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Supported on:

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First and last name	Grade	Quality
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اهداء

اشكر الله تعالى على أن وفقني للوصول إلى هاته المرحلة المتقدمة في دراستي. الحمد لله الذي تتم بحمده الصالحات حمدا كثير طيبا مباركا فيه، والصلاة والسلام على سيدنا محمد صلى الله عليه وسلّم وبعد

أهدي هذا العمل إلى امي وأبي الغاليين علي اللذين لم يتوانيا طرفة عين في بذل أقصى جهدهم لإسعادي فالواجب يقتضي شكرهم ومحاولة ردي بعض الجميل لإسعادهم يقول الشاعر في حقهم

فالولدان لهما الإحسان على البنين من زمان كانوا

والله في القرءان أوصى بهما فلهما كن ابدا معظما

وكذلك أشكر كل اساتذتي ومشاييخي وأخص بالذكر سيدي الشيخ قرافي أبوبكر وسيدي أولاد جعفري صالح

وإلى كل عائلتي وإخوتي وخاصة أخي عبد المالك وأخي أحمد الأمين وكذلك أخوالي عبد الحميد وإسماعيل ومحمد

وإلى كل أصدقائي وخاصة عبد الحميدو عبد الرزاق و عبد الكريم و سمير

وأهدي شكري الخاص الى كل إنسان مر في حياتي وترك أثرا في قلبي ولم يسعني ذكره لضرورة الاختصار

والسلام عليكم

اولاد جعفري خالد

إهداء

قال الله تعالى : قل اعملو فسيرى الله عملكم و رسوله و المؤمنون .

-الاهي لا يطيب الليل الا بشكرك... و لا يطيب النهار الا بطاعتك... و لا تطيب اللحظات الا بذكرك...

و لا تطيب الاخرة الا بعفوك... ولا تطيب الجنة الا برؤيتك... _الله جَلَّ جَلَالُهُ_

-الى من بلغ الرسالة و أدى الأمانة... و نصح الامة... الى نبي الرحمة و نور العالمين... _سيدنا محمد صلى الله عليه و سلم_

-الى من كلله الله بالوقار... الى من علمني العطاء بدون انتظار... الى من احمل اسمه بكل افتخار...

الى عزتي و عزي... الى حبيبي الأول و ملجاي بعد الله... _أبي الغالي_

-الى ملاكي في الحياة... الى معنى الحب و الى معنى الحنان و التفاني... الى بسمة الحياة و سر الوجود...

الى من كان دعائها سر نجاحي و حنانها بلسم جراحي...الى اغلى قلبي الذي ينبض... _أمي الحبيبة_

-الى كتفي الثالث الذي لا يميل... الى عيني الأخرى التي تبكي معي... الى قلبي الذي يضحك بفرحي...

ووجهتي التي اهرب اليها... الى اماني من الخيبات و مامني من الخذلان... _أخواتي الغاليات_

-الى سندي العظيم... الى قوتي و ضلعي الثابت الذي لا يميل... الى عرقي متصل بقلبي...

الى ذلك الذي لا يحلو النبض الا به... الى النبع الذي ارتوي منه... _أخي الحبيب_

-الى منارة العلم و العلماء... الى الصرح الشامخ... الجامعة الإسلامية...

الى الذين حملو اقدس الرسالة في حياة الذين مهدو لنا...

طريق العلم و المعرفة... _اساتذتنا الافاضل_

ثابت بثينة

TO THANK

Beginning, we praise God for the countless blessings and favors He has bestowed upon us. Peace and blessings be upon our master Muhammad, may peace be upon him.

Secondly, we would like to thank our supervisor, **Mr. Ahmed Marah**, as well as our mentor, **Mr. Bahaz Abdel-Salam**, for their advice and guidance in presenting our work in the best possible manner and contributing to its further development.

We would also like to express our gratitude to all the members of the evaluation committee for their approval and acceptance of our humble project. We pray to God for success and prosperity in developing this project to fulfill the desired aspirations.

Finally, we extend our thanks to everyone who has supported us, whether directly or indirectly, in the completion of this project.

Peace be upon you.

Summary:

This project presents a detailed study of a residential building consisting of a ground floor plus two additional floors. Its structure is being constructed in the province of ADRAR . This area is classified as Zone 0 in terms of seismic activity, according to the Algerian anti-seismic regulations RPA99.

Keywords: building _reinforced concrete_ reinforcement _formwork _beam_ column.

Résumé:

Ce projet présente une étude détaillée d'un immeuble résidentiel composé d'un rez-de-chaussée et de deux étages supplémentaires. Sa structure est en cours de construction dans la province de ADRAR . Cette zone est classée en Zone 0 en termes d'activité sismique, conformément aux réglementations anti-sismiques algériennes RPA99 .

Mots-clés : bâtiment _ béton armé _ ferraillage _coffrage _ pouter _pouteau.

ملخص:

يعرض هذا المشروع دراسة تفصيلية للمبنى السكني الذي يتألف من طابق أرضي زائد طابقين يتم انشاء هيكلها في ولاية ادرار . و هذه المنطقة مصنفة كمنطقة 0 من حيث النشاط الزلزالي وفقا للقواعد الجزائرية المضادة للزلزال .

الكلمات المفتاحية : بناية _ خرسانة مسلحة _ تسليح _ القوالب _ الرافدة _الأعمدة.

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Symbols:

As, A: Area of a steel section.

At: Sum of cross-sectional areas of a course of transverse reinforcement.

B: Area of a concrete section.

D: Diameter, rigidity.

E: Longitudinal elastic modulus, seismic.

Eb: Longitudinal deformation modulus of concrete.

Ei: Module de déformation instantanée

Evj: For an age of j days**)**.

Es: Elastic modulus of steel.

Ev: Time-dependent deformation modulus

(Evj: for loading applied at the age of j days**)**.

F: general force or action.

G: permanent load.

Q: operational overload.

I: moment of inertia.

L: ongueur ou portée.

M: most commonly occurring bending moment.

Mu: Design moment at the ultimate limit state.

Mser: Design moment at the serviceability limit state.

N : normal force.

Q : variable action or load.

S : section.

T,V : shear force.

Fcj: Characteristic compressive strength of concrete at an age of j days.

Ftj: Characteristic tensile strength of concrete at an age of j days.

