People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research

University of Ghardaia

Faculty of Science and Technology
Department of Hydraulic and civil Engineering

CONSTRUCTION TECHNIQUES AND RULES COURSE

Module UET 3.1, 3rd year Civil Engineering Licence

Dr. Cady Mokhtaria

2025 – 2026
http://www.univ-ghardaia.dz

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PREAMBLE

This document deals with construction techniques and rules, and presents the various construction regulations and standards. In order to carry out our projects with a perfectly studied and controlled technical control, it is essential to know the distinct stages of establishment of reinforced concrete, metal and mixed structures, which represent the acts of engineering and it is the primordial imperative. The development of a project is conditioned by well-defined techniques; these are consecutive steps in sequence; from the preparation of the technical file through to site preparation, the construction of reinforced concrete structures as well as metal and mixed structures, right up to the acceptance of the work. All these steps are the subject of this course, without ignoring the introduction to the various earthquake-resistant regulations for safer constructions. This course is aimed at 3rd year Bachelor of Civil Engineering students, with the aim of introducing them to the process of designing and building structures, in order to facilitate and clarify their tasks in design offices and even on building sites. The construction operation was shown from a technical and technological point of view, and an introduction was given to the notions of the different regulations used in reinforced concrete, in accordance with the RPA. The present document is made up of six (08) chapters which will help our students to enrich their knowledge base previously obtained in the fourth semester. It is designed in accordance with the syllabus for the 2015. 2016 and approved by the Ministry of Higher Education and Research. The course is structured as follows: chapter 1, project design techniques, chapter 2, site preparation techniques, chapter 3, reinforced concrete construction techniques, chapter 4, steel and composite structures, chapter 5, introduction to the various regulations. Chapter 6, RPA 2024 seismic regulations, chapter 7, verification of reinforced concrete structures, and chapter 8, specification of structural elements specification for the main elements.

Dr. CADY Mokhtaria

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GENERAL INTRODUCTION:

The application of rules and standards is essential, and an understanding and mastery of how to build stable, safe, durable and economical structures is indispensable for all those involved. Six (08) chapters are presented, the first three outlining the various techniques used to design and build a reinforced concrete project, the fourth presenting steel and composite structures. The last two chapters introduce students to the concepts of civil construction regulations applicable to reinforced concrete structures. In the first chapter, we present the preliminary stages of a project, defining the mission of each participant in the construction chain through a circuit of administrative and financial phases.

In order to carry out a project, the choice of site and installation of a structure must have a legal basis, and the geotechnical investigation is summarized in the determination of the mechanical characteristics of the ground and the evaluation of the natural risks. In the environment around the site of intervention, as well as verifying their impact on the future. The second chapter deals with site preparation techniques, comprising several operations; organization to facilitate construction tasks, workshop demarcation, earthworks and backfilling to prepare the site. The third chapter covers the techniques used to build reinforced concrete structures: laying the foundations, formwork and reinforcement, along with feasibility tips. The fourth chapter covers metal and composite structures, with welding and bolting techniques, as well as the assembly of metal compositions. The fifth chapter covers BAEL and Eurocodes regulations. The seismic rules RPA 2024 are set out in the sixth chapter. The seventh chapter covers verification of reinforced concrete structures, and the eighth chapter present the specification of structural elements.

CHAPTER I: TECHNIQUES OF PROJECT DEVELOPMENT

CHAPTER I: TECHNIQUES OF PROJECT DEVELOPMENT

Introduction :

The realization of a project has an initial stage, which is the development phase, with precious control. Feasibility requires an evolving sequence of stages. Each participant has an indispensable mission, and complementarity between them; is an indication of good management. This chapter illustrates the various phases of project execution and the people involved.

I.1. Definition:

I.1.1. Construction project:

To an extended and linked process; it can be varied according to its size, the number of participants, the financial envelope and the delivery date. In order to guarantee a feasible result, a number of stages must be followed:

- Project development, which begins with a customer and the call for tenders.
- Design, established by an architect or engineer.
- Layout: this stage takes place after the call for tenders, as soon as the construction company has been appointed, and before work begins, the contractor assigns his team (project manager, site engineer, contract administrator, safety manager, permanent superintendent) the task of preparing the construction site.
- Procurement: this involves taking delivery of materials, equipment and labor.
- Construction: meticulous planning must verify the working hours of each team, material storage time, supply storage location, traffic access and work control.

I.1.2 Project manager:

This is the person in charge of carrying out the project, and is the key member of the site team. He is primarily responsible for ensuring that the specifications are met, and for controlling deadlines and costs.

I.1.3. Project owner:

This is the owner; a developer, or a contractor, as it can be a legal entity such as an executive management or a local authority, their missions are :

- Define the needs and orientations of the project.
- Order the project.
- Draw up the project's technical and financial forecasts.
- Define project procurement (AP).

- Determine project schedule.
- Select design firm.
- Choosing the developer.

Regular monitoring until delivery or handover of keys.

I.1.4. Invitation to tender:

Is a set of conditions in the form of specifications; a tender drawn up by the project owner, intended for design firms and developers to facilitate selection according to their agreements.

I.1.5. Public contracts:

These are agreements for consideration with written economic assistants within the meaning of the legislation in force. These contracts meet the requirements of the contracting department for studies, supplies, works or prescribed services.

I.1.6. Management of a construction project:

This consists of organizing the phases of the project according to the batches that define them, without forgetting to control and direct each starting task towards completion on time and within the budget requested.

I.2. Process for carrying out a construction project:

Four (04) phases summarize the evolution of project execution:

Stage 1: preliminary study.

Stage 2: preparation of an ephemeris.

Stage 3: execution.

Stage 4: operation, figure 01.

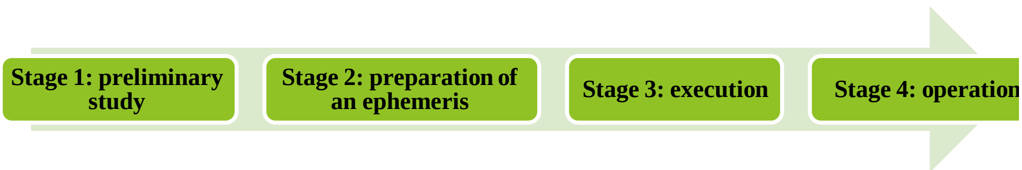

Fig 01 : Project execution evolutions

I.2.1. Preliminary study:

This is the preliminary study that precedes construction, such as: soil survey; legal and town-planning regulations; financial study and insurance. This study requires finalization of contracts and site information.

I.2.1.1. Finalizing contracts:

Preparation of specifications, followed by the appointment of the design office, the construction company and the safety coordinator.

I.2.1.2. Site information file:

Creation of the site information file (survey, survey, urban plan, road plan).

I.2.2. Planning:

This phase is indispensable for any project in life. In the case of a construction project, planning concludes the pre-project stage with a well-integrated scenario, in order to obtain a decision on an agreement in principle from the Ministry's authorities. If the requesting organization has this agreement, it can then move on to the feasibility study, which provides a schedule of the project's needs and technical studies; it then draws up a feasibility report defining the environmental strategy (the creation of a green building is an essential criterion in this process). The feasibility report has been determined, the requesting organization must define its project and mark it out by drawing up the plans, as well as the detailed financing plan (estimates, cost of carrying out each section of the work) with a clear method of carrying out the work (by lots, by phases, etc.), thus organizing the calls for tender. Secondly, the work schedule must meet the customer's objectives, as the project manager will have to take the necessary steps as soon as a delay is foreseen. The result of the planning phase is a construction program, which includes all the guidelines and information required to facilitate the work of the parties involved. The construction program is re-evaluated to check the accuracy of the data, and is used to reach a compromise between cost, quality and schedule for the project in question. A decision oversees the entire previous stage, ensuring that the promoter has final approval from all stakeholders. As soon as this decision comes to light, we can say that the project is ready for advertisement.

I.2.3. Realization:

Six (06) major stages can conclude the realization of a project:

- Architectural competition.
- Drawing up plans and specifications.
- Call for tenders.
- Construction
- Delivery.
- Operation of the project.

I.2.3.1. Architectural competition:

If the project exceeds a budget threshold defined by the promoter, it will not be carried out by mutual agreement, which obliges the Ministry to require a competition to define the architect. The professional advisor plays a key role in selecting the architect. This stage requires :

a. Recruitment of the professional advisor.

b. Program development.

c. Competition rules.

d. Approval of the program rules and regulations by the Association of Architects and the Ministry.

e. Appointment of jury.

f. Setting up the technical committee.

g. Public invitation to tender (contractors).

h. Call for applications (architects).

i. Site visit by bidders.

j. Submission of applications.

k. Evaluation and selection of bids.

l. Project development.

m.Technical offer evaluation (project analysis).

n. Final choice of design office.

o. The developer draws up a decision declaring and confirming his choice of architect to the Ministry.

I.2.3.2. Drawing up plans and specifications:

The architect draws up the plans and specifications, with any revisions that may be necessary. At this stage, the project will have a chance to be developed by specialists in: architecture, civil engineering, electricity, mechanics... and so on. And it's up to the architect to coordinate them all. Once the technical file has been finalized, in particular the agreed specifications, the project owner must submit an initial version of the tender, confirming that the financial envelope and work schedule have been respected.

I.2.3.3. Call for tenders:

To ensure better circulation, this call for tenders must be published in leading national daily newspapers. Bidders are asked to submit their cost proposals at competing prices, and the lowest bidder is awarded the contract. For this purpose, the cost of the work is known until delivery of the project, which is confirmed by a decision to approve the commitment to carry out the work.

I.2.3.4. Works:

As soon as the selected contractor receives his construction contract, a notice to proceed will give him the signal to start work on site. At this point, he must take out appropriate insurance cover for the project, and must also identify the engineers who will be permanently on site.

I.2.3.5. Handover:

The project handover process is carried out by issuing a final handover certificate. This certificate terminates the contract between the owner and the contractor, but does not release him from his obligations in respect of any defects that may subsequently appear.

I.2.3.6. Operation of the work:

Finally, after a final check in accordance with the requirements defined at the start of the operation, the project is ready for use.

I.3. Design and preparatory arrangements for work performance:

The design of buildings is often best carried out by an architect, while civil engineering works are carried out by a civil engineer, in which case a building permit will be issued. The construction project must comply with the rules of the trade, be regularly supervised by the designer, and be accepted by the contractor with a performance bond.

I.4. Selection of site and location of works:

The choice of site depends on the nature of the project, as well as on the need to find legally valid plots. The choice will be made once the site information file has been completed, which gives us access to the project.

I.5. Geotechnical investigations:

Firstly, geotechnical investigations are aimed at determining the mechanical characteristics of the soil to be used to support the structure. Secondly, geotechnics is used to assess all the natural risks surrounding the site. Geotechnical investigation provides us with impressive information that facilitates construction without unforeseen problems.

Conclusion:

There are a number of techniques involved in the development of a project, and these can be found in: the process of carrying out a construction project, the design and preparatory arrangements for carrying out the work, the choice of site and layout of structures, and geotechnical investigation. These steps lead to the simplification of the concept, clarification of objectives, preparation of the financial envelope, axiomatization of the project, prospecting of the collaborator, elaboration of a program of operation and finally, completion of the project. The purpose of this chapter was to outline the stages involved in developing a project, with each phase clearly defined and carried out, and followed by a complementary phase.

It's a seamless process, starting with the choice of designer and prime contractor, and ending with the acceptance and operation of the project. The designer carries out the design of the architectural or civil engineering project, the implementation and realization of the project on site is carried out by the realization company, under a control all respecting the conditions of the contract and the supply (AP).

CHAPTER II: SITE PREPARATION TECHNIQUES

CHAPTER II: SITE PREPARATION TECHNIQUES

Introduction:

This phase requires nine (09) consecutive steps; carried out by the main contractor. Work on the site involves a regular loop of weekly tasks in order to meet completion deadlines and the schedule for the completion of each lot. The team of labourers must assume its share of responsibility for the time and quality of the work subsidized by daily monitoring, and recorded in minutes which will be sent with a progress report and photographs to the project owner in order to justify the billing rights of the situations.

II.1.work preparation and building site organization techniques:

The project manager is responsible for all operations required to ensure that the work proceeds smoothly, and is therefore called upon to perform a number of tasks:

- Collect and archive administrative files. Managing the flow of information and updating mail. classification of work progress reports
- Allocation of roles to each person on site.
- Posting of a collection of notes explaining the various work constraints and listing them under a timetable.
- Photographic recording of each stage of the project, in compliance with deadlines.
- Tracing of a circulation path for machinery.
- Storage of materials and products.
- Guarding.
- Water supply.
- Construction of a site hut.

II.2. Staking and delimitation of the construction site:

The operation of piquetage is carried out with the help of a surveyor for the purpose of delimiting the overall surface of the building with its annexes. Staking requires the use of equipment such as a tacheometer, theodolite and sometimes GPS. The stakes will be marked on a plan with a designation of the project manager, the date and the project.

II.3.Earthwork and filling, earth removal techniques:

Earthwork is not often carried out, as it depends on the nature of the terrain.

Otherwise, earthworks involve stripping certain parts of the soil and filling in others, with the aim of making it flat and ready for construction.

II.4.Earth removal technique:

Earth removal is an earthmoving operation aimed at stripping a superficial layer of soil ranging from 10 cm to 40 cm, containing plant components and organic waste that could threaten the structure's foundations. If this layer is fertile, it will be stored for use in landscaping, or for sale, and if it is useless, it will be evacuated to a waste disposal site, figures 02, 03.

Fig 02: Soil removal

Fig 03: Soil stripping

II.5.Well digging:

Also known as excavation, well digging is carried out to establish foundations. Well digging takes place when the soil is very deep, figure 04.

Fig 04: Well excavations

II.6. Ramming :

Ramming is used to compact fill zones, figure 05.

Fig 05: The shelling

II.7.Recovery of plant ground:

The provenance of plants and also the quality of plants in the project has in order to create a balance between built and unbuilt, figure 06.

