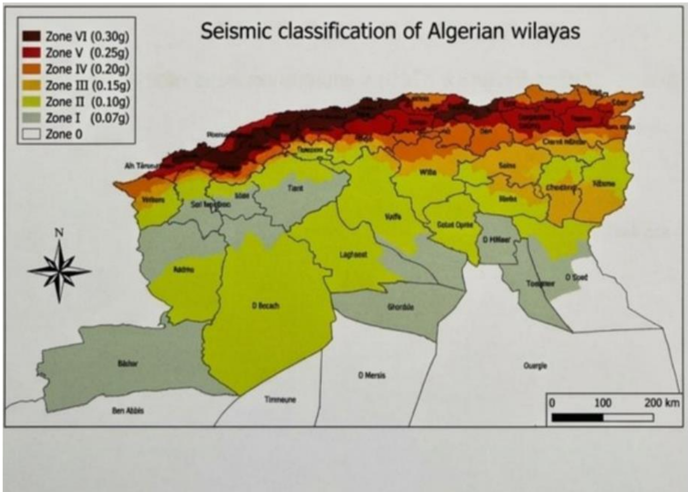
**VI.8. Seismic zoning and site conditions in the RPA 2024**

**-Seismic zoning**

The national territory is divided into seven (07) zones of increasing seismicity. This classification is used to define the seismic risk based on the geographical location of the project.




(a) Seismic zoning of Algeria: all zones 0 to VI



(b) Seismic zoning of Algeria: zoom on zones I to VI

**Figure 1.** Seismic zoning of Algeria.

-Zones and levels of seismicity :

-Zone 0: Very low seismicity.

-Zone I: Low seismicity.

- Zone II: Low to moderate seismicity.

- Zone III: Moderate seismicity.

- Zone IV: Moderate to high seismicity.

- Zones V and VI: High seismicity.

- **Acceleration coefficient (A):** The risk is characterized by the zone's reference acceleration coefficient (Ak), representing the maximum normalized acceleration at the rock level (S1 class soil) for a return period of 475 years.

· **Geographical distribution:** Annex A of the document specifies the classification by wilaya and commune. For example, the zones range from Zone 0 (for instance, in the extreme south) to Zone VI for the most seismically active areas.

**- Site classification**

The classification of sites is mandatory to determine the amplification of seismic waves by surface soil layers.

· **Site categories**: The RPA 2024 defines five (05) categories (S1 to S4 and SS) based on the average soil properties over the first 30 meters, primarily using the shear wave velocity (Vs,30):

· S1 (Rocky site): Rock or very firm formations with Vs,30 >800 m/s.

· S2 (Firm site): Very dense sand/gravel or overconsolidated clay (360

· S3 (Soft site): Deep deposits of medium-density sand/gravel or medium-stiff clay (180

· S4 (Very Soft Site): Deep deposits of loose sand or soft clay (Vs,30 <180 m/s).

· SS (Specific Site): Sites requiring in-depth investigations and specific studies due to risks such as liquefaction, unstable soil, or exceptional topographical conditions.

**VI.9 Site Selection Criteria:**

Particular attention must be given to unfavorable conditions during site selection, including: · Proximity to active faults.

Potentially liquefiable zones.

·Unstable terrain (slopes, cliffs, caves, or uncompacted fill).

·Rugged topography (ridges, valley edges) likely to cause topographic effects on the site.

**VI.10 Parameters of Seismic Action**

The seismic action is defined by an elastic response spectrum.

- **Types of spectrum**: The code distinguishes between Type 1 (for earthquakes with a magnitude Mw >5.5) and Type 2 (Mw ≤5.5).
- **Components:** The design seismic action includes both horizontal and vertical components.
- **Factors:** The calculation involves the acceleration coefficient (A), the importance factor (I) related to the building category, and the site coefficient (S).

**VI.11 Classifications of structures in the RPA 2024**

In the RPA 2024 (Algerian Seismic Regulations), structures are classified according to several criteria to determine the level of seismic protection and the required calculation methods. The main classifications include the importance of the building, the structural systems, and the regularity of the configuration.