D: Effective height.

Ht: total height of the floor.

Hdc: height of the compression slab.

Lx : Maximum length between axes.

A': compressed reinforcement section.

A: tensioned reinforcement section.

e: eccentricity of a resultant or force with respect to the center of gravity of the section.

S: general spacing of reinforcements.

St : spacing of transverse reinforcements.

Fe: Yield strength of steel.

Greek nomenclature:

γb: Safety factor of concrete.

γs : Safety factor of steel.

α: Angle in general, Coefficient.

εbc: Relative shrinkage of concrete.

εs: Deformation of steel.

η: Cracking coefficient relative to a reinforcement.

Θ: Dimensionless coefficient.

λ: Slenderness.

ν: Poisson's ratio.

ρ: Ratio of two dimensions; specifically the ratio of steel area to concrete area.

σ: Normal stress in general.

σbc: Compressive stress of concrete.

σs: Tensile stress in steel

A GENERAL INT – RODUCTION:

A General Introduction:

The process of construction has always been among the human's top priorities and one of the best professions for them. Over the years, this field has witnessed significant development, which can be attributed to the increased attention and its adaptation to technology.

This interest has grown with the passage of time and the demographic growth of the population, prompting decision-makers in most countries to adopt certain solutions. One of the most important solutions is the construction of tall buildings, given the increasing population density and limited land availability in cities.

For the proper design of a residential building structure, it is essential for the civil engineer to adhere to internationally recognized building codes and standards.

As part of preparing a final thesis for the first stage of your academic path to obtain a civil engineering license, you have conducted precise calculations for the construction of a reinforced concrete residential building (2+R). The study included determining the dimensions of formwork sections and the necessary reinforcements to ensure the structural efficiency and resistance of the building to applied forces.

To accomplish this, you performed the calculations manually and utilized digital calculation software, in accordance with Algerian regulations, particularly CBA 93 and RPA 99/2003.

In order to present the thesis correctly, this manuscript has been organized as follows.

It begins with a general introduction, followed by four chapters.

_ **Chapter One:** It is the overall description of the project, including an overview of the architectural aspect of the building elements.

_ **Chapter Two:** It entails the general description of the project, along with an exposition of the architectural aspect of the building elements.

_ **Chapter Three:** Specifically dedicated to secondary elements (staircase beams, balconies, and partitions).

_ **Chapter Four:** Includes reinforcing the various load-bearing elements of the structure (foundations, columns, and beams).

And finally, we conclude with a general conclusion.

Chapter 01: Presentation of the Project.

I.1. Introduction:

We have dedicated this chapter to discussing some general aspects of construction. We have provided an overview of the building structure's geometric properties and defined the mechanical properties of the materials used in construction. These steps are essential for conducting the necessary calculations.

I.2. Presentation of the work:

We are studying the structure of a building consisting of a ground floor and two additional floors (G+2). This project is designated for residential use. This building is classified according to the region in which it was constructed, which is Ghardaia province. Ghardaia is classified as a seismic zone 0 according to the 2003/RPA99 seismic classification.

I.2.1. Geometric characteristics of the structure:

- The height of the building: 10.46 m .
- Height of the ground floor: 3.06 m .
- Floor height: 3.06 m .
- Height of the parapet wall: 0.6 m .
- Length of the structure: 13 m .
- Width of the structure: 13.6 m .
- Total surface area of the structure: 180.715 m^2 .

Figure I.1. Main facade.