Fig 06 : Reuse of topsoil

II.8.Trenching and shoring :

Trenching and shoring is a compulsory procedure for consolidating excavation work, specifically when the excavation depth exceeds 1.30 metres and in respect of vertical walls. Its purpose is to support the cavity walls to prevent cave-ins and ensure worker safety. Shoring is particularly designed to avoid any danger of personnel being buried. The threat posed by a cave-in is generally underestimated, given that a proportional burial can result in death. Subsequently, for safety reasons, a trench excavation must always be shored according to its depth, figure 07.

Fig 07: Slicing and shoring

II.9. Embankment :

Embankment is the creation of a slope on a piece of land. Since slopes protect against collapse thanks to their oblique morphology, this operation is part of earthworks; it is intended for sloping terrain, and is used in swimming pool projects. In civil engineering, embankment is the task of protecting a bedrock, or uneven ground, for parts of works such as drainage, foundations, railroad and road bedrock works, particularly outdoor developments in urban areas, figure 08.

Fig 08: Embankment work

II.10. Management or valorization of waste:

Waste management and recovery involves arranging the collection, treatment, exploitation, and disposal of garbage, while promoting reuse, recycling, and energy use. With the aim of converting abandoned materials into products capable of reusing an energy solution. Then in the construction site, each team must ensure the cleaning and disposal of waste in order to free up and organize the execution of the work, figure 09.

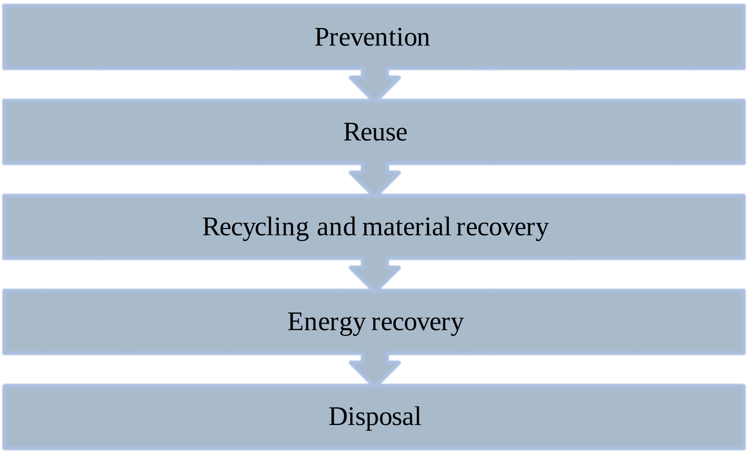

Fig 09 : Waste management and recovery

Conclusion:

The site preparation techniques presented in this chapter provide a generative idea of the progress of the construction work; the functions of the stakeholders are incorporated, overlapped, and prioritized.

The preparation of a construction site compromises several stations in order to ensure a reassured and flexible development of the work. These steps capture the preparation of work and techniques for organizing building sites, the staking and delimitation of the construction site, the earthworks and backfill, the techniques of carrying out land removal, the technique of carrying out land removal, well excavations, shelling, topsoil reclamation, trenches and shielding, hedging, waste management or valorization. It is very important to note that carrying out the preparation steps of a construction site facilitates the execution of work in a well-organized construction site.

CHAPTER III: PRODUCTION TECHNIQUES FOR REINFORCED CONCRETE STRUCTURES.

CHAPTER III: PRODUCTION TECHNIQUES FOR REINFORCED CONCRETE STRUCTURES:

Introduction:

Various techniques are used to build such structures; surface and deep foundation techniques. Techniques for reinforcing and forming the various structural elements.

III.1.Execution techniques for surface and deep foundations:

The foundation is the structural part of a civil engineering structure or building, and plays an essential role. It is defined as the lower part, which ensures the transmission of loads (operating loads, own loads, climatic and seismic forces) into the ground. It also makes it possible to control the permeability of the ground to the presence of water, and to test the pressures generated by the different weights it places on the ground. The designer chooses the type of foundation according to the soil's load-bearing capacity. Shallow, semi-submerged and deep foundations are the three (03) most commonly used types, each with its own role, geometry and construction. If the soil does not have the mechanical qualities to support the structure, it must be reinforced using suitable techniques. Trois types (02) les fondations qui sont couramment utilisées :

III.1.1. Superficial foundations:

Shallow foundations are low-pitting foundations, which stabilize on the ground or are gently embedded in the soil. They are worn for buildings on stable floors and allow the transmission of loads. The superficial foundation is used, whose depth does not exceed three 03 meters; it sinks slightly into the ground. The superficial foundation takes the form of a plot (takes the point loads of column, pillar and pole). If the depth of resistant soil exceeds three meters, we go to piles or wells, figures 10, 11.

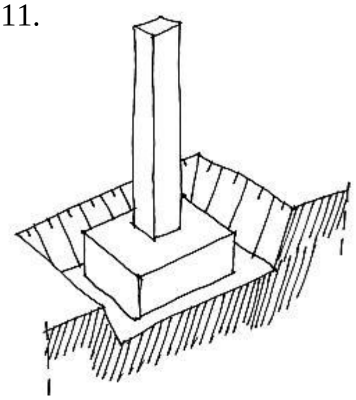

Fig 10: Plot

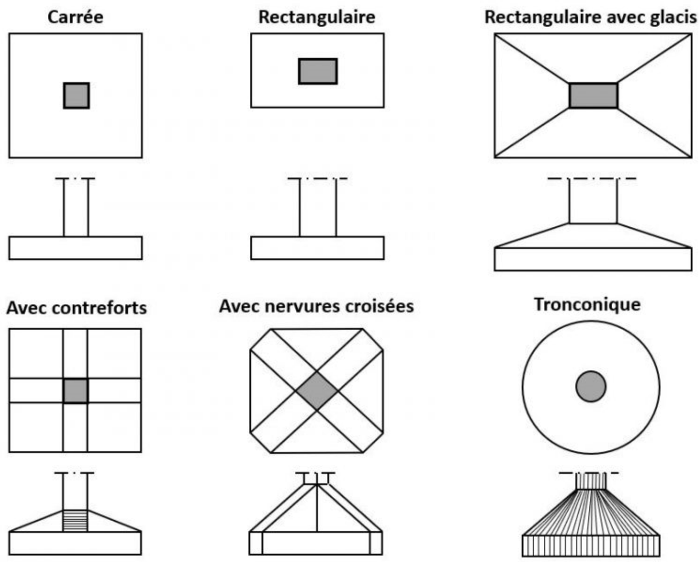

Fig 11: Types of insulated soles

III.1.2.The deep foundations:

The use of deep foundations is done when the surface layers of the ground do not support the loads of a construction. The deep foundations transfer loads to stable and deep layers. They are basic substances embedded in the soil. Our choice of foundation targets the deep foundation if the foundations are installed at depths that exceed their width, frequently extending tens of meters below ground level. They are feasible when the resistance of surface soils is low, Figure 12.

Fig 12: The deep foundations

III.1.3.The mechanism of choice of type of foundation:

The choice of foundation depends on the D/B ratio. This ratio is defined as:

D: The length hidden in the ground.

B: The diameter or width.

If $D > 3$ and $D/B > 6$, therefore our choice is in the deep foundation area.

If D < 3 and D/B < 6, therefore our choice is in the area of superficial foundations, figure 13.

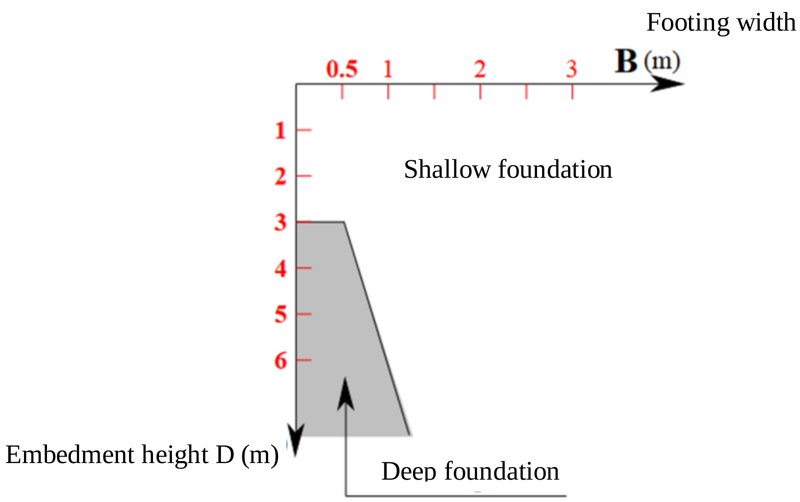

Fig 13: Areas of foundations

III.2. Formwork and reinforcement techniques for building structures:

III.2.1. Building structure formwork techniques:

Formwork of building structures is the operation that comes after the reinforcement of reinforced concrete construction elements. It is a provisional structure that precedes the casting of concrete, a preliminary structure that plays a thoughtful role in order to protect the reinforcement by respecting the space of enrobing which will be well studied. The formwork has for purpose to keep the concrete fresh, until hardening which will guarantee the desired shape.

III.2.2.The characteristics of formwork:

a. Stable.

b. Sustainable.

c. Waterproof.

d. Rigid, to withstand the forces of concrete pushing.

e. Non-absorbent.

f.Smooth, its skin must be smooth for artistic requirements.

g. Security, the contractor provides a secure formwork installation area.

III.2.3.The composition of the formwork:

A formwork consists of primary and secondary stiffeners, the trees shoot shoots, tightening with bolts of attached claws,

III.2.4.Types of formwork:

Several types of formwork are applied according to their importance and usefulness for good results

III.2.4.1.Wood formwork:

Wood is a traditional material, is one of the first types used its characteristics makes it easy to modify and assemble. Among the advantages of wood; it is less expensive, it uses for structured exposed concrete. The thickness of wooden boards must be between 27 and 40 mm to avoid warping, it has disadvantages, because this type of request a long time to put in assembly; a margin of maximum 20 reuses. But to increase its durability, boards of the waterproof marine plywood type 16-19 mm thick can be used, Figure 14.

Fig 14: wooden formwork

III.2.4.2.The metal formwork:

Metal formwork, among others, is characteristic; it is durable, exceeds 20 reuses, rigid keeps its initial shape after dismantling, easy to assemble, but its cost is high, it has heavy disadvantages which make its movement expensive, figure 15.

Fig 15: Metal formwork

III.2.4.3. Climbing formwork:

Climbing formwork is used for repetitive constructions such as tanks and bridge piles by with jacks attached to the formwork supported on the hardened part, figure 16.

Fig 16: Climbing formwork

III.2.4.4. Mixed formwork:

The mixed formwork is a pairing of metal and wood, it is easy to carry out, vigorous, and it requires a cyclical care.

III.2.5. The components of the structure concerned with formwork:

We will mention them in order of realization, the walls are sometimes made by concrete, see the importance of the project soles, posts, beams, and the walls.

All these elements will be formed by four (04) faces except the beam it would be formed by five (05) faces.

III.3. Reinforcement techniques for building structures:

Reinforcement is reinforcement, consolidation by steel. The reinforcement of building structures, is indispensable in the works of the site, but it offers a risk of the dangers attached to the tools of manual work which requires caution and awareness of:

- Wear appropriate and secure clothing at work.
- Helmet.
- Bezel.
- Gloves.
- Boots.

- The scrap dealer is called to carry tools that facilitate work such as:
- Coil.
- Marker.
- Hammers.
- Rod cutter.
- Bar cutter.
- Bolt-cutter.
- Bar shears.
- Socket wrenches.
- Pipe wrenches.
- Pliers.
- Rebar bending machine.

Conclusion:

The construction of reinforced concrete structures is a complex process that combines scientific, technical and practical principles. An approach that requires careful planning and precise execution, from design to maintenance of the structure. Each step must be carried out in accordance with the standards and specifications to ensure the safety, durability and performance of the work. Innovation in materials and construction techniques, such as prestressed concrete and prefabrication, also improves the performance of structures. These techniques reduce construction times while optimizing the strength and performance of structures. For example, prestressed concrete, by applying a tensile force on the reinforcement before or after casting the concrete, allows to maximize the strength of beams and slabs, This is particularly useful for large structures such as bridges or multi-storey buildings. However, the quality of construction is not limited to the construction phase. Maintenance plays a crucial role in the longevity of works. Cracks, water infiltration or chemical attack can reduce the durability of concrete and compromise the safety of the structure. It is therefore essential to carry out regular inspections, timely repairs and protective treatments to ensure the durability of the structures. The success of a reinforced concrete project is based on an in-depth understanding of materials and construction techniques, as well as rigorous quality management, compliance with standards and long-term maintenance. Reinforced concrete is one of the most worn materials, due to its versatility, relatively low cost, and ability to meet requirements in very diverse contexts. However, as with any discipline in engineering and architecture, constant attention to ethics, safety and integrity of construction processes is paramount to ensuring not only efficient works, but also responsible and respectful of environmental and societal standards.

CHAPTER IV: METALLIC AND MIXED ARTICLES.

CHAPTER IV: METALLIC AND MIXED ARTICLES.

Introduction:

Metallic and mixed works refer to structures used in construction, combining different materials such as metal and concrete to maximize their respective benefits. They are the object of bridges and buildings. They are used in civil engineering, architecture and various buildings.

IV.1. Metal products:

Metal structures are structures constructed primarily of steel or aluminum. These materials are used for their high tensile strength, relative lightness and durability; examples:

IV.1.1. Metal bridges:

Metal bridges are often used for large-scale crossings. The first metallic bridge was executed in 1779 in England; it was Iron Bridge built in cast iron by Abraham Darby III who had passed over the river with a reach of 30.5 m and a length of 60 m.

IV.1.2. Metal frames:

The metal frames are made of galvanized steel, such an exceptionally strong structure is adaptable to different structures; at first, they are used for the structures of industrial and agricultural halls. Currently, their field of use has become wider than before, which builders and engineers choose them in the realization of houses and industrial or commercial buildings. Among these advantages, lightness, they offer freedom of space, the more they are easy to install.

IV.1.3.Towers and pylons:

These are vertical structures intended for different uses, they indicate the transmission of electricity or communication. Towers support antennas, control platforms, otherwise communication towers; pylons are commonly used to maintain high-voltage electrical cables. Frequently towers and pylons are structures used in wind turbines and telecommunications, etc.

IV.2. Mixed works:

Mixed works are structures that combine several materials, such as steel and concrete, to combine the properties of both. Steel can be used to resist tensile forces, similarly concrete can offer compressive strength.