**VI.11.1 Importance Classification (Importance Groups)**

Buildings are classified into four groups based on their purpose and the risk their failure poses to the community. Each group is assigned an importance coefficient (I), which adjusts the seismic action.

- **Group 1A (Vital Importance):** Buildings that must remain operational after a major earthquake for survival, public safety, and national defense.
- **Examples:** Strategic decision centers, hospitals with emergency services, fire/police stations, telecommunication centers, and water production facilities.
- **Group 1B (High Importance):** Buildings that accommodate a large number of people or contain high-value assets.
- **Examples:** Schools, large mosques, theaters, high-traffic shopping centers, and major administrative offices.
- **Group 2 (Current Importance):** Standard buildings whose failure only affects the immediate surroundings.

**- Examples**: Residential buildings and small offices not exceeding certain heights or occupancy thresholds.

- **Group 3 (Low Importance):** Buildings with low occupancy or less significant industrial/agricultural structures

### VI.11.2 Classification of Bracing Systems

The 2024 RPA identifies various structural systems based on their resistance to horizontal seismic forces. Each system is associated with a behavior coefficient (R), which takes into account its energy dissipation capacity.

· **Reinforced Concrete Systems:**

**- Framed systems (Frames):** Beam-column frames.

**- Shear wall systems (Walls):** Walls that support the majority of horizontal loads.

- **Mixed systems:** A combination of frames and walls.

**- Steel systems:**

- **Moment-resisting frames:** beams and columns rigidly connected.

- **Braced frames:** Use of diagonal members in X or V configurations.

**- Masonry and Wood:** Confined masonry and various categories of wooden framing.

### VI.11.3 Configuration Classification (Regularity)

Structures must be classified as regular or irregular in plan and elevation to determine the appropriate calculation method (e.g., Equivalent Static Method vs. Modal Spectral Analysis).

**- Plan regularity:** Requires a symmetrical distribution of mass and stiffness, a compact shape (length/width ratio constraints), and limited eccentricity between the center of mass and the center of stiffness.

**- Regularity in Elevation:** Requires the continuity of vertical load-bearing elements and limited variations in the mass or rigidity of the floors between adjacent levels.

### VI.11.4 Classification of Non-Structural Elements and Equipment

RPA 2024 also classifies components that do not belong to the main load-bearing system.

· **Non-structural elements:** Elements such as partitions, facades, and parapets.

· **Equipment:** Classified into three categories based on risk (potential to cause injuries, release of hazardous materials, or operational criticality).

## VI.12 CONCLUSION

In conclusion, the RPA 2024 establishes a rigorous framework for seismic safety in Algeria by integrating an updated seismic map into seven zones and refined soil classifications. By imposing structural regularity, ensuring material ductility, and requiring systematic foundation connections, these regulations aim to prevent structural collapse during major earthquakes. Ultimately, the document offers an essential technical balance between high-level safety standards for the population and the socio-economic realities of the construction industry.

# Chapter VII.
# JUSTIFICATION OF REINFORCED CONCRETE STRUCTURES

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## VII.1 Algerian Regulations : (C.B.A.93) -(R.P.A.2003):

These are the Algerian technical regulations that replace the accepted practice of B.A.E.L (Concrete at Limit States); by providing special recommendations for the Algerian country in the seismic field R.P.A (Algerian Seismic Regulation).

## VII.2 The Principles of Limit State Calculation

### VII.2.1 Verification Principles

Limit state design is a procedure that takes into account the variable nature of loads, materials, construction practices, and the approximations made in calculations in such a way that the probability of a structure becoming unfit for use is reasonably low. Limit state design procedures encourage the engineer to examine the conditions or limit states that can cause structural failures. These conditions are classified as ultimate limit state (ULS) and serviceability limit state (SLS) depending on the project's situation. The verification of a structure according to limit state calculation principles must consider all possible project situations such as:

• Permanent project situations corresponding to normal use of the structure,

• Temporary project situations (during its construction or repair),

• Accidental project situations: fire, impacts,

• Seismic project situations: earthquake, We may also need to consider other effects such as temperature or differential settlement of supports.