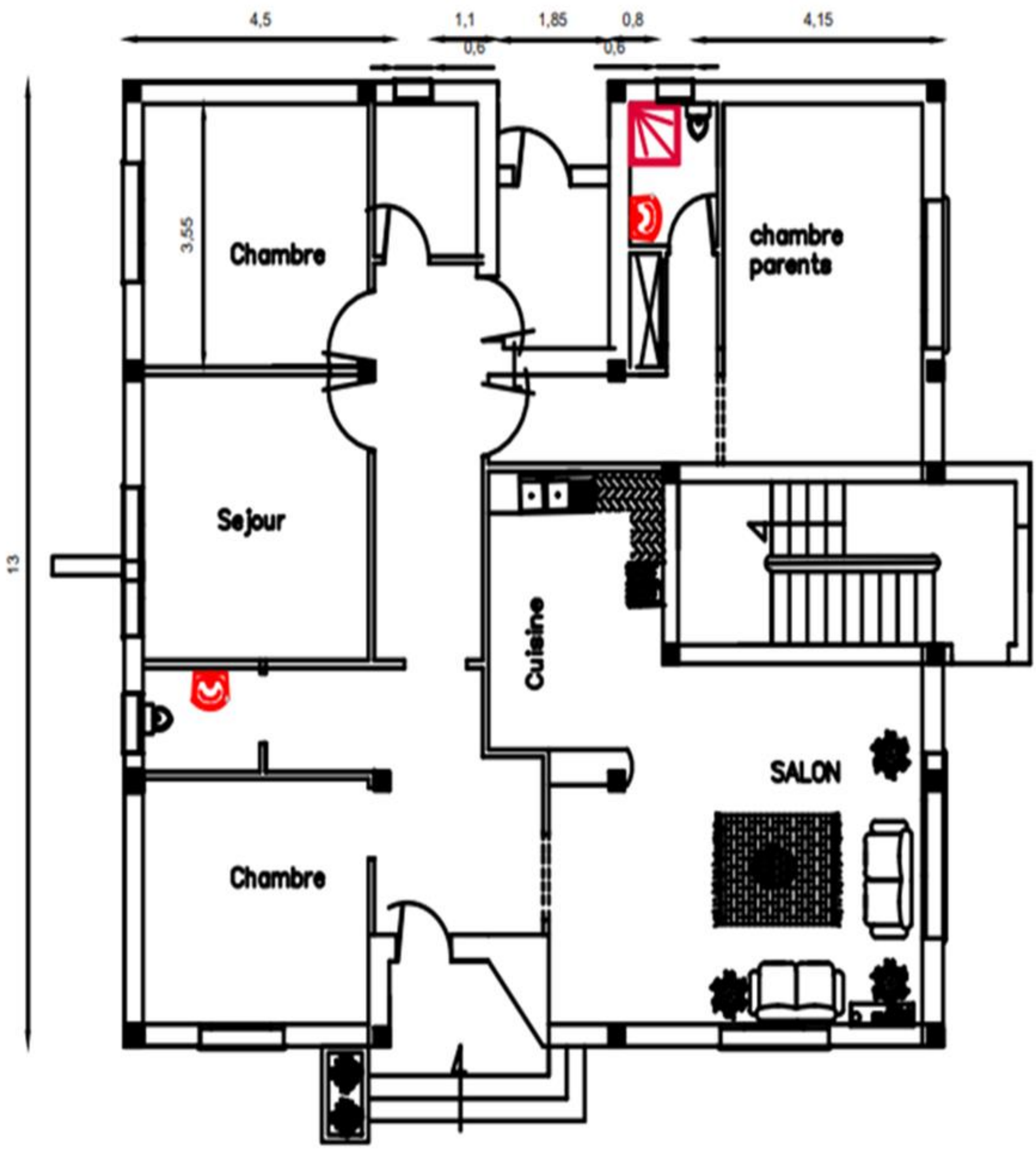


Figure I.2. Ground floor plan.

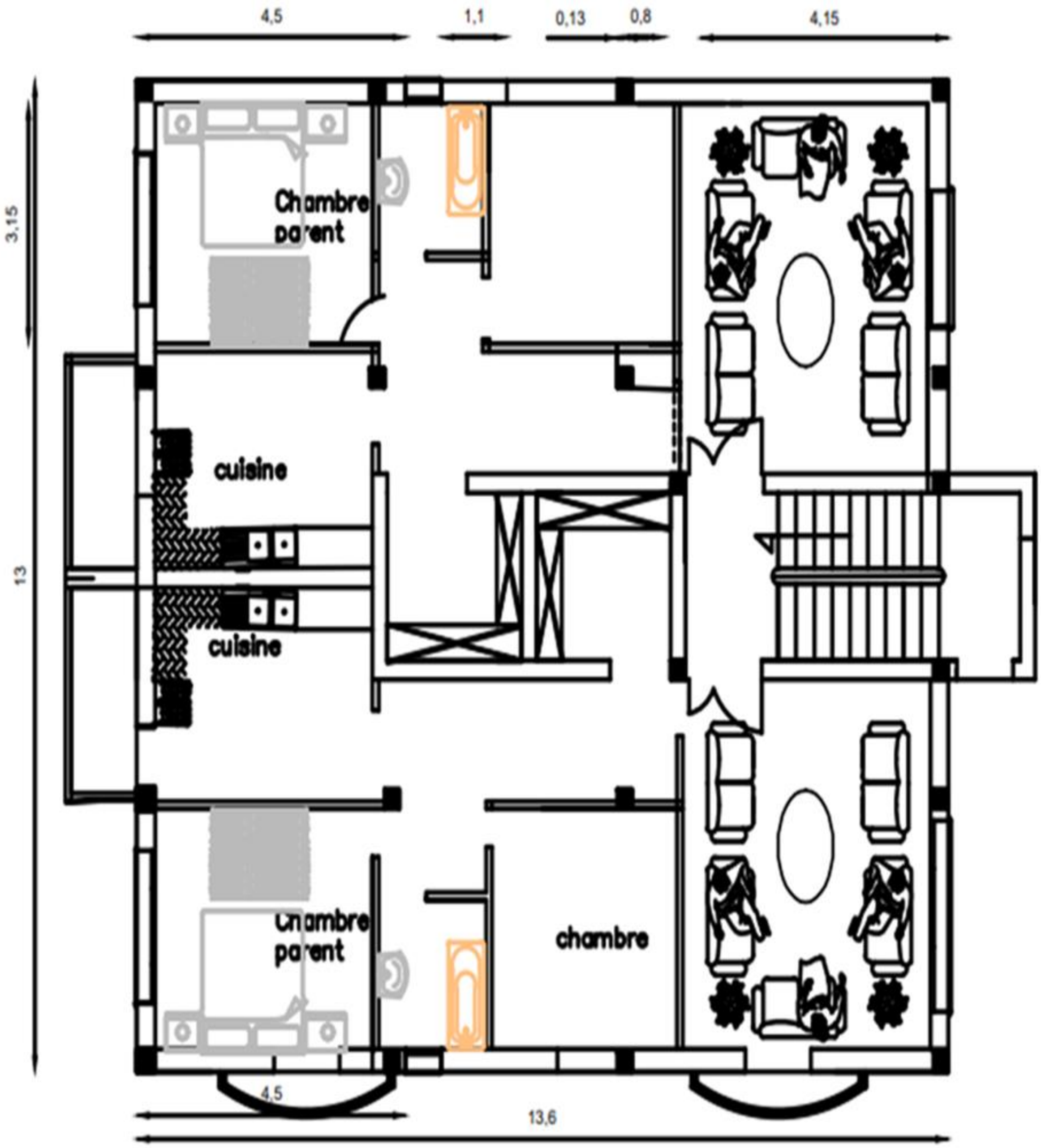


Figure I.3. First floor plan.