IV.2.1. Mixed bridges:

The mixed bridges comprise structural substances of reinforced concrete and steel or steel and pre-stressed concrete; these materials exhibit a complementarity between them within the framework of a mechanical constraint, with a process of procreation of a homogeneous whole. While realizing the specificity of these materials according to their ideal arrangements, especially traction for steel and compression for concrete, for example, a steel bridge with a concrete slab for pavement.

IV.2.2. Mixed buildings:

The mixed buildings are intended for a mixed use; this type of building integrates in its same structure many activities. They combine housing, commercial premises, service premises and industrial buildings. This hybridity of uses allows the creation of an active environment, producing users a fluidity to different spaces; where the support structure is steel and concrete floors.

IV.3. Advantages of metal and mixed works:

Metallic and mixed structures have many advantages over conventional buildings, especially in terms of time savings, stability, ductility of creation and endurance.

IV.3.1.Optimized performance:

Optimized performance combines the advantages of materials strength, lightness, durability .

IV.3.2.Speed of construction:

Prefabricated metal structures can be assembled quickly on site.

IV.3.3.Weight reduction:

Weight reduction allows for lighter structures compared to the use of concrete alone.

IV.4. Disadvantages of metallic and mixed works:

The disadvantages of metallic and mixed structures are summarized as follows:

1. Cost:

Metal, especially steel, may be more expensive than concrete.

2. Maintenance:

Metal may require more maintenance (rust protection), although treatments such as galvanizing or anti-rust paint are used.

IV.5.Welding and bolting:

Welding and bolting are two of the main methods used to assemble metal parts in metallic and mixed structures. Each method has its advantages and limitations, and the choice between one or the other often depends on the type of structure, intended use and economic considerations.

IV.5.1.Welding:

Welding is a key process in the manufacture and assembly of metal structures, particularly for metallic and mixed structures. It creates strong and durable joints between metal parts by melting the edges of these parts and adding a filler metal that, when cooled, forms a rigid bond. Here is a detailed overview of the main types of welding, advantages and disadvantages, as well as common applications in architecture and engineering.

IV.5.1.1.Welding patterns:

a. Arc assembly: this is one of the most common procedures. It is formed between an electrode and the base metal, it is to melt the parts to be assembled, as an example:

• Arc welding with coated electrode SMAW or MMA:

Uses a coated electrode that melts during welding. This method is relatively simple and inexpensive, ideal for outdoor work.

• Gas arc welding MIG or MAG:

The arc is protected by a gas (argon, carbon dioxide, or a mixture of both) that prevents contamination of the weld. This provides cleaner and faster welds.

• **TIG Tungsten inert Gas, welding:**

Uses a non-consumable tungsten electrode and an inert gas such as argon. This method is accurate and allows for high quality welds, often used in industries requiring aesthetic finish or fine welds.

b. Assembly by resistance; this process is based on the generation of heat by electrical resistance. It is often used to assemble thin sheet metal or for large-scale assemblies such as car bodies. Spot welding, the metal parts are held between two electrodes, and the heat generated by the electric current melts the parts at a melting point.

c. Laser assembly; this type of welding uses a concentrated laser beam to melt the parts to be assembled. It is highly accurate, used in high-tech applications such as aerospace and high-precision equipment.

IV.5.1.2.Benefits of welding:

a. **Strength and continuity: a** good weld creates an extremely strong junction and can be as strong as the base metal itself. This maintains structural integrity. Aesthetic welds can be discreet and aesthetic, especially with techniques such as TIG welding where the weld is fine and clean. Ability to weld complex shapes: Welding allows parts in various configurations (angles, curves), which can be difficult with other joining methods. No external fastenings unlike bolting, welded parts form a material continuity, which can be advantageous for the rigidity of the structure.

IV.5.1.3.Disadvantages of welding:

Sensitivity to weld quality; A poorly executed weld can cause defects (cracks, porosity, poor fusion), thus compromising the strength of the structure. Rigorous quality control is required. Thermal deformation, the intense heat of welding can cause the part to deform, especially for sensitive materials such as aluminum or low-carbon steels. High technical skills, the execution of quality welds requires skilled welders. In addition, careful control is essential to avoid errors. Equipment and maintenance costs, Welding equipment, especially for advanced techniques such as TIG or laser, can be expensive, and maintenance of the machines is necessary to ensure their proper functioning.

IV.5.1.4.Areas of application:

Welding is widely used in several fields, particularly in metal frame constructions

a. Metal structures; as beams, columns and frame assemblies) are often welded together, providing optimum strength and stability.

b. Bridges and infrastructure in metal bridges; structural steel elements are often welded to ensure continuity and endurance to different efforts.

C. Shipbuilding, aerospace; the naval and aerospace industries use welding extensively to assemble ship hulls, aircraft, and components where strength and precision are paramount.

d. Metallurgy and machining; the metal industries use welding to assemble parts in the manufacture of appliances, and supplies, and for the repair of damaged metal parts.

IV.5.1.5.Welding rules:

Welding is a highly technical operation that requires rigorous quality monitoring and controls. Many standards such as ISO 3834 for weld quality govern welding practices. Weld inspection may be performed by visual, radiographic, ultrasonic or tensile testing as required by the project. Welding is carried out in a workshop by a competent welder; in addition to this essential task on site, it is done under conditions which ensure several criteria:

a. The welding is carried out according to artistic standards, by sanding welded parts towards the completion of each work.

b. Metallization of welding areas for protection against oxidation and corrosion.

c. Welding is a continuous assembly of parts and is an essential technique in the construction of metallic and mixed structures, providing solid and continuous joints. However, it requires high skills, specific equipment and attention to quality to ensure optimal performance, Figures 17, 18.

Fig 17 : Ordinary welding

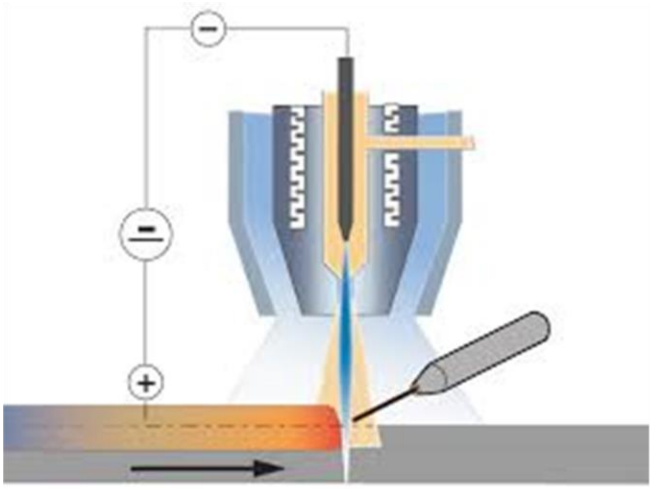

Fig 18 : Plasma welding

IV.5.2. Bolting:

Bolting consists of inserting a bolt (or screw) through the metal parts to be assembled and then tightening them with a nut. The tightening of the bolt creates a compressive force between the parts, ensuring the stability and strength of the assembly. This process relies on the application of tensile and compressive forces to hold the parts together.

IV.5.2.1. Bolt models:

Bolts are used according to applications and structural requirements:

a. Hex head bolts: These are the most common bolts, used for standard assemblies. They are often accompanied by a nut and washer to distribute the pressure and avoid damage to parts.

b. Square head bolts: Less common, these bolts are used in applications where high strength is required, or in situations where space for a key is limited.

c. Preload bolts high strength bolts: This type of bolt is designed to withstand strong tensile forces, often used in large metal constructions bridges, large structures. This type of bolt must be tightened to a precise preload to ensure good performance.

d. Self-drilling threaded socket bolts: They allow you to drill through the metal and fix them directly without requiring any prior drilling. Used in lightweight or prefabricated metal structures.

IV.5.2.2. Advantages of bolting:

Bolting has many advantages in welding or different assembly methods:

a. Ease of assembly and disassembly: Unlike welding, which is permanent, bolting allows the parts to be disassembled without destroying the assembly. This can be crucial in cases where structures need to be dismantled or modified.

b. Less thermal deformation: Bolting does not cause intense heat, so there is no risk of thermal deformation, unlike welding which can cause tensions in the materials.

c. Less specialized technical skills: Although bolt assembly require, knowledge to tighten them properly especially with precise tightening torques), it does not require as specialized training as welding.

d.Versatility: Bolting is particularly useful for temporary or demountable assemblies, such as in prefabricated structures or industrial installations.

e. Inspection and maintenance: Bolts can be easily inspected for condition and tightening, and can be replaced as needed without affecting the rest of the structure.

IV.5.2.3. Disadvantages of bolting:

However, bolting also has some limitations:

a. Weight and footprint: Bolted assemblies require additional elements such as washers and nuts, which can add weight and space compared to a more discreet welded assembly.

b. Aesthetic: Bolts, nuts and washers are often visible, which can affect the appearance of certain structures, especially in buildings where aesthetics is important (such as public buildings or large-scale architectural projects).

c. Corrosion hazards: Bolts, especially outdoors, can be subject to rust and corrosion. However, protective treatments such as galvanizing or the use of stainless bolts can minimize this problem.

d. Tightening: The bolting should be checked regularly to ensure that the bolts do not loosen due to vibration or load. This may require periodic inspections.

IV.5.2.4.Applications of bolting in architecture and engineering:

Bolting is commonly used in many types of metal structures, such as:

a. Metal bridges and steel structures: Bolting is widely used to assemble bridge elements or large metal structures, as it maintains stability and allows for quick adjustments if necessary. It is also a way to assemble prefabricated bridge sections.

b. Large buildings and towers: Building structures, including skyscrapers and other large steel constructions, may use bolted assemblies for metal structural elements. This allows faster assembly, with less risk of material deformation.

c. Industrial facilities: Heavy equipment and industrial structures such as tanks, towers, and pylons are often bolted together due to their ease of assembly and disassembly.

d. Temporary and removable structures: Temporary constructions such as scaffolding, marquees or exhibition installations often use bolted assemblies because they allow them to be easily disassembled and reused.

IV.5.2.5. Design criteria for bolting:

In order to achieve a feasible bolted assembly, the following criteria must be met:

a. Torque: It is essential to maintain a precise torque to prevent bolts from loosening under load or becoming too tight, which could damage metal parts.

b. Force Balancing: The bolts must be positioned so that the loads are evenly distributed between the assembled parts.

c. Corrosion protection: In outdoor or marine environments, galvanized or stainless steel bolts can be used to prevent rust.

d. Vibration and dynamics: In structures subjected to vibration or dynamic loads for example, in bridges or industrial facilities , locking devices such as brake washers or locking nuts may be used to prevent loosening.

Bolting has conditions to be met which are; bolt holes must be carefully drilled. The diameter of the bolts being 1mm lower than its hole. Bolting is a flexible, fast and widely used method for assembling metal structures. Although it may be less discreet and more cumbersome than welding, maintenance and ease of execution. Bolting can be a particular choice, Figures 19.

Fig 19 : Bolting of sections

IV.6. Assembly of metal structures in buildings and industrial halls:

Structural assemblies in buildings, especially for industrial halls, ensure the stability and durability of buildings. They are essential in the design of structures that must withstand heavy loads while remaining flexible and resistant. Here is an overview of the main types of assemblies used in these contexts:

IV.6.1.Weld connections:

Welding is a common method for connecting metal elements together, creating strong and durable joints. The most commonly used types of welding include curve welding, MIG (Metal Inert Gas) welding, and TIG (Tungsten Inert Gas) welding. Benefits, allows single-block connections, improves rigidity, and is widely used in projects requiring high strength. Disadvantages, may cause thermal deformation or local weakness if improperly executed.

IV.6.2. Bolting assemblies:

The bolts are used to connect metal elements in a dismountable way. They are often used in industrial halls for assemblies of load-bearing structures such as beams and columns. Benefits, easy to assemble and disassemble, ideal for modular structures. It also allows easier control of element strength. Disadvantages, Unscrewing or loosening the bolts may be an issue under certain vibration conditions.

IV.6.3. Riveting assemblies:

Although less used today than welding and bolting, riveting remains a reliable method for metal assemblies. It involves drilling holes in the metal elements and using rivets to fix them together. Benefits very resistant to fatigue, little sensitive to vibrations. Cons; Less flexible in terms of disassembly and requires more meticulous work.

IV.6.4. Screw and nut assemblies:

Very similar to bolting, but with greater precision in the alignment of the elements. Screws and nuts are used where high precision and resistance to very specific loads is required. Benefits ,practical removable, easy to install. Disadvantages, slower than welding and riveting for smaller or more complex structures.

IV.6.5. Nesting:

This type of assembly involves inserting metal elements into other elements to create a connection, often used for frames of light metal structures. Benefits, Easy to assemble, low cost. Disadvantages, less robust for heavy loads.

IV.6.6. Slip or dowel joints:

This type is particularly useful in the construction of light structures or for applications where some mobility or flexibility is required. It can also be used to reduce stress on metal elements subjected to temperature variations.

IV.7. Assembly of metal structures in building:

The assembly of structural elements in the building is a crucial aspect of architecture and civil engineering. This requires various types of metallic materials mainly steel and techniques to ensure the stability, strength and durability of structures. Here is an overview of the main elements and processes in steel structure assembly.

IV.7.1. Metal components:

Beams and columns, are the main load-bearing elements in a metal structure. They are often made from steel profiles, such as IPE, HEA, or HEB. Hoppers, Beams and Spacing, are horizontal elements that distribute the loads evenly. Connectors and bolts, essential elements for assembly. Bolts are often used in metal structures, but welds can also be used for permanent joints.

d. Metal platforms and stairs:

These elements are often made of steel to ensure robustness and durability.

IV.7.2.Welding methods:

Welding is a permanent joining technique used to join metal elements, such as beams and columns. It can be made by arc welding, TIG, MIG, etc.

IV.7.3. Bolted assembly methods:

Used to facilitate on-site assembly, the bolted joint allows metal elements to be fixed together using bolts. This method has the advantage of being dismountable if necessary. Riveting, although this technique is less and less used, riveting was once commonly used for metal structures. The rivets are heated and then struck to fix two metal elements together.