### VII.2.2 Ultimate Limit State Verification Procedures

Ultimate limit states (ULS) concern the resistance to applied loads and equilibrium when the structure reaches the point where it becomes significantly dangerous. For typical building structures, the checks for ULS primarily focus on the strength and stability of structural elements. In all cases, the effect of the action E (characterized by the moment MEd, the shear forces VEd, and the normal forces NEd) acting on a structural element must be less than the resistance R of that same element (MEd, VEd, NEd). In this case, the verification translates into a condition of the type:

$$\mathbf{E\ d \leq R}$$

Where:

**Ed:** calculated value of the effect of actions,

**Rd:** calculated value of the resistance defined by the Eurocodes.

**VII.2.3 Service ability limit states:**

They concern the service ability of the structures and are subject to verification on the following points:

• The deformations of the structure under normal use.

• The comfort of people (vibrations of floors, for example). The designer must seek to verify that the structure fulfills its function satisfactorily when subjected to its service or operational load. The verification translates into a condition of the type:

$$\mathbf{E\ d \leq C}$$

Where

**Ed ;** calculated value of the effect of actions (deformation, vibrations,)

**Cd ;** limit value of the criteria at service ability limit states

**VII.3 The actions**

**VII.3.1 Actions on structures**

An action F on a structure can either be a force or an imposed deformation due to temperature or settlement, for example. The actions to be considered are classified based on their occurrence and duration of application. These are :

Permanent actions G Variable actions

**Q**: they include imposed loads I (operation) and climatic loads (wind W and snow S).

Accidental actions **A**: they include explosions and impacts, their probability of occurrence is very low. For actions due to earthquakes, refer to Eurocode 8 and the RPA.

**VII.3.2 Characteristic Values of Actions**

The characteristic value of an action denoted ($G_k$, $Q_k$) is its main representative value, that is, its most reliable value.

**-Permanent actions**

Permanent actions can be evaluated with good precision because their variation over time is negligible. The average value of the self-weight of structures is often known, although there can obviously be substantial variations during the execution of the works, particularly in the case of cast-in-place concrete (e.g., the self-weight of the structure, the fixing devices, and permanent finishes). We therefore define, to account for the variability of permanent actions, a maximum characteristic value Gk,sup and a minimum characteristic value $G_k$,inf.

**- Representative value of variable actions Q k**

The imposed loads are subject to considerable variations. Representative values are values whose probability of being reached or exceeded is low over a period that is generally 50 years. Their modeling is often done in the form of a uniformly distributed load. k The climatic loads due to snow S and wind W are highly variable. It is possible to predict, with a certain degree of certainty, their characteristic values because a considerable amount of reliable statistical data has been collected over the decades. There is a DTR that evaluates wind and snow loads in Algeria ; it is the DTR C-2.47 called RNV 99.

## VII. 4 ACTION COMBINATIONS

According to BAEL 91-99, the design combinations to be considered are :

- ➢ ULS (Ultimate Limit State)
- ➢ SLS (Service ability Limit State)

Fundamental combinations :

1,35G + 1,5Q (7,1)

Accidental combinations:

1,35G + 1,5Q + FA (7,2)

G + Q (7,3)

According to the RPA 99-v2003, seismic action is considered an accidental action in the sense of the limit state design philosophy. The combinations of actions to be considered for determining the design forces and deformations are:

G + Q + E (7.4)

0,8G ± E (7.5)

For columns in self-stable frames, combination (7.4) is replaced by the following combination:

G + Q ± 1,2E (7.6)

Où, G = permanent loads, Q = unamplified operational loads, FA = nominal value of the accidental action, and E = seismic action represented by its horizontal components.