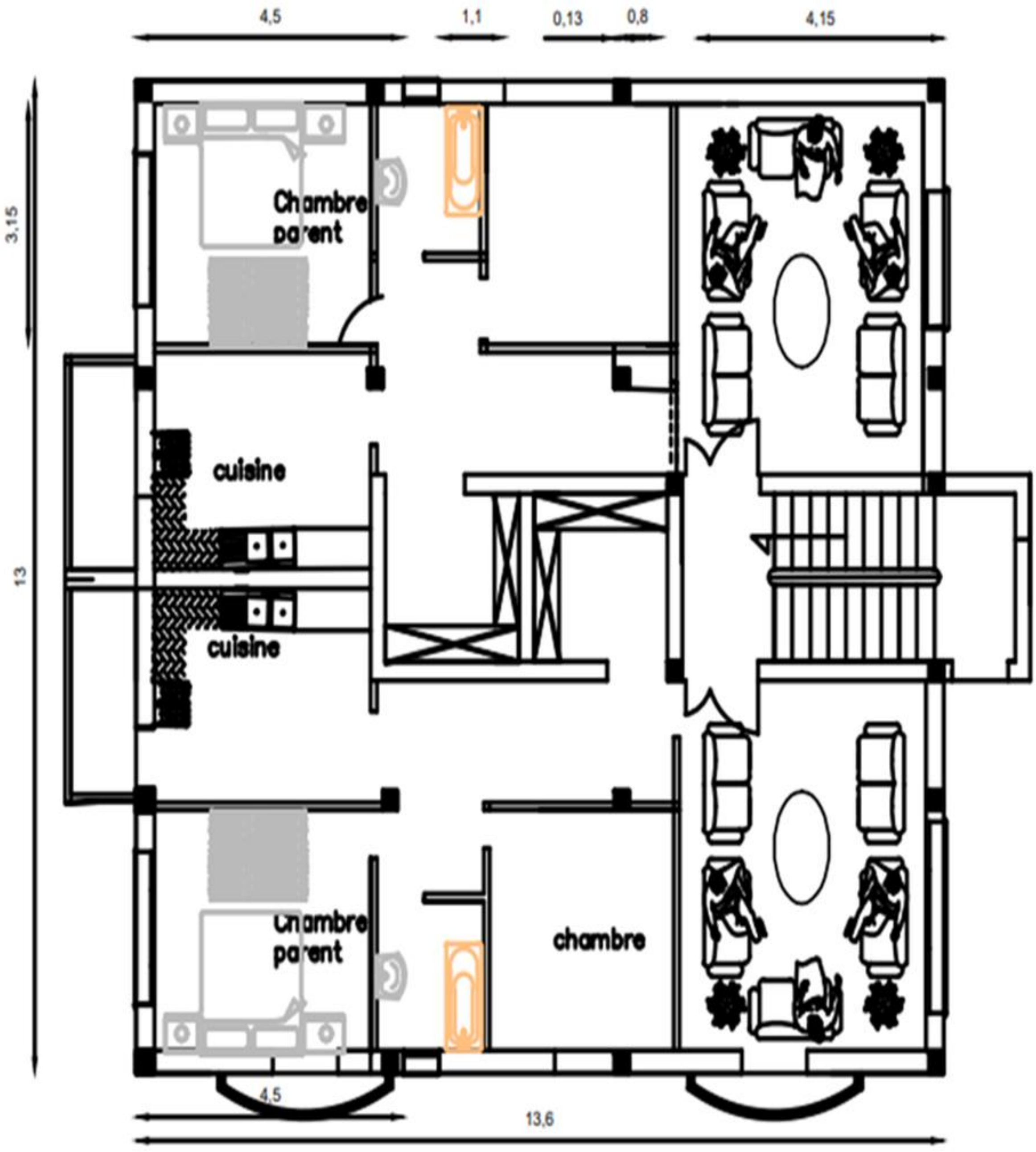


Figure I.4. Second floor plan.

I.3. Definition of the elements of the work:

- **Floors:**

They are made up of hollow cores with a topping slab that forms a rigid horizontal diaphragm and ensures the transmission of forces acting within its plane to the bracing elements.

- **Stairs:**

In our building, we have one type of staircase.

A straight staircase with two flights, a landing, an intermediate landing, and a starting landing. It will be constructed using reinforced concrete that will be poured on-site.

- **Facades and partitions:**

The exterior walls will be constructed using double hollow bricks with a size of 10+10 cm, separated by an air gap of 5 cm.

The internal partition walls will be made of a single wall of bricks with a thickness of

15 cm.

- **The terrace:**

In our project, the terrace is inaccessible.

- **The parapet:**

It is an embedded element in the reinforced concrete terrace floor, which will serve as a guardrail.

I.4. Regulations and standards used:

The regulations and standards used are those in force in the building sector in Algeria. Specifically, we have relied on:

- RPA99 / version 2003 (Algerian Seismic Regulations)
- BAEL91 / version 99 (reinforced concrete at limit states).
- DTR B.C.2.2 (Charges permanentes et surcharges d'exploitation).

.

I.5. Characteristics of materials:

I.5.1. Introduction:

Reinforced concrete is composed of concrete and reinforcements. Concrete exhibits good compressive strength but low tensile strength, while steel provides good tensile strength. By combining these two materials, a composite material is created in which each one effectively responds to the forces it is subjected to.

I.5.2. Concrete:

Concrete is a mixture of aggregates (gravel, sand), binders (cement), water, and optionally, additive products (admixtures). In well-defined proportions, it is dosed at 350 kg/m3 to achieve suitable strength and good quality after hardening.

I.5.3. Components of Concrete:

- **Cement:**

Cement acts as a binder. Its quality and characteristics depend on the proportions of limestone and clay, or bauxite, as well as the temperature at which the mixture is fired.

- **Water:**

Water should be clean. If it contains chlorides, a chemical reaction will occur, modifying the cement setting. As a result, the concrete will lose its strength properties.

- **Aggregates:**

The aggregates used are sourced from quarries or crushed rock blocks. The size of the aggregates is indicated by two numbers, representing the largest and smallest dimensions of the particles. For concrete used in construction, the most common aggregates are sand and gravel.

- **Sand:**

Sand is formed by the disintegration of rocks into tiny grains. The size of its grains is typically smaller than 5mm. Good-quality sand contains grains of various sizes, but it should have more coarse grains than fine ones.

- **Gravel:**

Gravel consists of rock grains that are typically between 5mm and 25-30mm in size. They should be hard, clean, and non-frost susceptible. Gravel can be sourced from riverbeds (rounded materials) or obtained by crushing hard rocks (crushed materials).

I.5.4. Mechanical characteristics of concrete:

I.5.4.1. Compressive strength:

Concrete is defined by its compressive strength at the age of 28 days, known as the required characteristic value, denoted as f_{c28}.

When loads are applied to concrete that is less than 28 days old, reference is made to the characteristic strength f_{cj} obtained at the specific day (j) under consideration.

According to the orocode design law, it is generally accepted that for $j \geq 28$, the strength f_{cj} of non-heat-treated concrete approximately follows the following laws:

1. For $fc28 \geq 40$ MPa, $fcj = [\frac{j}{1.4+0.95.j}] \times fc28.$
2. For $fc28 \leq 40$ MPa, $fcj = [\frac{j}{4.76+0.83.j}] \times fc28.$

   - From our projector, $fc28 = 25$ MPa.

I.5.4.2. Tensile strength:

The characteristic tensile strength of concrete at (j) days, denoted as $f$tj, I conventionally defined by the relationship:

$$ftj = 0.6 + 0.06 \times fcj.$$

- In our project, $ft28 = 2.1$ MPa.