IV.7.4. Modern and advanced techniques, modular assembly:

Today, many metal structures are manufactured as prefabricated modules. This allows for faster on-site assembly, better manufacturing quality and less risk of human error.

IV.7.5. Digital technologies and 3D modelling:

The use of software such as BIM (Building Information Modeling) facilitates the design, simulation and assembly of steel structures. This allows potentially critical errors to be detected before actual construction begins.

IV.7.6.Laser cutting and punching:

These technologies allow for more accurate assemblies and reduce human errors. They are commonly used to cut steel sheets and metal profiles before assembly.

IV.7.7. Safety requirements:

Safety is essential during the assembly of metal structures, especially when using large metal parts and working at height. Strict standards are put in place to prevent accidents, whether during the manufacturing phase or on-site assembly.

Regular inspection of metal assemblies for possible cracks, deformations or corrosions is also essential to ensure the durability and safety of the structure.

IV.7.8. Advantages and challenges of steel structures:

a. Benefits:

It is a light and strong material, allows the reduction of the weight of buildings while ensuring high stability. Metal structures are more resistant to fire and earthquakes than other materials such as concrete. They offer great flexibility for future modifications or extensions.

b. Challenges:

Corrosion is a major problem for metal structures, especially in wetlands or marine areas. This requires regular maintenance and corrosion protection. The costs can be relatively high compared to other materials such as concrete, in part because of the need for custom manufacturing, Figures 20.

Fig 20 : The joining of sections with bolting

IV.8. Assembly of metal structures in industrial halls:

This is a crucial aspect of the construction of spaces. Metal structures are often chosen for their durability, their ability to cover large spans without the need for intermediate supports, and their speed of construction. The following are some important points regarding steel structure assemblies in this context:

IV.8.1. Bolted assemblies:

Very common in industrial halls, bolts allow fast and reversible assemblies. They are often used to assemble beams, columns and other structural elements.

IV.8.2.Welded assemblies:

It is used for more permanent joints and provides better strength; it is frequently used for joints between sections of metal profiles.

IV.8.3. Riveted assemblies:

Although less common today, rivets were used in ancient metal structures such as those of bridges or industrial buildings from the early 20th century.

IV.8.4. Main components in industrial halls:

Main components in industrial halls are; Columns; often made of profile steel (IPE, HEA, HEB) to withstand vertical loads. Beams; metal beams are used to support roofs and floors, usually steel or rolled steel beams. Ligatures and spacers; these elements are used to stabilize the structure and prevent deformation under load. Roof panels, often made of metal or sandwich materials, roofing panels can be fixed by screws, bolts or clip systems.

IV.8.5. Specific assembly methods:

High strength bolt assemblies; very common in modern industrial halls for their ease of execution and competitive cost. These bolts are often used in column and beam joints. Spot or continuous welding, the welds are made to ensure continuity between the metal elements. Continuous welding is often used for sections under heavy loads, whereas spot welding may be sufficient for less stressed assemblies. Assemblies with plates and brackets, metal plates and brackets may be used to reinforce the assembly of beams or columns, particularly in areas subject to torsion or bending forces.

IV.8.6. Challenges in the assembly of metal structures:

Alignment and accuracy; the assembly of metal structures requires great precision to ensure the correct alignment of the different elements. Deformations due to assembly errors or manufacturing tolerances can compromise the stability of the structure. Quality control and testing, metal assemblies shall be inspected by experts for defects in welds or bolts. Non-destructive tests such as ultrasonic or radiographic testing are used to check the quality of welds. Thermal impact, taking into account the thermal impact on the structure is essential, in particular to avoid deformations. It is also important to avoid cracks due to excessive heat.

IV.9. Eurocodes construction standards and codes:

In Europe, Eurocodes such as Eurocode 3 for steel structures, provide guidance on metal structures.

IV.9.1. National Standards:

There are also specific standards for each country, such as the French standard NF EN 1993 or the American standard AISC for steel constructions. The combination of these design elements and assembly methods ensures not only the safety of the structure, but also its efficiency in terms of cost and construction time, figures 21, 22, 23.

Fig 21 : Fastener bolt

Figure 22 : Mechanical bolt assembly

Fig 23 : Mechanical assembly

Conclusion:

Metallic and mixed structures refer to construction structures that incorporate mainly metal elements steel, aluminium, etc. Or a combination of metal and other materials such as concrete or wood. Mixed structures are structures that combine metal with other materials, including reinforced concrete steel-concrete composite beams, collaborative floors, etc. to optimize mechanical and economic performance. Metal structures are structures constructed entirely or mainly of metal; examples: steel bridges, metal frames, towers, industrial buildings.

Considering the importance of metallic and mixed structures in the fields; economic less long-term costs due to sustainability and reuse of materials; environmental steel is 100% recyclable, which promotes sustainable construction; technological allows innovation in engineering and architecture such as large spans and complex shapes; safe good resistance to earthquakes and extreme loads such as wind and snow, etc.

The utility of metallic and mixed structures has been distinguished by the advantages they offer; modularity and flexibility ideal for scalable buildings or demountable structures. Steel allows to design resistant structures while remaining relatively light; adaptability suitable for industrial buildings, commercial buildings, bridges, skyscrapers and even complex works of art; speed of execution manufacturing in workshop and rapid assembly on site; reduction of waste,less material waste, especially in prefabricated structures.

CHAPTER V: INTRODUCTION TO THE DIFFERENT REGULATIONS.

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Introduction:

The regulation of a construction derives from its nature, the regulation is carried out for the purpose of raise the quality of safety, facilitate accessibility to the building and evacuation of people in case of danger such as fire or earthquake. Ensure sound and noise insulation, build a well-ventilated structure, and to achieve a traffic convenience for the disabled and elderly.

V.1.Introduction to different construction standards, BAEL standards and eurocodes:

V.1.1.The BAEL standards:

The BAEL standards reinforced Concrete in Boundary States, are technical rules in French reinforced concrete that introduces the designs of the works all the more their calculations subsequent to the process of the boundary states, the dimensioning of reinforced concrete structures based on limit states ultimate limit state - ELU, and service limit state - ELS. Their classification indices are: P18.702; and their Eurocode standards are NF EN1992.1.1.These standards are now largely replaced by Eurocode 2 (1992), but still used as a reference or in some specific contexts. Here is a detailed presentation of the BAEL standards in particular the revised version BAEL 91 99 which is the most common before the introduction of Eurocode 2:

V.1.1.1. Fundamental principles of the BAEL:

BAEL is based on the concept of boundary states, ultimate Limit State (ELU), prevents collapse, ensures safety. Service Limit State (ELS): limits deformations, cracks and vibrations for normal use of the structure.

V.1.1.2. Materials used: The materials used are concrete and steel**. Steel;** type: HA (High Adhesion), typically FeE 500 (f_y = 500 MPa). Modulus of elasticity: E = 210,000 MPa. Mechanical grip ensured by the ribbed shape. Concrete; features: compression strength (f_{ck}), density, modulus of elasticity. Common classes, B20, B25, B30, B35, B40; the characteristic resistance is measured at 28 days.

V.1.1.3.Calculation assumptions:

Flat sections remain flat after deformation Bernoulli hypothesis, concrete has no tensile strength, bilinear model for steel elastic perfectly plastic. Concrete compression stress; equivalent parable-rectangle or rectangular, depending on the case.

V.1.1.4.States Limits:

Ultimate Limit State (ELU), checks the tensile strength of sections bent, compressed or subjected to compound forces (tensile, bending, torsion...).

• ELU Sizing**:**

$$\gamma_f \cdot F_d \leq R_d$$

where:

γ f: safety coefficient (often 1.5 for loads),

Fd: calculation solicitation,

Rd: section resistance.

b. Service Limit Status (SLA):

• Deformations: maximum deflection to be respected.

• Cracking: controlled crack width (< 0.3 mm in general).

• Material constraints not to be exceeded.

V.1.1.5.Solicitation cases processed:

Simple bending, calculation of the tensioned and compressed reinforcement; shear force, check with or without transverse reinforcement calipers. Twisting, often combined with shear; normal force + bending: check for compressed beams and poles. Anchors and connections: anchor and overlay lengths.

V.1.1.6.Practical sizing:

Bending basic formula, rectangular section:

$$M_{Rd} = A_s \cdot f_{yd} \cdot z$$

with:

As: steel section,

fyd: calculation constraint of the steel,

z: lever arm.

b. Cutting edge:

• Verification of shear stress T =V/(b z).

• If T>Tlim, stirrups are required.

V.1.1.7.Partial coefficients :

• Permanent charges : γ G=1.35

• Operating expenses: γ Q=1.5

• Material strength:

Concrete: γ c=1.5

Steel: γ s=1.15

V.1.1.8.Cracking:

Crack width check**:**

$$W = s_r \cdot \varepsilon_m$$

where:

sr: crack spacing,

ε m : mean deformation of steel.

V.1.1.9.Defects and limitations of BAEL:

Sometimes too simplified approach, example for highly stressed or atypical structures. Not fully compatible with current European standards Eurocode 2.

V.1.1.10.Transition to Eurocode 2:

Eurocode 2 is now the reference standard in France for reinforced concrete; more comprehensive, suitable for calculation software; incorporates the more advanced concept of probabilistic reliability.

V.1.2.Eurocodes:

Eurocodes are a set of European standards developed to standardize the design, calculation and verification of safety of structures in the field of building and civil engineering across Europe. They cover all common structural materials concrete, steel, wood, masonry, aluminum, as well as actions on structures loads, wind, snow, earthquakes, etc., calculation bases, and geotechnical rules.

V.1.2.1.Origin and development:

The Eurocodes were developed by the European Committee for Standardization (CEN) at the request of the European Commission. Their development began in the 1970, and they became officially European standards (EN) from the 1990, gradually replacing the national standards of the Member States. Each Eurocode is published in the format EN 199x, where x represents the domain of the structure. They are complemented by National Annexes (NA) which allow each country to adapt certain parameters safety factors, climatic conditions, characteristics of local materials....

V.1.2.2.Fundamental objectives of the Eurocodes:

The Eurocodes are intended to ensure a consistent level of safety and reliability in construction at the European scale; Facilitate trade and the free provision of services in the construction sector across the EU. Replace national standards with a unified framework, and foster innovation and technological development in structural design and analysis methods. The Eurocodes are European standards related to civil engineering works, including:

• Bridges.
• Airports.
• The dams.
• The tunnels.
• Nuclear power plants.
• Underground works.
• Major architectural works.

The Eurocodes are also standards relating to the design of buildings and their calculations. These standards provide two (02) major parameters:

a. The stability of the structure.

b. Eurocodes for resistance to unforeseen events such as fires or earthquakes.

V.1.2.3.Structure of the Eurocodes:

The calculation of structures is not fixed, because texts are optional and depend on special choices that have a relationship with the national context or that depends on the specificities of the project nature.

There are ten (10) families of Eurocodes:

1. Eurocode N°0 (1990): aims at the foundations of calculation of structures.
2. Eurocode N°1 (1991): refers to acts on structures.
3. Eurocode N°2 (1992): refers to the calculation of concrete structures.
4. Eurocode N°3 (1993): refers to the calculations of steel structures.
5. Eurocode N°4 (1994): refers to the calculations of steel-concrete mixed structures.
6. Eurocode N°5 (1995): refers to the calculation of wooden structures.
7. Eurocode N°6 (1996): refers to the calculation of masonry structures.
8. Eurocode N°7 (1997): for the calculation of geotechnical structures.
9. Eurocode N°8 (1998): for calculations of the resistance of structures to earthquakes.
10. Eurocode N°9 (1999): refers to calculations of structures made of aluminium alloys.

Conclusion:

The application of BAEL technical rules is important during the design of works also the calculations of boundary states, in order to guarantee the safety of construction and users, even of the workers, since the moderation of the reinforced concrete structure is based on the calculations of the boundary states.

The ten (10) families of Eurocode constitute 58 homogeneous and harmonized standards that apply and adapt with the different types of constructions, with the variety of materials that compose them.

CHAPTER VI: SEISMIC RULES RPA 2024.

CHAPTER VI: THE SEISMIC RULES RPA 2024.

Introduction:

The Algerian RPA seismic regulation, which was granted by the Permanent Technical Commission ,CTP in 1999; aimed at the protection of buildings and their users; Algeria has had a terrible experience with the earthquake, particularly between the years 1980 and 2003. RPA 99 version 2003, is the third version that was preceded by RPA 81; after the earthquake, which caused the death of more than 3000 people on October 10, 1880, followed by an update to the 1983 version; RPA 81 was created to calculate seismic force; The latter is based on the equivalent static method. A new calculation method has been introduced in RPA 81; this is the method of spectral modal analysis, which was the subject of the appearance of RPA 88. In 1999 a new calculation method was added to the appendix, it was the spectral modal dynamic method, in addition to the seismic rules became more complete than before, which made the RPA 99 appear and because of the earthquake of May 21, 2003 of Boumerdés which caused a tragedy; more than 10,000 wounded and more than 2,300 dead. RPA 99 was followed by a revision in 2003 and in was developed with RPA 2024 .

VI. 1. Criteria for the classification of works 2003:

For the classification of works, there are two criteria:

VI. 1. 1. Their Configurations:

The configuration of the structures is summarized in three ,03 classifications:

- The balance of the template.
- Regularity in height.
- Homogeneity in plan.

VI. 1. 2. Their importance:

We give the four 04 groups of works classified according to their usefulness:

- Works of vital importance: 1A
- Works of great importance: 1B
- Current works: 2
- Structures of low importance: 3
- The criteria for classifying works in this volume are mainly based on the acceleration coefficient of zones A.

Tableau 01 : Value of the zone acceleration coefficients.

Groupe	I	II a	II b	III
1A	0.15	0.25	0.30	0.40
1B	0.12	0.20	0.25	0.30
2	0.10	0.15	0.20	0.25
3	0.07	0.10	0.14	0.18

Source : RPA 99-version 2003/RCAD ING P, 02.

VI. 2. General rules of seismic zone design 2010:

The seismicity zones of the territory have been set according to Decree N° 2010-1254 of 22 October 2010, which resolved the acts of seismic risk protection, three 03 hierarchical zones identified as follows, negligible hazard:

- Zone 0. Low hazard:
- Zone 1. Medium hazard:
- Zone 2. High hazard:
- Zone 3.