## VII.5 Verification regarding the resistance, overall equilibrium, and stability of the foundations

### VII.5.1 Verification regarding strength

The following resistance condition must be satisfied for all structural elements, their connections, as well as critical non-structural elements:

$$Sd \leq Rd \tag{7.7}$$

Where, Sd = design action resulting from the combinations defined in 7.2, including possible second-order effects, and Rd = design resistance of the element, calculated based on the properties of the constituent material.

### VII.5.2 Verification with respect to overall equilibrium

This equilibrium condition refers to the overall stability of the building or structure subjected to overturning and/or sliding effects due to forces resulting from the combinations of actions.

**-Verification against overturning**

The stabilizing moment calculated based on the total weight of the structure (Ms) must be at least 3/2 times the overturning moment caused by the seismic action (Mr), that is, $Ms/Mr \geq 3/2$ (7.8)

**-Verification against sliding**

-The stability of the construction soil against sliding must be ensured.

- The stability of the foundations against sliding must be verified.

The justification for the absence of sliding of a foundation therefore relies on the verification of the following inequality:

$$Hd \leq Rh,d + Rp,d \qquad (7.9)$$

Where: Hd = design value of the horizontal component of the load transmitted by the shallow foundation to the ground, Rh,d = design value of the sliding resistance of the foundation on the ground, and Rp,d = design value of the frontal or tangential resistance of the foundation to the effect of Hd.

In the particular case of so-called "semi-deep" foundations, it is also possible to take into account the friction on the vertical faces in the direction of the force Hd.

**-Verification regarding the stability of the foundations**

For the verification of foundation stability, the following requirements and/or provisions should be referred to:

For the stability checks of the foundations, it is necessary to refer to the following requirements and/or provisions:

**Interconnection of Support Points**

a- The support points of the same block must be interconnected by a bidirectional network of connecting beams or any equivalent device designed to oppose the relative displacement of these support points in the horizontal plane;

b- The minimum dimensions of the cross-section of the connecting beams are:

- 25cm × 30cm: site category $S_2$ and $S_3$,
- 30cm × 30cm: site category $S_4$.

The connecting beams or equivalent devices must be designed for tension. The minimum reinforcement must be 0.6% of the cross-sectional area with stirrups spaced at intervals of no more than 20 cm and 15 times the diameter of the longitudinal reinforcement (Øl) ;

c- Interconnection by tie beams or equivalent devices is always required, except in the case of foundations anchored in sound and unfractured rock ($S_1$ category sites) and in the case of an $S_2$ category site in zone I;

d- In the case of lightweight structures (warehouse type), tie beams can be replaced by floor slabs acting as tension members or transverse buttresses;

e- In the case of heavy structures (large buildings) composed of several blocks separated by joints, it is recommended to eliminate the joints at the foundation level if the foundation system and the quality of the foundation soil remain identical under the different blocks;

f- The ground floor beams of a building can only be considered as linking beams if they are located at a distance from the bottom face of the foundations or footings of less than 1.20 m. If applicable, a floor slab can replace the connecting beams when it complies with the previous rule.

## VII.6 Construction Requirements

Foundation systems must be constructed according to the methods and technical provisions contained in the applicable DTR (Technical Design Regulations). The construction measures to be adopted in the presence of a potential instability (liquefaction, unstable soil) will be those recommended following a specific study required in such situations.

### VII.6.1 Verification of Bearing Capacity

Foundation systems must be verified according to the methods contained in the current design and calculation DTR, subject to the following modifications:

**-Superficial foundations:** superficial foundations are designed according to the action combinations presented in equations (7.4) and (7.5), taking into account the application of a safety factor of 2.0 to the ultimate bearing capacity of the soil (qu).

**-Deep foundations:** deep foundations are designed according to the action combinations presented in equations (7.4) and (7.5), taking into account the application of partial safety factors (see Chapter 5 of the DTR BC 2.332).