Where $f$tj and $f$cj are expressed in MPa, and this formula is valid for values of

$f$cj < 60 MPa.

I.5.4.3. Limit stresses:

The calculated loads must not exceed the ultimate limit loads in the unfavorable direction.

- **Ultimate limit state stress:**

The ultimate compressive stress of concrete is given by the relationship:

$$f bu = \frac{0.85 \times fc28}{\gamma b \times \theta}.$$

The constant 0.85, which represents the safety factor, takes into account the fact that aconcrete specimen is crushed under an instantaneous load, while the structure is subjected to long-term applied loads.

γ_b : Safety factor of concrete.

γ_b = 1,5 ………………………… common stock cases.

γ_b = 1,15………………………… cases of accidental actions.

θ **:** Coefficient dependent on the duration of application of actions.

θ = 1……………………………. duration of application of loads exceeding 24 hours.

θ = 0,9………………... duration of application of loads between 1 hour and 24 hours.

θ = 0,85………………..………... duration of application of loads less than 1 hour.

In our study, we will use fc28 = 25MPa: $\boldsymbol{fbu = 14.17MPa}$

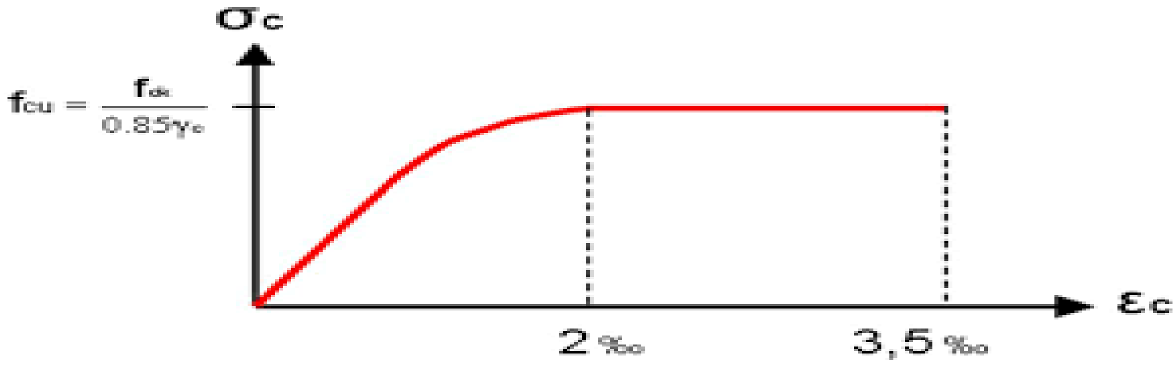


Figure I.5. Stress-Strain Diagram of Concrete.

❖ **Shear ultimate stress:**

The shear ultimate stress is given by: $\tau u = \frac{\mathbf{Vu}}{\mathbf{b0 \times d}}$.

Vu: represents the shear force.

d: represents the effective height of the concrete section being considered.

b0:represents the width of the concrete section being considered.

The allowable shear stress:

- In the case of minor or insignificant cracking:

$$\overline{\tau u} = \min \left[0.2.\frac{fc28}{\gamma b}; 5\right] = 3.33 \text{ MPa} .$$

- In the case of harmful or highly detrimental cracking:

$$\overline{\tau u} = \min \left[0.15.\frac{fc28}{\gamma b}; 4\right] = 2.5 \text{ MPa} .$$

❖ **serviceability limit stress:**

The ultimate serviceability limit state in compression $\overline{\sigma bc}$:

$$\overline{\sigma bc} = 0.6 \times fc28 \Rightarrow \overline{\sigma bc} = 15 \text{ MPa} .$$

I.5.5. Steel:

I.5.5.1. Mechanical characteristics of steel:

❖ **Guaranteed yield strength (fe):**

The conventional designations, grades, and corresponding yield strength limits are provided in the following table:

Table I.1. The elastic limit of steel.

Class	Subtlety	fe (MPa)	job
Ronds lisses	FeE24	235	Current job Lifting pins for parts.
HA bars	FeE40	400	Current employment.
Smooth welded -mesh Class4	TSL TSHA	500 520	Current employment.

The steel chosen for the longitudinal reinforcements is a high bond steel **HA FeE40**. Class 1 **(**yield strength **fe = 400 MPa)** steel is used for longitudinal reinforcements, while smooth round **FeE24 (fe = 235 MPa)** steel is used for transverse reinforcements.

The elastic modulus: **Es = 2×10^5 MPa.**

TLE500 welded mesh with a yield strength of **fe = 500 MPa.**

❖ **Ultimate tensile strength:**

The ultimate tensile strength of steels in service is limited only in the case of slightly detrimental, detrimental, or highly detrimental cracking.

$$\sigma s = \frac{fe}{\gamma s} \quad \text{yield strength of steel.}$$

fe **:** yield strength of steel.

γ_s **:** Safety factor of steel depending on the nature of the loads. $\begin{cases} \gamma s = 1.15 . \\ \gamma s = 1.1 . \end{cases}$

In our case:

$\varepsilon = \frac{\Delta l}{l}$ **:** Strain at fracture of steel.

❖ **Service limit stress:**

-Low-harm cracking:

No verification is required in this case, except that the stress in the concrete needs to be checked.

- Harmful cracking:

$$\sigma s \leq \min \left(\frac{2}{3} \times fe \,;\, 110 \times \sqrt{\eta \times ftj}\right) \text{MPa} .$$

-Very harmful cracking:

$$\sigma s \leq \min \left(\frac{1}{2} \times fe \,;\, 90 \times \sqrt{\eta \times ftj}\right) \text{MPa} .$$