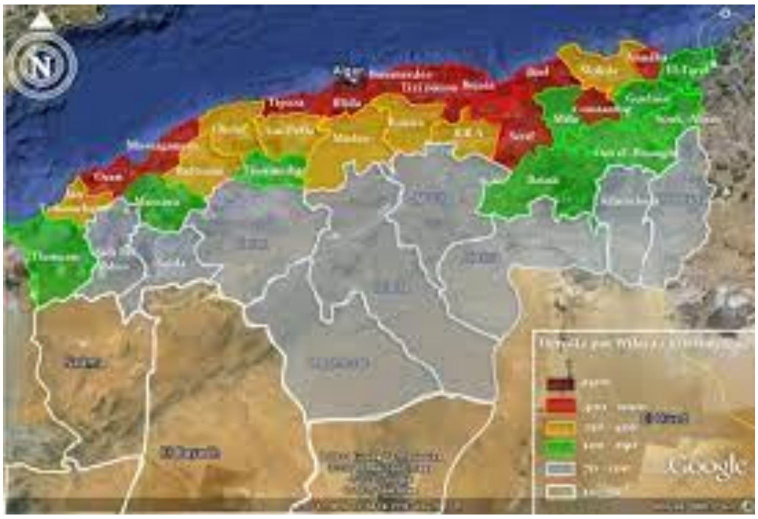

Fig. 24: Seismic zones in Algeria

VI.3. The Algerian seismic code RPA 2024

The Algerian Seismic Code RPA 2024 constitutes the most recent national reference for the design and sizing of structures subjected to seismic actions. Officially published in 2024, it replaces previous versions, particularly RPA 99/2003, which had long been used as the normative base in Algeria. The enforcement of this new regulation marks a major evolution in design, analysis, and inspection practices, both for new constructions and for rehabilitation projects. RPA 2024 is a major update of Algeria's seismic regulations. It reflects a national commitment to improving the resilience of buildings against natural hazards, integrating technological advances, and strengthening public safety. With refined seismic zoning, an accurate soil classification, modern calculation methods, and rigorous structural rules, this code serves as an essential reference for the design and assessment of structures in seismic zones. Each zone is associated with a seismic intensity level used to define the design seismic forces.

VI.3.1. Objectives of RPA 2024:

Adapting the code to new materials and techniques; It now includes new structural strengthening techniques, base isolation systems, mixed systems, steel–concrete, and lightweight constructions wood, structural panels. Modernizing calculation methods; the code adopts more rigorous approaches concerning ductility and energy dissipation, displacement and drift control, collapse mechanisms, structural modeling, and consideration of dynamic behavior. Enhancing the seismic safety level By integrating the most recent scientific knowledge, feedback from past earthquakes in Algeria, Chlef, Boumerdés, Mila…, and international advances in earthquake engineering. Redefining zoning and soil categories, to refine seismic risk assessment across regions and improve the relevance of seismic actions assigned to construction projects.

VI.3.2. Updated seismic zoning:

RPA 2024 introduces a new division of the Algerian territory into seismic zones based on a more precise geological and seism tectonic analysis, taking into account the seismic history, characteristics of sedimentary basins, active faults, and peak ground accelerations.

VI.3.3. Soil classification:

The regulation introduces a more detailed classification of soils based on their deformation capacity, liquefaction potential, local amplification risks, dynamic properties, and stiffness. This classification directly influences the seismic response spectrum used in calculations.

VI.3.4. Structural design:

RPA 2024 is based on three essential principles:

VI.3.5. Regularity:

Encouraging simple structural forms: continuity, symmetry, homogeneous stiffness, and absence of vertical or horizontal discontinuities. Design favors progressive collapse mechanisms rather than sudden failures.

VI.3.6. Strength:

Ensuring that structural elements possess the required capacity to withstand amplified seismic actions.

VI.3.7. Ductility:

Promoting energy dissipation mechanisms, enabling the structure to undergo significant deformations without brittle failure.

VI.3.8. Calculation and analysis methods:

The code specifies the following methods:

VI.3.8.1. Modal response spectrum analysis:

Recommended for medium- to high-rise or irregular buildings.

VI.3.8.2. Nonlinear analysis:

Used for complex structures, ductility verification, seismic isolation techniques, and innovative systems.

VI.3.8.3. Equivalent static analysis:

Suitable for regular and low-rise structures. RPA 2024 strengthens requirements regarding load combinations, drift calculation, force redistribution, and performance conditions.

VI.4. Requirements applied to materials and structural systems:

The regulation provides detailed guidance for masonry; usage limitations according to zone, reinforcement through tie beams, height restrictions; and mixed structures, steel-concrete force transfer, composite behavior.

VI.4.1. Steel structures:

Deformation tolerance, global stability, continuity of connections, buckling protection.

VI.4.2. Reinforced concrete:

Design of dissipative zones, detailing of reinforcement, confinement of joints, reinforcement rules in critical regions.

VI.5. Modern techniques:

Base isolation, dampers, and energy dissipation devices.

VI.6. Existing and heritage structures:

RPA 2024 provides a framework for seismic studies of existing buildings, including; preliminary diagnosis, modeling adapted to historical structures, and analysis of potential failure modes; strengthening strategies compatible with original materials, heritage constraints, and conservation objectives.

VI.7. Regulatory scope:

RPA 2024 applies to all new constructions, extensions, vertical extensions, transformations, public or private projects, strategic infrastructures ,schools, hospitals, barracks…, and industrial projects.

Conclusion:

In conclusion, these rules are essential to ensure safe and sustainable construction in Algeria. They must be scrupulously respected by all actors in the building and public works sector.

The strict application of RPA 2024 allows; protect human lives by reducing the risk of collapse, minimize property damage and ensure business continuity, meet international standards and improve building quality, and strengthen urban resilience to natural disasters**.**

CHAPTER VII: VERIFICATION OF REINFORCED CONCRETE STRUCTURES

CHAPTER VII: VERIFICATION OF REINFORCED CONCRETE STRUCTURES

Introduction:

This chapter provides an overview of the primary steps in the structural assessment of reinforced concrete structures within the scope of civil engineering design and analysis. The primary purpose of the structural assessment is to confirm that the structural components meet the guidelines outlined in the relevant code regarding their safety, strength, stability, and durability. The first part of the chapter discusses how to determine and combine the forces that act on reinforced concrete structures. Permanent, variable, and accidental loads will be defined and combined to create reference states that will be used for structural assessment. The second part of the chapter describes how to assess the load-bearing capability of reinforced concrete elements. The assessment should determine the forces of compression, tension, bending, shear, and torsion experienced by the structure throughout its lifespan and ensure that the structure will continue to have the ability to withstand these forces for the duration required. The third part of the chapter describes how the reinforced concrete structure must maintain structural equilibrium when subjected to combined loading conditions, so as to not be in danger of overturning, sliding, or encountering excessive deflection. The primary focus of the fourth section is the stability of foundations.

VII. 1. Combination of action:

VII. 1. 1. Definition:

Combined actions are an essential element in designing and verifying reinforced concrete structures because they ensure that the structure will remain stable, safe, and able to withstand the effects of environmental loading over time. The state-of-the-art engineering methods being used in designing reinforced concrete structures include the evaluation of combined action using the principles of Eurocodes 0, 1, and 2, all of which require that the design/verification process considers all applicable loading conditions as one entity, the combined action. This approach is intended to eliminate or reduce the risk of negative impacts on both the structural performance and overall integrity of the structure.

VII. 1. 2. Objectives:

The combination of actions involves considering multiple types of loads that may act together on a structure to estimate the most critical internal forces. The objectives are to ensure that the structure remains safe against failure ULS; guarantee its proper behavior in service SLS without excessive deformation or cracking; represent the real operating conditions of the structure. Each action combination therefore corresponds to a representative load case of a specific operational situation a structure under construction, in service, or subjected to exceptional actions such as an earthquake or wind.

VII. 1. 3. Classification of actions:

On a structure, applied actions can be classified according to the following criteria:

VII. 1. 3. 1. By nature:

There are three distinct actions that relate to the behavior of concrete during delayed reaction or curable ; shrinkage and creep are two examples; thermal action, for example, contraction and expansion, occurs when temperature fluctuates. Mechanical action, which includes any force applied, such as the weight of an object, any live load placed on it people or furniture, pressure from objects located somewhere else.

VII. 1. 3. 2. By variation:

Over time there is a minor distinction between application and variable actions. Generally, accidental actions, or A, are rare occurrences infrequent, and as such, their duration is minimal when they do occur; impact, earthquake, explosion, variable actions, or Q, fluctuate and evolve as time progresses especially magnitude. The location at which the action is located changes, and the directions of the action change examples of variable actions are both live loading imposed by people furniture, snow load, wind load and temperature load. Permanent actions are classified as G, and as such, there is little to no change in G over time for examples of G are the self-weight of all structural pieces, coverings placed on those pieces, all fixed furniture and equipment permanently attached to the structure.

VII. 1. 4. Principles of action combination:

Concrete design guides have identified a number of different combinations of combinations to be considered for analysis or design based on the limit state

VI. 1. 4. 1. At ultimate limit states ULS:

The purpose of the ultimate limit states ULS action combinations is to ensure the safety of the structure based solely on action combinations. According to Eurocode 0, the equation for determining the ULS action is:

$$\text{ULS: } \sum G_k + \gamma_Q \cdot Q_k$$

Or more precisely:

$$\gamma_G \cdot \sum G_k + \gamma_Q \cdot Q_{k,1} + \sum \psi_{0,i} \cdot \gamma_Q \cdot Q_{k,i}$$

where:

- $\mathbf{G_k}$ = characteristic values of permanent actions,
- $\mathbf{Q_{k,1}}$ = leading variable action,
- $\mathbf{Q_{k,i}}$ = other simultaneous variable actions,
- $\boldsymbol{\gamma_G, \gamma_Q}$ = partial safety factors,
- $\boldsymbol{\psi_{0,i}}$ = combination factors.

These factors take into account uncertainties in the loads and material strengths.

VII. 1. 4. 2. At serviceability limit states SLS:

Serviceability limit states SLS describe conditions in which a structure will have little or no adverse impact on the utility of a building structure. These combinations of serviceability limit states can determine how comfortable a user feels when using the structure, how long the structure may remain durable with respect to components responding to excessive vibrations and cracking, and how the adhesion rate of components will evolve over time:

- **Quasipermanent combination:**

$$\sum G_k + \sum \psi_{2,i} Q_{k,i}$$

- **Frequent combination:**

$$\sum G_k + Q_{k,1} + \sum \psi_{1,i} Q_{k,i}$$

- **Rare combination:**

$$\sum G_k + Q_{k,1} + \sum \psi_{0,i} Q_{k,i}$$

There are three types of SLS combinations; coefficients ψ0, ψ1, ψ2 are used to determine the like lihood of multiple loads acting at the same time.

VII. 1. 5. Practical application

Let us take a simplified example of a floor slab:

- Self weight of concrete G: 4.0 Kn/m²
- Floor finishing + partition G: 1.5 Kn/m²
- Live load Q: 3.0 Kn/m²

The combination can be written as:

$$1.35G + 1.5Q = 1.355.5 + 1.53.0 = 12.675 \text{ Kn/m}^2$$

VII. 1. 6. Importance of action combination:

The various loading combinations that provide the structure with a legal structure, according to building codes. Financially acceptable economical and realistic to what the structure actually does minimize both the chance of under or over design of a concrete structure, given that the actual loading will vary throughout the life span of a structure, and ensure that the structure can safely carry its required loads.

VII.1.7. Load combinations according to the BAEL 91/99 regulations:

The topic of load combinations is of utmost importance for the design and verification of reinforced concrete structures according to BAEL 91/99, through the load combination system; that provides a method for combining adding together. The three types of actions used to calculate the development of a reinforced concrete structure using the partial safety factors assigned to each of the types of actions. Thus, the ultimate goal of this system to ensure, structural safety, ultimate limit states ULS, Acceptable performance at serviceability limit state SLS by taking into account the uncertainties in loads and the probabilities that they will coincide.

VII.1.7.1. Classification of actions in BAEL:

Permanent Actions G, as fixed partitions and floor coverings have always existed and continue to exist, the loads they impose on the building structural system are constant over the life of the building. Furthermore, the loads of the fixed partitions, floor coverings, and their own weight, are not significantly changing, the fixed partition walls are dead loads that are always self supporting. Variable Actions Q, the following loads will likely change over time climatic load wind or snow, additional loads, and store load. Accidental Actions A, these loads fall under the category of exceptional loads impact accidental or deliberate collision with a physical object, fire, and explosion.

VII.1.7.2. Limit states considered:

a. Ultimate limit state ULS

The ultimate limit state ULS combination is based on a higher safety factor γ to ensure that the structure can withstand the worst case scenario.

b. Serviceability limit state SLS

The serviceability limit state SLS , for details of SLS discussion see below; limits deflection and provides a level of comfort to users and controls cracking. SLS combinations are divided into, categories frequent, rare and quasi permanent. Dep ending on the type of effect being considered, different categories would be used.

VII.1.7.3. Load combinations at ULS:

General form for a fundamental situation:

$$\Sigma_{ULS}=1.35\ G+1.50\ Q_1+1.50\ \psi_0 Q_2+1.50\ \psi_0 Q_3+\ldots$$

A load combination will consist of one leading variable action and the rest of the variable actions multiplied by a reduction factor, ψ_0, particularly because the non leading variable actions do not all occur at their maximum value at the same time. Typical values of ψ_0

Synthetic Example

Given:

- *G* = 5 kN m²
- *Q* = 3 kN m² leading action
- *Wind* = 1 kN m² ψ_0 = 0.6

$$ULS=1.35\cdot 5+1.50\cdot 3+1.50\cdot 0.6\cdot 1=12.15\ Kn/\ m^2$$

VII.1.7.4. Load combinations at SLS:

SLS Rare, they will be used in crack control:

$$\Sigma_{rare}=G+Q_1+\psi_0 Q_2+\psi_0 Q_3+\ldots$$

SLS Frequent, they will be used in instantaneous deflection checks:

$$\Sigma_{freq}=G+\psi_1 Q_1+\psi_1 Q_2+\ldots$$

SLS Quasipermanent; They will be used to calculate long term deflection and creep:

$$\Sigma qp = G + \psi_2 Q_1 + \psi_2 Q_2 + \ldots$$

VII.1.7.5. Accidental combinations:

In terms of an exceptional action fire or impact:

$$\Sigma_{acc} = G + Q + A$$

The reduced partial factors used for these combinations, and therefore correspondingly reduced safety factors, may be assigned less weight because the probability of their simultaneous occurrence is low.