### VII.6.2 Verification of Overturning Stability

Regardless of the type of foundation, it must be verified that the eccentricity (e) of the resultant of the vertical gravitational forces and the seismic forces remains within the central half of the base of the overturning-resistant foundation elements ($e = M/N \leq B/4$). Where M and N are the moment and the axial force acting on the foundation and B is the width of the foundation.

## VII.7 DEFINITIONS AND JUSTIFICATIONS OF JOINTS

In construction, joints refer to the separations made between two parts, each part being able to move independently. Joints in construction allow for the absorption of potential movements of the structure. There are therefore different types of joints.

**- The functions of seals ;**

Seals can perform 5 functions. Firstly, they help to cope with climate changes and thermal expansion. Indeed, significant temperature variations can cause cracking of supports and facades, or even their lifting. This phenomenon can compromise the stability of structures and prove dangerous for their occupants. The joints can also reduce and partially compensate for the consequences of Settlements differentials of the foundations caused by vertical and horizontal forces. Moreover, the joints limit the phenomenon of concrete shrinkage (thermal and hydraulic shrinkage) during its drying.

**VII.8 The different types of seals** :

There are 4 types of joints, which differ according to their specific function.

**-Expansion joints** :

The expansion joint concerns the spacing between two parts of a structure, and its role is to allow each part to move independently of the other. The expansion joint helps reduce the effects of expansion during high heat, or those of contraction during low temperatures. The current regulations require, in the absence of a thermal calculation, the installation of expansion joints based on the location, temperature, and humidity level characteristic of the region.

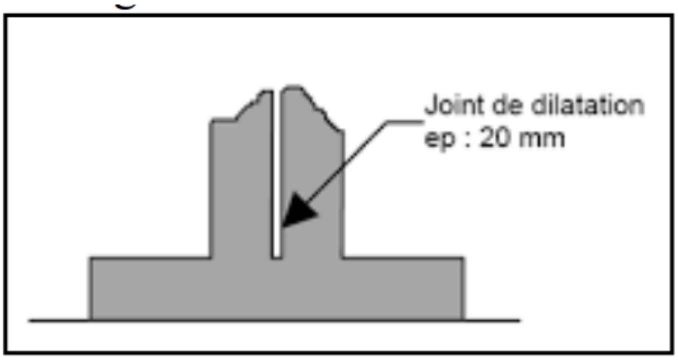


**Figure 1**. Expansion Joint

**- Shrinkage Joints**

Shrinkage joints are designed to facilitate the shrinkage of concrete while controlling the position and effects of any potential cracking. These joints are made between the expansion joints using a mechanical saw. The depth of the shrinkage joints must be between one quarter and one third of the thickness of the slab.

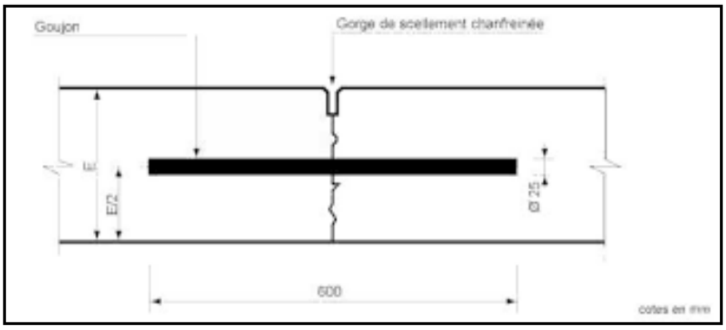


**Figure 2.** Shrinkage Joint

**- Expansion Joints**

The expansion joint consists of dividing the foundations to avoid the risks associated with differential settlements. Indeed, a risk of differential settlement is conceivable as soon as the structure is made up of components of different weights, or when another construction is attached to the first.