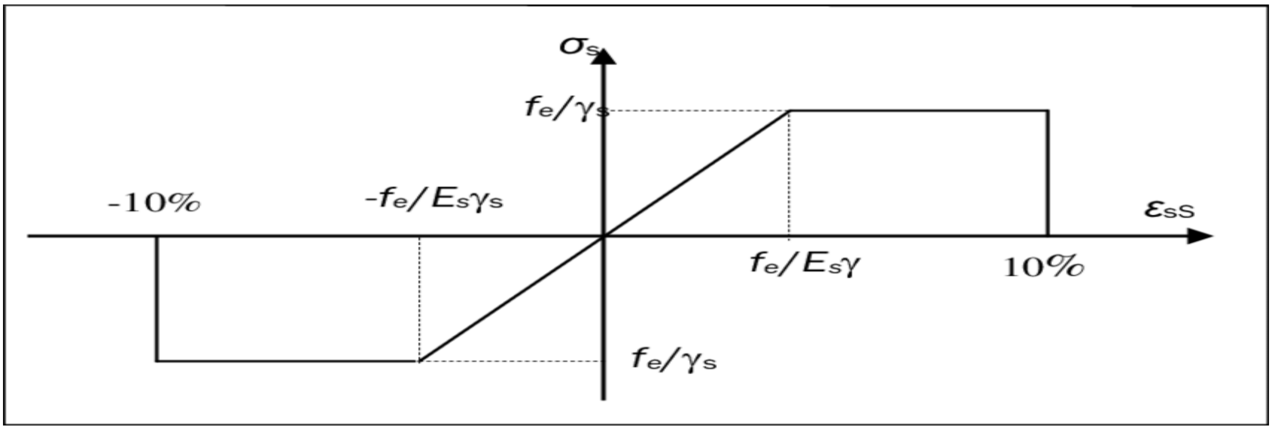


Figure I.6. Stress-strain diagram of steel.

With: n Cracking coefficient, whose value is: $\begin{cases} \eta = \mathbf{1,00}\ \textbf{\textit{For smooth round steel.}} \\ \eta = \mathbf{1,60}\ \textbf{\textit{For high} - \textit{strength steel.}} \end{cases}$

I.6. Actions and loads:

I.6.1. Loads:

The actions are forces and moments resulting from applied loads (permanent, climatic, operational) and imposed deformations (temperature variations, settlement of supports).

Note that:

- G: Permanent loads (self-weight of the structure + fixed equipment).
- Q: Variable loads (operational + climatic).

I.6.2. Stresses:

The stresses are calculated from the actions and comprise of normal forces (axial forces), shear forces, bending moments, and torsional moments.

- ❖ **Design loads or design forces:**

The combinations used in our study are:

- At ultimate limit state (ELU):

1,35 G + 1,5 Q.

1,35 G + Q

1,35 G

- At the Serviceability Limit State (ELS):

G + Q.

G

I.7. Conclusion:

Finally, in this chapter, we have presented and described our project along with the various materials used to create the artwork that is the subject of this study.

Chapter 02: Load Calculation and Preliminary design of structural Elements

II.1. Introduction:

Pre-design consists of estimating the preliminary dimensions of structural elements prior to studying the project. The work elements must include a minimum section to list the procedures and requirements to which they are subject. Pre-sizing is carried out according to the regulations dictated by CBA93, BAEL, EC02, and RPA99. The sections that can be obtained are not final and can be increased after verification processes.

II.2. Load distribution:

The process of load descent aims to calculate the vertical forces resulting from the effect of vertical loads on various vertical elements supporting the foundations in order to measure them in advance.

Permanent loads are obtained from the dimensional characteristics of the elements and structures. They are deducted from the drawings and the volumetric weight of the constituent materials.

a) Dead loads:

- **Non-accessible terrace floor (hollow core):**

1- Mortar screed layer (5cm)0.05*2000……………………………………..…1KN/m^2.
2- Thermal insulation layer in sand or tuff (8cm) 1800*0.11………...………1.98KN/ m^2.
3- Mortar layer (3cm) 0.03 x 2000…………………………………………….…0.6KN/ m^2.
4- Hollow core + Compression slab (20+4)…………………………………3.3KN/ m^2.
5- Cement plaster (1.5 cm) 1800*0.015………………………………………0.27 KN/ m^2

G =7.15 KN/ m^2.

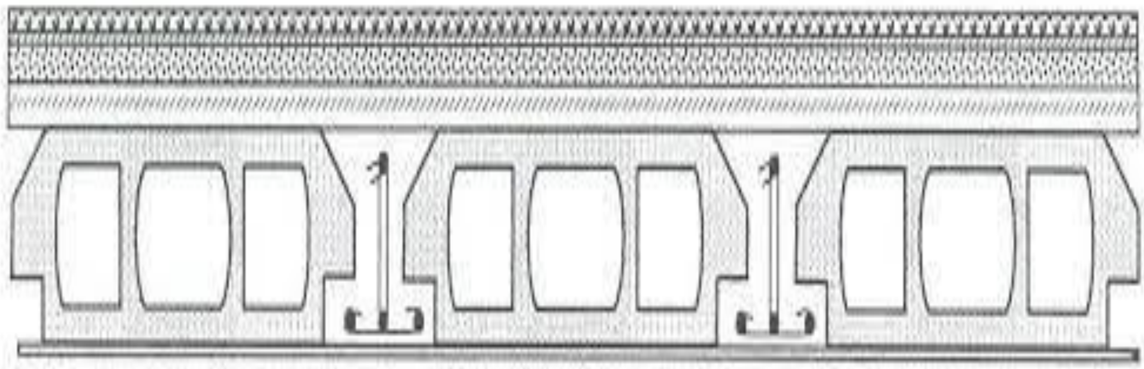
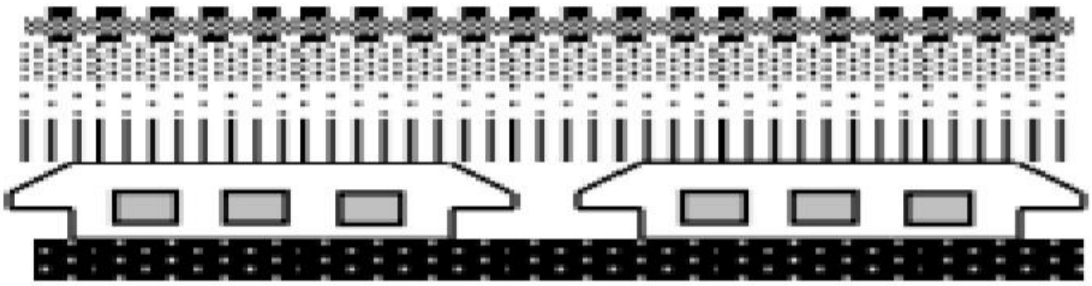


Figure II.1. Components of a hollow core slab roof.