VII.1.7.6. Interpretation and role of BAEL load combinations:

The coefficient ψ and γ reflect, the real behaviour of a structural system when subject to various loading conditions, the need to have an adequate margin of safety for the structural system the possibility of the loading occurring simultaneously. The load combinations enable reliable structural design by incorporating the unknown uncertainties regarding the actual usage of a structure.

VII.1.8. Load combinations according to the RPA 2024 regulations

The new national reference framework for designing structures subject to seismic loads is the Algerian seismic design code RPA 2024. The code specifies the load types that should be investigated when designing structures, and also specifies how these loads should be combined to assess the structural behaviour under both seismic and no seismic loads to ensure that structures are safe, stable and resilient to permanent, variable and accidental actions, including seismic actions.

VII.1.8.1. Types of actions considered:

The structural design process as required by RPA 2024, includes several categories of actions. Permanent actions are all those loads that act continuously on the structure for example; the self weight of structural elements, fixed partitions, floor systems and surface finishes. Variable actions are those loads that may fluctuate over time, for example: live loads, occupancy related surplus effects and some climatic effects associated with the seismic situation. Seismic actions are considered to be accidental actions of exceptional nature and comprise the main horizontal components of ground acceleration plus, where applicable, a separate vertical component.

VII.1.8.2. General principles of RPA 2024 load combinations:

The load combinations used within the scope of RPA 2024 are used to create a composite load to establish the maximum demands to which the structure will be subjected. Every seismic action must always be applied with gravitational loads in combination, so that together they produce the overall load to design against; variable loads are only included in part ; a portion of the expected variable load, as there is only a small probability that the two loads will occur at the same time during a seismic event. So generally speaking, when applying loads we would take in addition to permanent loads, a portion of all of the variable loads , how much dep ends upon their nature; plus the seismic action acting in a specific direction usually the seismic direction.

VII.1.8.3. Consideration of seismic directions:

There are two main seismic action directions as defined by the RPA that should be evaluated separately for each of the two horizontal principal directions of the structure, x and y axis respectively. Thus, the RPA 2024 has introduced the concept of applying seismic loading alternatively along one axis, and then the other, while also potentially combining the same load with part of the seismic loads along the other direction combination event**.**

VII.1.8.4. General form of load combinations in seismic conditions

In general, therefore, each of the seismic action combinations defined in RPA 2024 can be written in a format similar to the following:

Permanent loads + reduced variable loads + seismic action.

The variable loads are reduced by a factor dep ending upon the type of variable load; live load vs. Occupancy surcharge etc. Seismic response is represented using one of the horizontal components of the design spectrum; whether or not the seismic action will be added to, reduced from, or removed from the design spectrum will dep and upon the specific case being analysed. In some circumstances, especially with respect to more sensitive structures, the vertical component of seismic action can be added to the combination as it significantly affects the internal force of the structure.

VII.1.8.5. Specific features of RPA 2024

The seismic code revisions include substantial improvements in the recognition of the effects of seismic loading. Following are some important revisions made to the seismic code as a result of changes made in the last decade to better understand the impact of seismic loading during earthquakes that occurred in Algeria, los Angeles, California, japan, and other parts of the world. An improved evaluation of the appropriateness of the combination of the multidirectional component of the seismic load during the design process. Greater precision in seismic loading parameters; a more systematic consideration of where it is necessary to include the vertical seismic effect within the design combination; stricter criteria for the verification that the structure meets the ductility, global stability, and displacement requirements for the structure. These improvements are designed to help achieve the highest degree of resiliency for structures that are subjected to seismic hazard within the most vulnerable regions of the country.

VII.1.8.6. Practical considerations for design:

In preparing structural analysis results associated with an RPA 2024 structural analysis report, it is recommended that all permanent, temporary, and accidental actions are clearly identified and included in the structural analysis report. The Seismic load combinations for the two principal directions be calculated; the reduction factors used to predict the seismic loads for all temporary actions are determined and provided with a justification whether to use them for the vertical component as well. All of the assumptions made, selected coefficients, and load cases must be clearly indicated. For each combination analysed provide calculated results of internal forces, displacement values, stress levels, and critical structural components.

VII.2. Verification of reinforced concrete structures with respect to strength:

Verification of reinforced concrete structures to strength is a scientific process which is used to ascertain that structures are safe, stable and durable. The verification relies on the true determination of the extreme design action, reliable material characterization, strict details during construction, and full analysis of failure modes the strength verification provides a means to determine that every structural member is capable of supporting the forces to be applied to it. Strength verification is the most important phase of the structural design process. The purpose of strength verification is to ensure that every component will have the capacity to resist extreme forces produced during the service life of the structure without reaching a limit state that could impose safety or stability risks. Strength verification is based on the concept of ultimate limit state ULS and applies partial safety factors to mitigate the uncertainties associated with design models, materials and actions. An element is considered satisfactory as long as it meets the following fundamental in equation:

$$Rd \geq Ed$$

• Rd: Ultimate resistance of a structural section

• Ed: Effects of the actions increased according to the most unfavorable ULS combinations. This approach provides a structure with a sufficient degree of safety to prevent failure mode under extreme loading conditions.

VII.2.1. Mechanical properties of materials and safety factors:

In order to verify the strength of structure, the designer must have a complete understanding of all mechanical properties associated with the concrete as well as the reinforcing steel, and the unknowns related to them.

VII.2.2. Characteristics, behaviour, and influencing parameters of concrete:

Concrete is a composite material that does not possess uniform properties, and the mechanical properties dep and primarily on the following, concrete mix method and amount of compaction type of aggregate cure conditions age of concrete etc. The design of concrete compressive strength is based on the characteristic compressive strength measured at 28 days, also referred to as $\mathbf{f_{ck}}$. A partial safety factor $\boldsymbol{\gamma_c}$ is applied to account for the uncertainty of construction data in order to obtain the design strength:

$$\mathbf{f_{cd} = f_{ck}/\gamma_c}$$

Important factors to consider in concrete design include: non linear behaviour of concrete under compression and a gradual increase in load to reach brittle break. Low tensile strength, leading to a requirement for reinforcement. Time related effects creep, shrinkage, on deformation and equilibrium of forces, and environmental effects moisture, carbonation, chemical attack on durability and therefore strength.

VII.2.3. Mechanical properties and structural role of reinforcing steel: Reinforcing steel, by its properties, possesses a high yield strength $\mathbf{f_{yk}}$, good ductility, and a strong bond to concrete and is therefore the design strength:

$$\mathbf{f_{yd} = f_{yk}/\gamma_s}$$

The reinforcing steel is given by the ability to resist tensile forces which are incapable of being sustained by a solid mass is a primary function of the steel concrete composite element. It also supplies the ductility necessary to warn of imp ending failure. The quality of the steel concrete bond is significant in the transfer of load.

VII.2.4. Determination of design actions:

The evaluation of design actions is through either static or dynamic analysis and is derived from a combination of :

VII.2.4.1. Permanent actions G:

Weights of structural elements and their impacts, all fixed partitions and recommended finishes. Equipment that will be supplied and installed as part of the structure and remain attached to the structure for its life span.

VII.2.4.2. Variable actions Q:

All live loads at all points on the structure; include at least one PW60 consideration per occupant on all levels, climatic loads associated with snow and wind. All usage surcharge loads, as previously specified, and any combination thereof.

VII.2.4.3. Accidental actions A:

All accidental actions that may impact the structure: the earthquake action, impact damage, fire, and explosion; each of which may or may not cause additional loading to surrounding building elements. ULS combinations must be reported in accordance with the formulas included in the building code and will have associated with them Partial Safety Factors for all actions $\boldsymbol{\gamma_G}$ and $\boldsymbol{\gamma_Q}$, and combination factors ψ with the intent of maximizing the design effects; b ending moments, shear forces, axial forces, torsion:

$$E_d = M_{Ed}, V_{Ed}, N_{Ed}, T_{Ed}$$

VII.2.5. Study of failure modes and associated checks:

All elements are also required to be verified against all possible failure modes as the strength of a structure is determined by the type of loading that is most relevant.

VII.2.5.1. Flexural failure simple or combined b ending:

Flexural failure , simple or combined b ending, beams and slabs will generally fail due to b ending actions; verification of this action will establish :

$$M_{Rd} \geq M_{Ed}$$

Resistance dep ends on the resistance based on the concrete compression zone's load carrying capacity, the tensile capacity of reinforcement, the position of the neutral axis, and the ratio of reinforcements, however, must be maintained below the prescribed minimum and above the prescribed maximum limits.

VII.2.5.2. Shear failure:

Shear failures are usually abrupt and occur when the structural member experiences rapid diagonal cracking. Therefore, the resistance for shear failures is derived from the inherent concrete capacity, the amount of transverse reinforcement afforded to the system:

$$V_{Rd} \geq V_{Ed}$$

VII.2.5.3. Compression or buckling failure:

It is important to verify the performance of compression members columns, walls, especially when they have a moment arm eccentricity. The types of loads on these members include axial force moment interaction, global stability, and buckling Behaviour, which can be influenced by effective length of the member, longitudinal and transverse rigidity of the member and overall resistance to buckling. The method of verification for axial load, moment interaction and buckling behaviour is to use stability curves.

VII.2.5.4. Torsion and complex interactions:

Torsion can act individually or with b ending and shear. Additional longitudinal and transverse reinforcing bars are required to provide adequate torsional strength.

VII.2.6. Ductility, force redistribution, and ultimate behaviour:

Ductility is one of the primary factors in structural safety. A ductile structure has the following characteristics a warning system to warn of a potential failure, the ability to sustain large deformations without collapsing, energy absorption capabilities, which are especially needed in seismic areas, the ability to redistribute internal moments.

To ensure ductility an appropriate ratio of longitudinal to transverse reinforcing bars reinforcing ratio, sufficient confinement of the concrete in high stress zones, adherence to anchorage lengths, and adherence to seismic design requirements.

VII.2.7. Importance of construction detailing:

Theoretical analyses alone do not provide an adequate indication of the strength of a concrete structure. Quality of construction has a significant influence on the actual strength of a concrete structure. The following are some important considerations during construction to ensure that the actual behaviour of a concrete structure will be as predicted by the analytical model quality control of the concrete during placement, with respect to the strength of the material, the proper spacing of the reinforcing bars to facilitate vibration during placement. The minimum thickness of the concrete cover provided to protect the reinforcing bars, the proper placement of stirrups in areas of shear failure, following proper anchorage and lap splice lengths; and providing continuity of the reinforcing bars in the tension zones and supports of the structure.

VII. 3. Verification of armed concrete structures with regard to the overall balance

Verifying global equilibrium in the design process of reinforced concrete structures is an important step. Global equilibrium will identify if the reinforced concrete structure can support all anticipated loads and that all loadbearing components interact properly so that internal forces are redistributed as intended.

VII.3.1. Concept of global equilibrium:

Global equilibrium is defined as the ability of a structure to carry applied loads, while being stable, no overturning, sliding, or collapsing and working in harmony compatible internal forces with each other. Verification uses the fundamental principles of Statics; that is, when multiple loads are applied to the structure, the total of the applied forces and moments must be equal.

VII.3.2. Types of loads to consider:

To verify global equilibrium, a complete evaluation of all applied loads must be performed. The applied loads are broken down into the following three categories accidental loads A earthquakes, accidents, fires, and extreme pressure conditions. Permanent loads G self weight, fixed partitions, finished flooring, and finished ceiling. Variable loads Q: service loads, occupancy loads, and environmental loads; wind, snow. The loads from all three categories are combined according to limit state principles ultimate limit state and serviceability limit state, which ensure both safety and serviceability.

VII.3.3. Methods of verification:

VII.3.3.1. Global Analysis:

The global analysis of the structure aids in identifying critical areas; Verifying that different elements of the structure beams, slab, columns, shear walls; are compatible in terms of stiffness.

VII.3.3.2. Redistribution of forces:

For a statically indeterminate system, the distribution of internal force is non-uniform across the entire structure and as such, by redistributing these forces properly, we can achieve a more ductile structure as a whole, lower local stress concentrations, and optimize the strength of the structure's materials.

VII.3.4. Stability criteria:

To evaluate the overall structure of a statically indeterminate system, a variety of factors are considered, including global stability; that is the box must be able to resist movement which could lead to global instability, load carrying capacity; in other words, all internal forces b ending moments, axial force. Must exceed the structures maximum design resistance, and compatibility of distortion; that is, all different structural members must have compatible displacements and rotations in relation to each other.

VII.3.5. Application to reinforced concrete structures:

In terms of determining if a reinforced concrete structure satisfies the global equilibrium in the design process. A number of things must be evaluated, including proper placement of the longitudinal and transverse reinforcement; proper installation of shear walls and any shear torsion resisting members; proper sizing of the beams, columns, slabs, Verification of the stability of the foundation, and any soil-structural interaction effects.

VII.3.6. Importance of global verification:

Through the evaluation process, we can assure control of cracking and distortional response, optimal use of materials, the ability to prevent local or global failures, and provide a safe and durable structure.

VII.3.7. Tools and calculation methods:

Engineers have different methods to confirm that the entire design of a structure is in equilibrium. They can model the entire structure's behaviour using matrix methods or finite element analysis programs to help with construction confirmation. The engineers also must consider the loads placed on the structure and the maximum stresses, moments and deflections that will result from the loads. The engineers perform a linear or non-linear analysis of the structure to determine the internal forces and moments within the structure due to the loads; and to verify that the individual limit states ULS SLS are not exceeded due to the loads placed on the structure.

VII.4. Verification of reinforced concrete structures with respect to foundation stability:

The foundation of a reinforced concrete structure is a major element in the design; foundations must provide adequate stability to support the weight of the reinforced concrete and allow the weight to be transferred to the ground without excessive settlement, sliding, or overturning of the structure. A stable foundation is critical to the performance of concrete buildings in a safe and consistent manner.