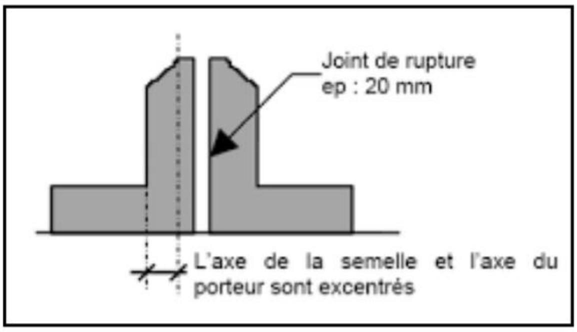


**Figure 3.** Expansion Joint .

**- Construction Joints**

Construction joints are made during a prolonged pause in concreting. Depending on the size of the slab and its future use, dowels may be inserted to allow for load transfer. The dowels are steel bars that allow for the transfer of shear forces while keeping horizontal movements free.


**Figure 4.** Construction Joint

### VII.8.1 Justification of the Width of Seismic Joints

Two adjacent blocks must be separated by seismic joints whose minimum width dmin satisfies the following condition :

min = 15mm + (δ1 + δ2) mm 40 mm δ1 and δ2: maximum displacements of the two blocks, calculated at the level of the top of the lower block, including components due to torsion and possibly those due to the rotation of the foundations.

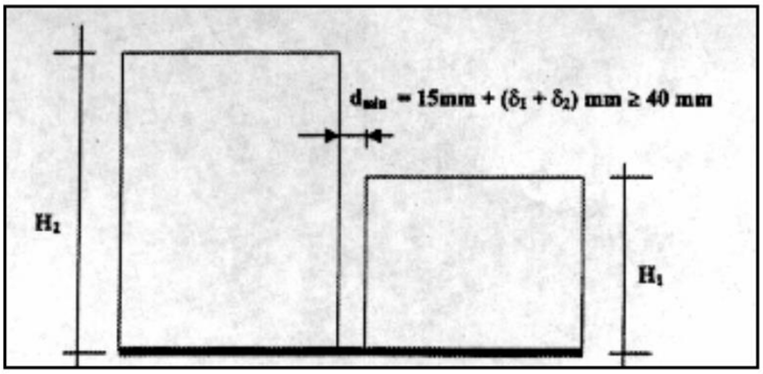


**Figure 5.** Seismic joint between two blocks.

# CHAPTER VIII.
# SPECIFICATION OF STRUCTURAL ELEMENTS

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**VIII.1 Introduction :**

According to the process followed, the prefabrication of buildings is done using the closed method where the company creates an element from design to assembly.Or according to open prefabrication, starting from the construction of elements from a catalog in a company. The work is carried out in a more or less mechanized manner where the site operations consist simply of the assembly and joining of prefabricated elements.

**VIII.2 The prefabrication of industrial buildings :**

The prefabrication of industrial buildings used to employ much more diversified processes until recent years, specific to each operation. It was therefore essentially the domain of formed prefabrication, with each project subject to a special study and execution by the company on site.

For the open process, the buildings constructed according to its principles are mainly single-story industrial buildings featuring beams, columns, roofing elements, etc.

**VIII.2.1. Types of prefabricated elements :**

1- The columns

2- the floors.

3–the facades.

4- the beams.

**VIII.2.1.1 The columns:**

**They are generally used:**

- In load-bearing industrial facades.
- In industrial buildings (factories, warehouses)
- In public works (stands, parking lots)
- For a structure composed of reinforced or prestressed concrete.

**N.B:**

- the columns may include corbels intended to support overhead crane beams or floor beams.

The connection of the columns with the foundation is made using two main techniques :

**A –concrete connection :**

The foundation includes a basin whose dimensions in plan, in both directions of the column, are approximately 5 cm larger than the column section and a depth of 30 to 40 cm. The post is set in this basin with an interposition, at the bottom of a layer of fresh mortar; the height adjustment is achieved by a leveling screw, and it is kept in a vertical position by props and temporary wedges until the mortar bedding between the edges of the basin and the post is sufficiently hardened.

**-B/ metal connection:**

The column has at its lower end a metal shoe anchored by reinforcements embedded in the concrete.