- **Floor slab:**

1- Tile + laying mortar + Sand……………………………………………….1.04 KN/m².
2- Hollow body + Compression slab (20+4)……………………………….3.30 KN/m².
3- Cement plaster (1.5 cm) 1800×0.015. ……………………………………..0.27 KN/m².
4- Lightweight partition………………………………………………………… 1.00 KN/m².



$$G = 5.61\ KN/m^2.$$

Figure II.2. Components of a hollow core floor slab.

- **The parapet:**

Cross-sectional view of the parapet**:**

$$S = (0.6\times 0.1) + (0.08\times0.1) + \frac{(0.02x0.1)}{2} \Rightarrow S = 0.069\ m^2.$$

Self-weight = **0.069×25 =1.725 KN/ml.**

Cement coating = **0.02x20 [0.6+0.2+0.08+0.1+0.5] =0.592 KN/m².**

$$G = 2.317\ KN/ml\,.$$

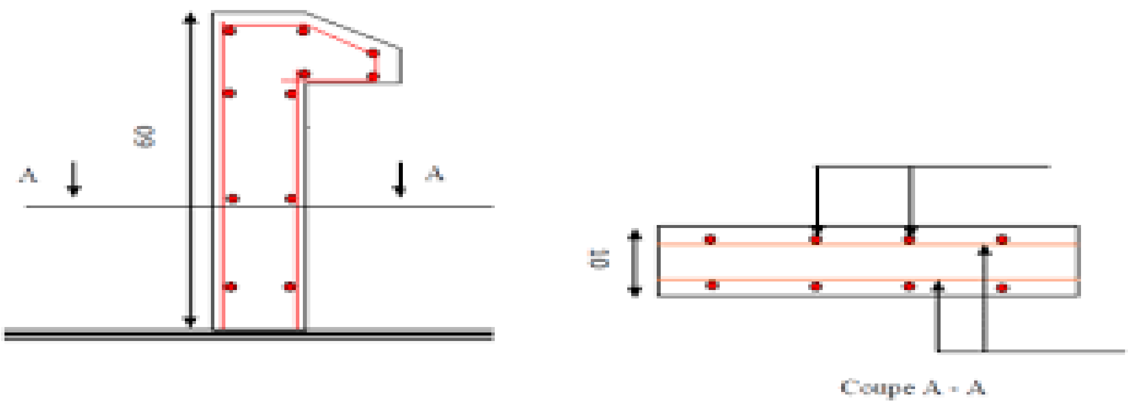


Figure II.3. Cross-section of a parapet wall.

- **Exterior walls:**

We have chosen a double-walled brick masonry:

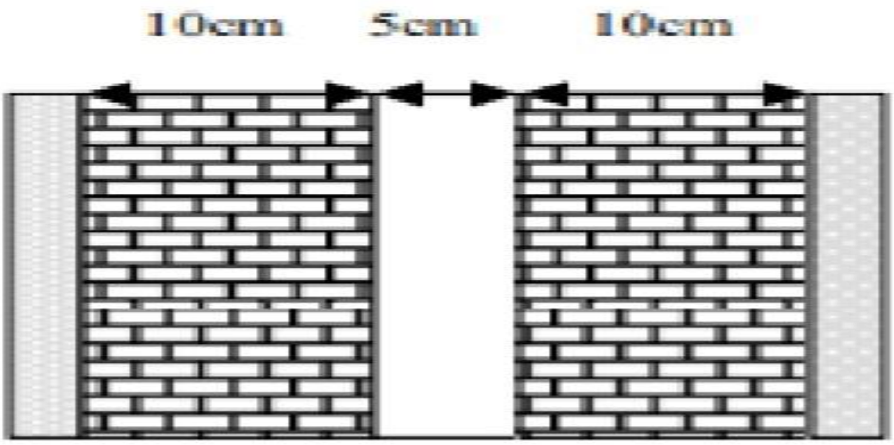
1-The exterior coating……………………………...……………….. 0.02x20=0.40 KN/m².

2-Hollow bricks (10cm)…………………………….………………… 0.1x0.9=0.9 KN/m².

3-Hollow bricks (10cm)………………………………..……………… 0.1x9= 0.9 KN/m².

4-Internal coating…………………………………………………… 0.015x13 =.195 KN/m².

5-Cement coating……………………………..……………… 0.02 x 18 =0.36KN/m².



G=2.755 KN/m².

Figure II.4. Cross-section of exterior walls.

- **Interior walls:**

Our choice has fallen on brick masonry (10 cm).

1-Translates to plaster coating……………………………………..0.02 x 12 = 0.24 KN/m².

2-Translates to hollow bricks (10cm)…………………………………... 0.1 x 9 = 0.9 KN/ m².

3-Translates to plaster coating...0.02 x 12 = 0.24 KN/m².

G=1.38 KN/m².

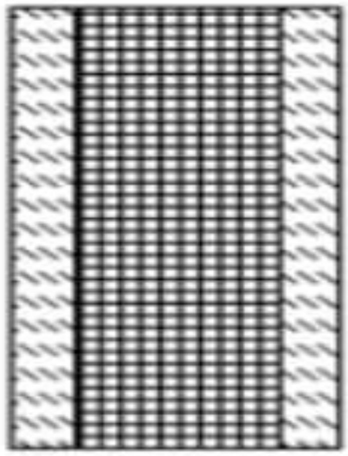


Figure II.5. Interior walls.

- **Balcony:**

Evaluation des charges :

1-Tiling…………………………………………………………………………… 0.44 KN/m².

2-Laying mortar ……………………………………………………..........………...0.60 KN/m².

3-Solid slab floor……………………………………………………………......... 3 KN/m².

4-Plaster coating…………………………………………………………………… 0.24 KN/m².

G =4.28 KN/m².

- **Stairs (α = 30°):**

a) **Bench:**

1-Self-weight...25 x 0.15 x 1cos α = 4.43 KN/m².

2-Weight of steps..(22 x 0.17 x 25)/2 = 1.87 KN/m².

3- Tiling...22 x 0.02 x 1 = 0.44 KN/m².

4- Setting mortar...20 x 0.02 x 1 = 0.4 KN/m².

5-Coating..20 x 0.012 x 1cos α = 0.28 KN/m².

6- Metal guardrail..0.1 k KN/ m².