VII.4.1. Concept of foundation stability:

The definition of the stability of a foundation refers to the overall stability of the foundation, as it pertains to preventing any tipping, sliding, or collapse of the structure. A foundation also provides a way for the internal forces to be distributed evenly throughout the structure so that the foundation and superstructure work together to produce stability. Vertical and differential settlement of the foundation must remain within specified allowable values to ensure that the foundation does not become damaged or lose integrity once constructed. The verification of foundation stability is based on the simultaneous evaluation of vertical, and horizontal forces, and moments transmitted from the structure to the underlying soil. To sustain a correct structural foundation system, a structural system must be evaluated collectively against the vertical and horizontal loads and moments created by the structure.

VII.4.2. Types of foundations and loads:

Foundations experience many types of loadings; vertical loadings, the vertical loads on a foundation are caused by; the weight of the structure. Permanent live loadings and variable live loadings: for example, wind forces, seismic forces, lateral forces from earth pressure. B ending moments on footings: a foundation is subjected to a b ending moment from structural components of the load columns and walls with loads above them, which transfer the load to the foundation.

VII.4.3. Methods of Verification:

VII.4.3.1. Bearing capacity:

Verify that the foundation's bearing capacity is; greater than the maximum allowable stress for the soil. If the foundation's bearing capacity exceeds the allowable stress of the soil, it indicates that a local soil area is not failing; is also indicating the foundation has sufficient strength for its intended use:

$$q_{adm} \geq NA + \text{combined effects of moments and shear forces}$$

To determine the allowable bearing capacity of soil use the equation: $q_{adm} = N/A$

Where q_{adm} is the maximum allowable stress for that type of soil

N = total axial load;

A = area of base area of the footing.

To prevent localised soil failure from causing failure of the foundation, this equation can be used.

VII.4.3.2. Settlement control :

To avoid cracking and large deformations of a structure, the total overall settlement and differential settlement must be below the allowable limitations set by the structure itself.

VII.4.3.3. Sliding and overturning verification:

The applied horizontal load is less than the resisting force of friction at the foundation:

$$F_h \leq \mu \cdot N$$

The force generated by the weight of the building structure and it's foundation must exceed the horizontal force that causes the building to topple over:

$$M_{stab} \geq M_{applied}$$

VII.4.4. Influence of soil properties

It is important to note that geotechnical factors, soil properties, will determine how large, how wide, how deep or how tilted a foundation can be, hence stabilising a foundation, will be completed using geotechnical property testing. In order to determine that a foundation has enough strength to withstand the forces acting on it, a geotech property Test must be carried out. When performing a soil property test we recommend that the following geotechnical parameters are taken into account: soil strength, soil cohesion, soil depth and moisture level, area where ground appears wet, other compressible layers, any non-homogeneous distribution of soil, soil being prone to liquefaction during earthquakes.

VII.4.5. Considerations in seismic zones

Foundations built in areas that experience ground shaking and vibrations must-also meet additional criteria, because of the dynamic horizontal loads that the building's roof creates on the foundation, the differential settlement caused during an earthquake and local uplifting on some footings and raft foundations. The loads from the superstructure and dynamic loads are considered together in a vertical structural analysis, using a national seismic code RPA.2024 for designing the foundation and overall load combinations.

VII.4.6. Importance of construction practices:

The strength of your foundation's structural integrity ultimately dep ands upon how well you construct it: Building to the specified dimensions and depths, compacting concrete properly, placing reinforcement correctly to protect against moisture and erosion, placing reinforcement correctly to provide adequate anchorage overlap lengths, which will ensure that the performance of your foundation matches that of your design model

VII.5. Joints in reinforced concrete structures:

VII.5.1. Definition:

In a reinforced concrete structure, reinforcement concrete joint is the location at which two different elements cast at two separate times or for two entirely different functional uses come together as a single unit. The purpose of the joint is to provide for the continued mechanical continuity of the structure and to accommodate any changes in load.

VII.5.1.1. Types of joints and clarifications:

They are multiple types of joints;

a. Construction joints:

The joint is used due to the inability to place and finish the entire concrete mass at one time, for instance, either in the case of large slab or long beam applications. The preparation for the joint must include all appropriate methods for having a roughened surface, a cleaned surface, a moistened surface, and extending reinforcement across the joint in order to establish an adequate bond with the new concrete being poured. The end result of following all of the steps outlined above is not only to maintain the structural integrity of your structure, but also to reduce the likelihood of producing planar cracks across the joint.

b. Contraction shrinkage joints:

Planar cracks across a joint are caused by dimensional changes that result from either plastic shrinkage, long-term shrinkage or creep. End result of placing and finishing the concrete for a joint using these methods will produce a solid bond between the joint surfaces and surrounding concrete, which will help to eliminate any possibility of developing cracks across the joint.

c. Expansion joints:

Joints separate building components and restrict strain due to temperature effects, wind loads, unequal settlement, and earthquakes. Joints are generally filled with elastic or compressible material and may also be fitted with sliding or water protection devices. When designing structures, it is essential to determine where joints will be located, as the location of joints should be based on how stresses will be transmitted and how structures will behave when loaded. Both the kind of joint and the way that joint is treated have a direct relationship with how long the building will last and function properly.

VII.5.2. Verification:

The rationale for employing joints is to ensure structural integrity, safety, and longevity**.**

VII.5.2.1. Management of deformations and stresses:

Concrete structures will experience forces associated with shrinkage, creep, thermal expansion, differential settlement. Concrete joints provide openings in the finished structure where movement can occur because of these same mechanical forces and are used to help control the creation of uncontrolled cracks in concrete and to help prevent strength, durability, and serviceability failure.

VII.5.2.2. Structural continuity and force transfer:

A construction joint allows for the transfer of b ending moments, shear forces and axial loads from one section of the structural member to another, as well as to provide an uninterrupted connection and bond between concrete sections in any of the finished concrete structures.

VII.5.2.3. Adaptation to construction sequencing:

Adaptation to a construction sequence, joints provide a space in the finished structure for movement due to factors such as shrinkage, creep, thermal expansion, and the differential settlements of the concrete. These joints also help limit the occurrence of uncontrolled cracking that can lead to failures in power and workability.

VII.5.2.4. Resistance to exceptional actions:

To properly resist horizontal ground motions associated with earthquake activity, joints must be designed to perform this function. In the event of an earthquake, the joint allows the redistribution of forces created during the earthquake event and allows for ductility.

VII.5.3. Treatment methods and design considerations:

For optimal performance of concrete joints, the following treatments should be implemented:

VII.5.3.1. Construction joints:

The hardened concrete surface should be roughened and moistened, the reinforcement ending from the concrete joint should be permitted to transfer forces. The performance of the joint should be checked using ULS and SLS designations.

VII.5.3.2. Shrinkage and expansion joints:

Compressible fillers or elastomeric materials should be used to absorb movement; sliding interfaces should be incorporated into the joint for stress transfer reduction. The joint sizes should be based on the geometry of the elements, the material properties of the concrete, and environmental conditions.

VII.5.3.3. Inspection and maintenance:

On a continual basis, evaluate concrete joint integrity for the presence of crack growth or a water-tight seal along the joint edge. If joint filler needs to be replaced, repaired before the joint becomes ineffective.

Conclusion:

This is an important component of structural verification. The foundation is usually built upon the earth's soil, therefore it must be assessed to ensure it has adequate bearing capacity to bear the vertical loads from the super structure as well as limit differential settlement and therefore avoid structural failure. The importance of joints in allowing for the movement of temperature and moisture and changes to the structure as a result of load on the structure is illustrated in this chapter. Joints are critical to increasing the durability of the reinforced concrete structures and extending the life of the reinforced concrete structures. Thus, structural verification must be based on a combination of mechanical analysis, building code and regulations compliance, and material performance assessment, to ensure the long-term safety and reliability of reinforced concrete structures.

CHAPTER VIII: SPECIFICATION OF STRUCTURAL ELEMENTS

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Introduction:

Structural component specifications form an essential part of civil engineering as they fulfil the intent to provide an outline that can be follower for design, construction and maintenance of structures for safe, reliable and sound structures. The intention of this specification is to formally definer the following attributes; mechanical material strength, reinforcement for reinforced concrete. whether permanent or variable load due to self-weight, live loads, snow, wind and seismic actions. Geometric provides the size, shape and proportion of columns, beams, slabs and floors, walls and shear walls ensuring all loads are distribute effectively within the structural system. Functional global and local stability, comfort for user's vibration, cracks, deflection within allowable limits, and long-term durability. Thorough specifications will affect all phases of the structure from design structural analysis through construction and quality control and will define the maintenance and long-term durability aspects of the structure. The chapter has been divided into three distinct sections, which cover the following; primary , columns, beams, floors, slabs, walls and shear walls; forming the primary components of the structure, providing the strength and stability that are necessary in order for the structure to be successful. Lintels, secondary beams, staircases, and secondary bracing systems; providing additional support to the primary structural components of the structure. Materials used in the construction of structures, including concrete, steel, aggregates, admixtures and special products; ensure quality, long-term durability and compatibility of the various materials with one another on the project. Each of the three sections provides a practical and educational framework that links together theory, design, and practice in order to achieve a technically and functionally successful structure.

VIII.1. Specification for primary elements:

The primary elements of a building’s, columns, beams, floor slabs, shear walls, are considered to be the framework of the building; they provide the support for all loads applied to the structure. The importance of the primary elements of a structure consists of three main functions:

1. Resistance to both permanent and transient loads; the dead weight of the building, the live, snow, wind and seismic loading.

2. Overall stability to the structure; in maintaining structural equilibrium and preventing excessive deformation of the structure.

3. Elements establish the functional performance of the structure; the primary elements need to provide adequate stiffness for comfort to the occupants, limit the level of vibration experienced by occupants, control potential cracking, and provide durability throughout the service life of the structure. Before discussing individual characteristics of each primary element, the following principles should be kept in mind. Structural dimensions must be appropriately size for the loads to be supported by the element. Therefore, the cross section and height of all primary elements must be size to resist all permanent and transient loads, to ensure that the primary element does not fail or buckle due to excessive deformation. Concrete and steel cross sections and grades used in the primary elements of the structure should conform to applicable national and international standards NF EN, ACI, BAEL to ensure that the primary element is safe, durable, and efficient. Structural cross sections, shapes, and rebar layouts must be compatible with the construction techniques available for constructing the building; therefore, the designs of the primary elements must be based on the techniques for constructing the structure, ensuring that the structures can be constructed using approved methods and that design intent can be achieved.

VIII.1.1. Columns:

Columns support vertical loads from floors and roofs to foundations, and can provide some resistance against horizontal forces from wind or earthquakes. The column characteristics:

a. Dimensions and cross sections; columns with heavy loads or combined compression and bending must be larger or reinforced. Design of column dimensions and cross sections must be based on applied loads and effective height to determine buckling risk and axial forces. Columns can be rectangular, square, or circular.

b. Clear height between supports; the clear height between supports has a direct effect on the required size cross section of the column and the amount of reinforcement needed to prevent buckling, and must be determined to provide structural stability.

c. Reinforcement; layout of steel and quantity of steel are based on design codes and expected loading conditions. Transverse reinforcement is for confinement and shear resistance. Longitudinal reinforcement is to resist compression and tension.

d. Material; the reinforcing steel shall be B500B or equivalent and meet the requirements for ductility and bond strength. The concrete used must be of class C25/30.

e. Additional considerations; use adequate formwork to ensure compaction of concrete. Ensure symmetrically placed reinforcement to avoid torsional forces on the column.

VIII.1.2. Beams:

Beams are load bearing members which transfer loads from the floor roofs and slabs down to columns or to other load bearing walls. Beams experience either distributed loads or concentrated loads when loaded, and beams maintain a suitable stiffness, as well as providing comfort and safety as required by their application. The design characteristics of beams are:

a. Beam cross section and beam span; the appropriate beam cross section is designed based upon the anticipated applied loads and maximum allowable deflection. Depending upon the type of floor system utilized, and the architecture of the building, beams have a rectangular; T shaped, or ribbed beam cross section

b. Beam reinforcement longitudinal and transverse; beam longitudinal reinforcement is put in areas of positive or negative beam moment based upon the continuity scheme of beam construction; the main reinforcement bars are to provide resistance to the beam moment being experienced. Shear stirrups provide shear resistance and confine concrete.

c. Beam supports continuity; beams that are continuous provide for different moment and bending force distribution. The type of support for a beam can be classified as simply supported, fixed or continuous.

d. Beam crack control; beam control is established as a function of maximum crack width based upon the intended use of the structure, its provided to limit cracking due to the effects of shrinkage or thermal deformation, by adding control reinforcement to the beam at that location.

e. Other complementary beam aspects; verify the bearing connection of the beam with the columns slabs to ensure optimum load transfer.

Consideration should be given to builder construction tolerances and materials, and time depended creep and shrinkage deformations :

a. The minimum thickness must be designed with consideration to architectural and usage constraints. The minimum thickness is determined using the following criteria; span of the slab, type of slab solid, ribbed prestressed, applied loads on the slab.

b. Primary reinforcement; the primary reinforcement is used to resist the principal bending moments in the slab. In addition to the primary reinforcement, the slab will also require secondary reinforcement to resist secondary bending moments, shear forces and control of cracking.

c. Joints and supports; the joints and supports must be designed to accommodate for any shrinkage or expansion that may occur due to the length of the slab. There should be continuity between the beams and columns to allow for maximum efficient load transfer.

d. Fire resistance and vibration control; the fire resistance and vibration control must be taken into consideration to ensure that both the fire safety standards are maintained; and the vibration limits for the comfort and safety of the occupants have been adhered to the fire resistance and vibration control. Will vary based on the intended use of the building offices, residential, industrial.

e. Additional considerations; where applicable, check for alignment of the slab with the beams and columns when calculating the design loads of the building. The designer should also ensure adequate design loads are being accounted for including live loads, permanent equipment partitions, and heavy furniture.