This base plate has plan dimensions larger than those of the column, so it can be fixed laterally with bolts set during pouring.

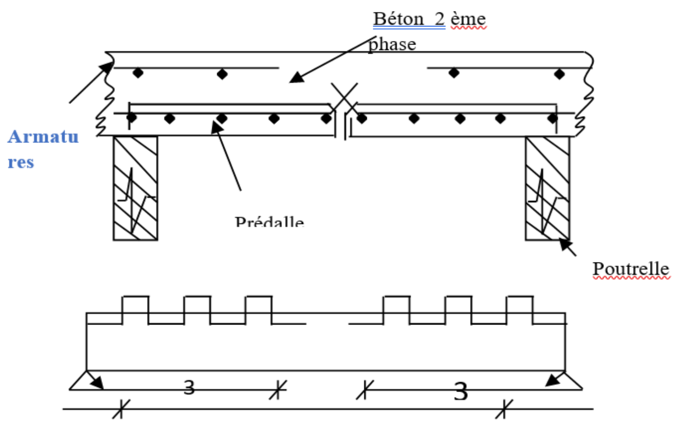
**VIII.2.1.2 The floors:**

**There are many types of prefabricated floors.**

**1/ Precast slab floors:**

It consists of precast or cast-in-place beams, between which precast slabs are placed. The predalles are thin slabs (minimum thickness 4 cm) prefabricated in reinforced or prestressed concrete. They serve as lost formwork. On top, a reinforced concrete slab (concrete known as phase 2) is poured.

- For the whole to be monolithic, the upper surface of the predalles must be sufficiently rough! Otherwise, it is necessary to provide stitching bars, in the form of Greek bars for example, in the first third and the second third of the span to balance the sliding force in these areas.

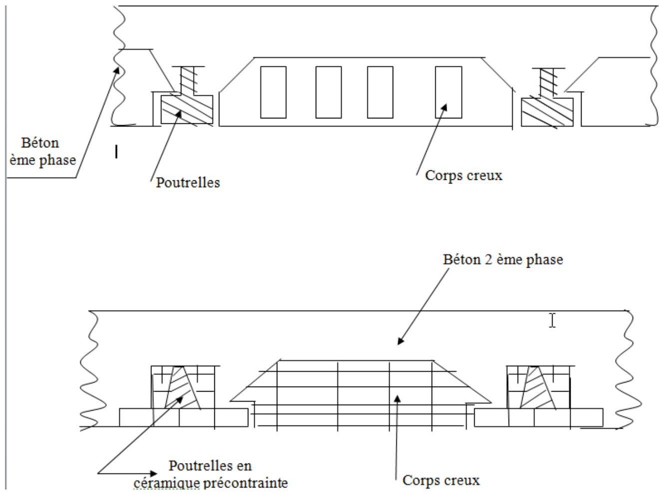



**2/ Hollow core slabs:**

They consist of prefabricated reinforced or prestressed concrete beams, between which hollow cores (hollow blocks) made of ceramics or concrete aggregates are placed.

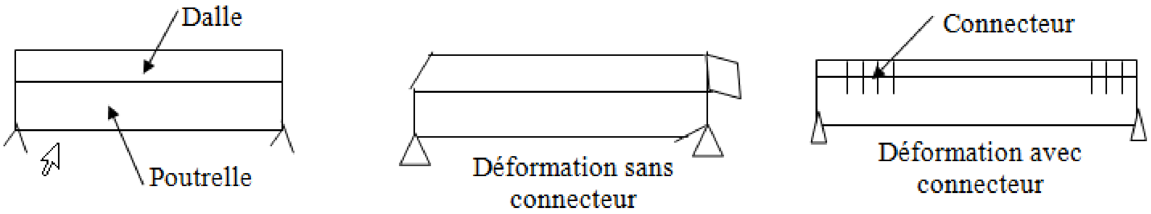
- A second-phase concrete slab is poured; with a minimum thickness of 4 cm to bond everything together. The blocks making up the hollow core slabs, also called voids, can also be made of polystyrene.

- The blocks making up the hollow core slabs, also called void formers, can also be made of polystyrene. The beams can also be made of prestressed ceramic.



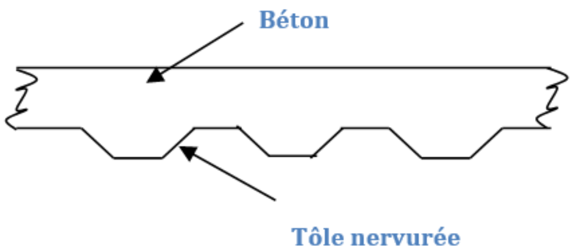

**3/- Composite slabs:**

They consist of metal beams of Prédalles or hollow core slabs, and a second-phase concrete slab. It is necessary to be able to transmit the sliding forces from the metal beam to the cast-in-place concrete. For this, metal connectors are welded onto the base of the profile; the most common are studs or angles.




**4/ - Other floors:**

There are other types of prefabricated floors (Hollow core slab) formwork floor Collaborative metal floor.

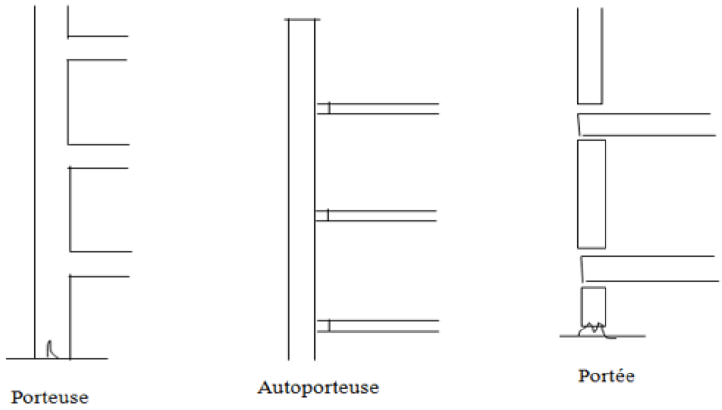


### VIII.2.1.3 The façades :

**1/- Types of facades:**

Prefabricated facades can be load-bearing, self-supporting, or supported.

- A load-bearing facade supports the vertical loads brought by the floors.
- A self-supporting facade only supports its own weight.
- A supported facade consists of wall elements supported on each floor by the slab.




## VIII.3 SPECIFICATIONS FOR SECONDARY ELEMENTS

The structural detail provisions to be implemented, in addition to those of the traditional rules, are as follows:

### VIII.3.1 Beams, Joists, and Slabs

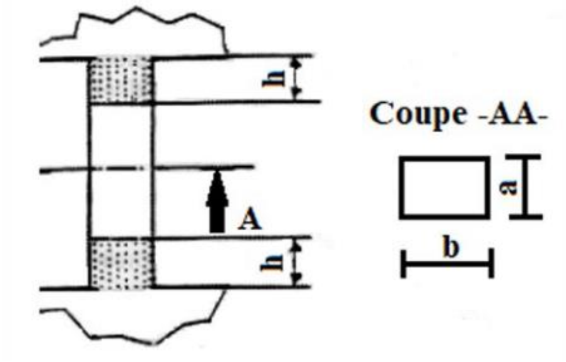
An appropriate connection between the supported element and the load-bearing element must be ensured by using reinforcement that provides mechanical continuity.

This mechanical continuity can be ensured either by the continuity of the lower reinforcement, or by upper bars (negative reinforcement) resisting at least 0.15 of the moment value (M0), or by folded bars anchored at the supports.

### VIII.3.2 Columns :

Mechanical continuity of the reinforcement must be ensured at the column ends (see Figure VIII.11). Furthermore, the transverse reinforcement at the column ends over the height b must have a maximum spacing not to be exceeded, equal to the minimum of (12Øl, 0.5a, 30 cm).

**-Zones of mechanical continuity for reinforcement in secondary columns.**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