VIII.1.3. Shear walls:

The load bearing walls and shear walls of the building provide both vertical load bearing capacity and provide lateral stability against wind or seismic forces. The following characteristics identify the shear wall:

a. Thickness and height; thin shear walls require reinforcement to limit potential for buckling and cracking, and therefore must be determined in accordance with vertical loads and material strengths.

b. Reinforcement; the arrangement of reinforcement is determined in accordance with local building codes and the anticipated loads applied. The orientation of the reinforcement must be appropriate for both shear and moment forces.

c. Openings reinforced or linted openings to prevent structural concentration of stress using reinforcement support above or around openings; minimize opening size, proper positioning and orientation of opening, to maintain maximum rigidity stability of structure.

d. Earthquake protection design to applicable seismic zone height and local codes RPA 2024 of the structure including the amount of ductility provided by and on the shear walls and redistribution of forces through the shear walls for the dissipation of seismic energy.

e. Interrelated components ensure that floors maintain continuity for the diaphragm to function as intended with maximum rigidity for the conception of vertically horizontally created loads on structure to create maximum safety level.

VIII.2. Specification for secondary elements:

While supporting elements lintels, supports, secondary beams, light bracing systems, and staircases are not structural components of the main framework itself, they are important to overall structure effectiveness. These types of elements allow for partial transmission of loads to primary elements through locally redistributing forces. Allow for functional layout and provide access through walls or vertical circulation of the structure. Provide local safety and comfort by limiting deformation, controlling the local buckle failure, and providing stability to non-load bearing areas of the structure. It is critical to reiterate the following basic principles when discussing the any characteristics of each type of supporting element. Local stability and safety supporting elements are designed to limit deformation, prevent the local buckle failure and ensure safety for all occupants of the building. These supporting elements do not support any of the primary load bearing members. Load transfer supporting elements will partially collect loads and transmit loads to column, beam or load bearing wall. Layout and functionality supporting elements contribute to architectural continuity, user comfort and spatial organization of the structure.

VIII.2.1. Lintels:

Lintels are horizontal members placed over openings in a wall. They are used to collect load from an above wall or structure and to distribute this load to supporting members. Lintels are generally made from steel, wood, or reinforced concrete.

a. Cross-sections and dimensions; vertical loads of wall and concentrated loads. Rectangular or profiled sections according material reinforced concrete, steel, wood. The width of the opening span and the loads applied are taken into consideration

b. Longitudinal bars for bending moments. Stirrups for shear resistance and transverse reinforcement.

c. Reinforced concrete class C25/30 or local standards; B500B or equivalent reinforcing steel.

d. Length of span suitable for width of opening and loads applied; sufficient bearing length to prevent sliding, shear failure or rotation.

e. Additional considerations; check concentrated stresses at ends; provide minimum overlap of reinforcing bars to ensure adequate anchorage

VIII.2.2. light bracing systems

Light bracing systems enable lateral stability of no-load bearing elements, temporarily during construction and permanently during use to improve the element's stiffness properties. The characteristics of light bracing systems:

a. Function; increase lateral stiffness of partitions, lightweight panels and secondary floors. Provide temporary stabilization of elements during construction.

b. Dimensions profiles; determined based on height of element and lateral loads wind loading, performance based on lateral load, accidental loads. Cross section shape adapted to materials used wood, steel, lightweight metal profile.

c. Anchorage to primary elements; strong anchorage points to primary elements enable efficient transfer of forces anchorage enables efficient transfer of forces.

d. Complementary aspects; potential weak points should be verified during assembly, and the combined effect of both lateral and vertical loads should be taken into account for determining stability.

VIII.2.3. Staircases

Staircases provide an essential element of vertical circulation for building occupants. Primary characteristics of staircases are as follows:

a. Dimensions; minimum allowable widths based on occupancy for residential buildings are 1.20 m wide more for public buildings. Riser heights and tread depths must comply with comfort and safety standards.

b. Structural resistance; the overall design of a staircase must take into account the combined impact of live loads related to both occupants and furnishings. Typical materials used to construct staircases; reinforced concrete, steel and wood, which have sufficient resistance to bending and shear.

c. Safety and comfort; staircases are ideally designed so they will limit vibrations and deflections that are acceptable for user comfort, and handrails and guardrails should be in compliance with local codes.

d. Complementary aspects; staircases need to be compatible with the surrounding floors and columns, enabling a logic and continuous structural connection; and need to take into account dynamic and accidental loads.

VIII.2.4. Secondary beams:

Secondary beams provide local additional reinforcement or support to the redistribution of concentrated loads mostly located within the floor slab or floor systems with large spans or localized loads. The primary characteristics of secondary beams are as follows:

a. Cross section and span; both the cross section and span of secondary beams should be based upon the anticipated local loads as well as the distance between primary supports.

b. Reinforcement; longitudinal and transverse reinforcement to resist bending moment and shear force

c. Material; reinforced concrete, or steel depending on compatibility with primary elements

d. Function; supporting partitions, localized pieces of equipment, or architectural components; maintaining continuity and stiffening floors to limit the possibility of excessive local deformation

e. Complementary aspects; verification of both the alignment and overlap of the reinforcement with the primary beams; consideration of the combined effects of both permanent loads and variable loading conditions.

VIII.3. Specification concerning materials:

The characteristics and quality of the materials utilized for construction of the structural elements; have a major role to play in determining their strength, stability and durability. Therefore, it is important to note that the overall mechanical performance of the structure; does not only depend on its geometry or size but rather is influenced by the properties and characteristics of the materials being use. If the materials do not meet required specifications, or are not adequately controlled, the load-bearing capacity of the structural elements may be diminished. In addition, it will decrease the lifespan of the structural elements causing the early development of cracks, corrosion, and other forms of deterioration. Compromise the safety of a structure by causing the risk of the structure partially or completely collapsing; thus, it is necessary to develop and document appropriate material specifications. Material specifications; mechanical properties, such as compressive strength; tensile strength; flexural strength; modulus of elasticity; ductility. Physical properties of the material; density, porosity, distribution of particles; and consistency. Chemical properties; the chemical composition of material; its durability regarding chemical exposure; and its compatibility with other structural materials. Means of controlling and verifying compliance with these specifications are through laboratory tests; on-site testing; and compliance with standard laboratories.

VIII.3.1. Fundamental principles for material selection:

It is very important to understand the general principles for selecting items that will be put into a structure as well as the general principles, before evaluating what types of materials may be utilized in a structure. The principles of selecting materials guide us in selecting materials that will allow the structure to perform as intended, with regard to safety, durability, and compatibility between items being use to construct the structure.

VIII.3.2. Compliance with national and international standards:

Materials must adhere to the appropriate standards based on their location, as dictated by national and international codes, including NF, EN, ASTM, and ISO, for example. Compliance with these standards provides for a uniform level of quality for the materials used, allows for traceability, facilitates accountability in cases of non-compliance, and helps to prevent structural failure due to the use of uncertified or sub-standard materials.

VIII.3.3. Durability under environmental and mechanical constraints:

Materials need to be capable of withstanding environmental factors, including rainfall, frost, relative humidity, and ultraviolet radiation, as well as needing to resist chemical factors, such as corrosion and attacks from acidic or saline environments. Also, materials will be required to support mechanical loads. These permanent dead -weight loads due to gravity; fixed loads; and variable loads due to snow, wind, or seismic activity. Materials that do not exhibit sufficient durability can have a detrimental effect on the service life of a structure, while also increasing the need for ongoing maintenance and upkeep.

VIII.3.4. Compatibility between materials:

When utilizing multiple materials, concrete, steel, wood, glass, and composites, careful consideration must be given to the compatibility of the various materials. Areas of concern would; thermal expansion and dimensioning; the bond between materials, between concrete and steel in reinforced concrete applications; and prevention of deleterious chemical reactions, such as galvanic corrosion or acid attack. The embedded steel in the concrete, must be provided with adequate corrosion protection and must exhibit an optimum bond to achieve the anticipated structural performance.

VIII.3.5. Detailed material specifications:

Each type of material will have certain characteristics that will dictate the extent of control necessary to ensure the successful performance and longevity of the structure.

VIII.3.5.1. Concrete:

Concrete is one of the most common construction materials, and its physical properties are determined by the composition of materials and the proportion of those materials. Concrete has five classifications based on the required characteristics of the concrete, including strength class; C25/30, C30/37, C35/45. Strength class is determined by the characteristic compressive strength of concrete at 28 days' age. The consistency of concrete is determined through a slump test and indicates its workability and ability to compact adequately. Water content of concrete must also be controlled to minimize porosity and maximize the strength and durability of concrete. Admixtures that may accelerators, retarders, and plasticizers allow for flexibility when creating concrete to meet the environment site condition and mechanical specifications. Excessive water content and lack of consistency can result in premature cracking of concrete and reduce the strength of the concrete itself.

VIII.3.5.2. Steel:

Steel, in most instances. It is used in reinforced concrete for ductility and tensile strength. There are two grades of steel; B500B and B500C, which indicate the characteristic strength of the steel and the level of ductility present in the steel. Ductility is essential to allow for such types of deformation without breaking and provides an important factor in assessing seismic performance. The yield strength of steel, in conjunction with the ultimate strength, determines the total capacity of the steel reinforcing to support loads without breaking down. The bond between concrete and steel is directly related to both the surface roughness of the steel and the method of corrosion protection. A strong bond provides a means of transferring the load from the concrete to the steel. Poor-quality steel or improperly installed steel may also result in cracking and loss of load-bearing capacity for the concrete.

VIII.3.5.3. Fill materials aggregates:

Concrete is mostly made of sand, gravel, and stone aggregates that greatly impact the properties of concrete. Particle size distribution; with an ideal particle size distribution, aggregates produce less voids in cured concrete and allow for greater compaction of concrete. Cleanliness and hardness; these attributes prevent chemical reaction between aggregate and concrete and add to the overall strength of the concrete. Practical considerations; poor quality aggregates tend to produce greater amounts of concrete shrinkage and cracking.

VIII.3.5.4. Special products:

Specialized products are materials that serve as complementary products to traditional materials. Additives and fibers that enhance the ductility, strength, and fire resistance properties of concrete. Choices for anti-corrosion and waterproofing that are used to protect both concrete and reinforcement that may be exposed to harsh environments such as seawater or industrial areas. The choice of specialized products should be based on how they will interact with other materials and the project constraints.

VIII.3.5.5. Material control and verification:

The quality of materials can only be maintained through strict quality control measures that laboratory-testing tests conducted on both fresh and hardened concrete, tensile compressive testing of both steel and aggregates, aggregate particle size analysis. On site controls measurement of concrete consistency, verification of location and quality of reinforcement steel, moisture and density testing of aggregates.

Documentation traceability certificates of compliance, technical data sheets, control reports, and acceptance test results. All quality control measures will ensure compliance with project specifications, reduce risk of construction defects, and provide an optimal service life for a structure. The careful selection of material types and their performance characteristics will be an essential component of the construction and the design process for all structures. Through proper selection, you can ensure that your structure will provide adequate structural integrity- balance, weight bearing capacity and weather resistance which will be very significant in the long-term when considering a structure's longevity. Structural integrity, durability, and strength; the overall structural performance and stability of a structure is tied to the quality of materials selected for the construction process, therefore it is important to select superior quality materials that will allow the structural elements to carry both constant and variable loads. Using inferior quality materials could lead to cracking, excessive deformation, premature failure and ultimately lessening the overall safety of the structure itself. Durability and service longevity will be directly proportional to the performance of a material against various forms of environmental aggression, rain, frost, moisture, UV radiation. Furthermore, as it relates to corrosive chemicals attack; sulfates, chlorides and other forms of corrosive material, proper material selection can significantly reduce ongoing maintenance expenses, maximize the overall lifecycle of the structure. User safety and functionality; the ability to build with a material that meets or exceeds all international and national building codes will ensure compliance with regulatory standards and how to build.

a. structure to avoid accidents from material or element failure. In terms of technical specifications and quality assurance, each material will be defined through its compressive and tensile strengths, modulus of elasticity, density, criteria for crumb size or granular size distribution, porosity and chemical make up or composition as well as any chemical durability traits. In order to verify that all materials conform to the defined standards and are homogeneous in nature, both laboratory tests and on site verification will be required. The systematic examination of materials is the foundation for the design, research, and engineering behind the construction of a structure. It is an important starting point for future engineers to establish a solid foundation for understanding how materials work together to create a functioning structure.

Conclusion:

Specifying structural elements is an integral step in creating a building or other civil engineering work during the design and construction phases. This process transforms the requirements for safety, function, and durability into specific technical requirements. These technical specifications are then used to ensure that the structure being built is safe for those who occupy it, strong enough to withstand material loads, and can last for a long period. This chapter further illustrates how this process can be used collaboratively by using more than just the structural strength of a material; it incorporates the shapes and dimensions of each structural element as well as the function of that element in relation to the entire structure as a whole. By utilizing this process, students can relate the theoretical concepts they have learned in class on the strength of materials, structural mechanics, and design principles with the actual construction of a structure. Accurately defining both principal and secondary members on a structural element as well as selecting appropriate materials will aid students in understanding how their design will respond to loads and external forces, whether it be through normal use or during extreme conditions. The division of this chapter into clear sections will aid students in understanding and learning through analysis. This type of organization will allow students to analyze each load-bearing system one step at a time, leading to a better understanding of what each element does, as well as the systematic approach teaches logical thinking patterns and structural methods, both of which will aid students in problem-solving and selecting appropriate solutions for their projects.

In conclusion, this chapter lays the foundation for students to gain the skills and knowledge necessary to complete the technical portions of the course with competence. This chapter is developed through methodologies that meet established civil engineering standards and applicable practices.

GENERAL CONCLUSION:

The development of this polycopiate presents a course for learning different techniques and building rules subsequently it presents the distinct prerogatives of building rules and standards. As to execute our projects with respect to a well-studied technical control, it is mandatory to disclose the different stages of realization of works in reinforced concrete, metallic and mixed, which reveals the engineering initiatives and this is the imperative necessary.

The course presented is based on tangible experiences from prospecting. It deserves to be needed for teachers in civil engineering. Hope that the publication of this modest work will provide scientific favor to colleagues as there is a glaring lack of educational documentation in this area.

In fact the work about techniques and rules of construction are very rare.

We thank you for giving us your opinions, in order to enrich it.

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