G = 7.52 KN/m² .

b) Landing:

1- Self-weight..25 x 0.15 x 1 = 3.75 KN/m².

2-Tiling.. 0.44 KN/m².

3-Setting mortar.. 0.40 KN/m².

4-Coating...0.24 KN/m².

$$G = 4.83\ KN/m^2.$$

- **The columns:**

Sp= $\frac{5.25+3.9}{2} \times \frac{4.05+4.05}{2} = 18.53\ m^2$.

Sr= $\frac{5.25+4.05}{2} \times \frac{3.90}{2} = 9.3\ m^2$.

Sc= $\frac{5.25}{2} \times \frac{3.90}{2} = 5.12\ m^2$.

Table II.1. The column section and the permanent loads.

S(m^2)	Ng(KN/ m^2)	Nq(KN/ m^2)	Nu(KN/ m^2)
Sp	340.39	74.12	570.71
Sr	170.84	37.2	286.434
Sc	94.05	20.48	157.69

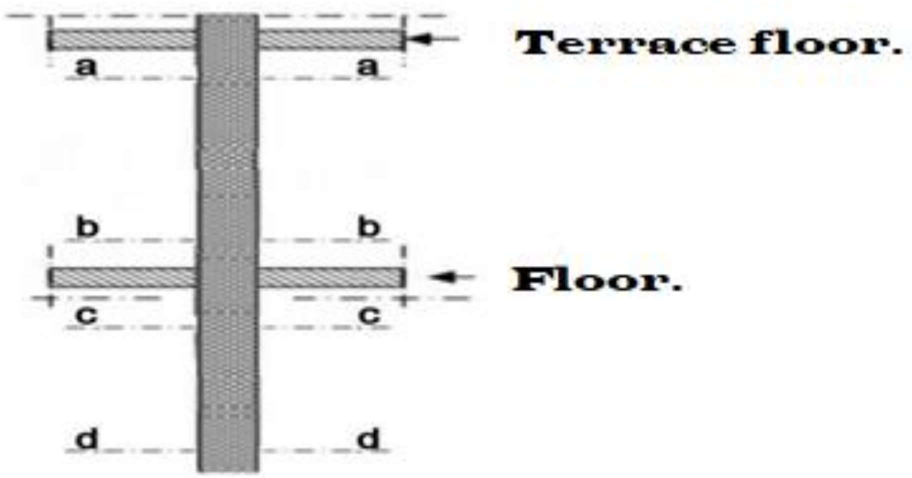


Figure II.6. Showing the different sections.

b) Variable charges:

- **For the floors:**

Are defined according to Article 7.2.4 of the Technical Regulations for Building Construction (DTR BC-22) entitled "Permanent Loads and Operating Loads" in the following table:

Table II.2. Operating loads.

Nature of the space	Operating load Q (kN/m2)
Inaccessible terrace	**1**
Typical floor	**1**.5
Stairs	2.5
Balcony	3.5

II.3. Preliminary sizing of elements:

II.3.1. Beams:

In general, beams can be defined as horizontal load-bearing elements. The preliminary sizing must adhere to the deflection criterion.

According to the rules of **BAEL 91**, we have: Lmax

$$\frac{Lmax}{15} \leq h \leq \frac{Lmax}{10} \quad \text{and} \quad 0.3h \leq b \leq 0.7h .$$

With:

h: height of the beam.

b: width of the beam.

L: is the span of the beam, measured between the axes of the supports.

Sections of the columns to be considered in the calculations: **(25x25) cm^2.**

a) The main beam:

We have: Lmax= 5 m.

So: $\frac{500}{15} \leq hp \leq \frac{500}{10} \Rightarrow 33.33\ cm \leq hp \leq 50cm .$

$0.3(45) \leq bp \leq 0.7(45) .$

$13.5 \leq bp \leq 31.5.$

So, we have: $\begin{cases} \boldsymbol{hp = 45cm}. \\ \boldsymbol{bp = 25cm}. \end{cases}$ **(bp,hp):** dimensions of the main beam.

❖ **Verification of RPA conditions:**

- bp = 25cm>20cm , verified . Verify RPA.
- hp = 45cm>30cm , verified .
- $\frac{\text{hp}}{\text{bp}} =$ 1.8<4 , verified .

Therefore, RPA conditions are met, so we take the dimensions of the main beams (m.b) [transverse] : (25×45)cm^2.

b) The Secondary beam:

We have: Lmax= 5 m.

So: $\frac{\mathbf{500}}{\mathbf{15}} \leq \mathbf{hp} \leq \frac{\mathbf{500}}{\mathbf{10}} \Rightarrow \mathbf{33.33\ cm \leq hp \leq 50cm}$ **.**

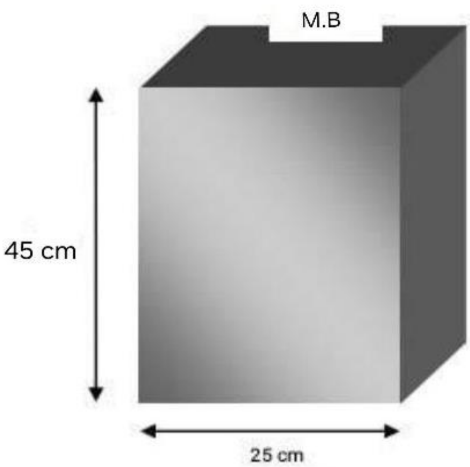
$\mathbf{0.3(40) \leq bp \leq 0.7(40)}$ **.**

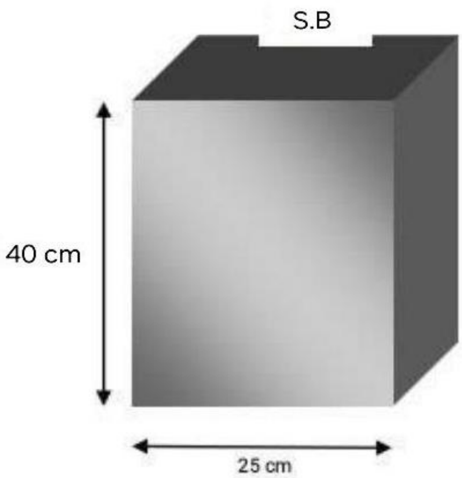
$\mathbf{12 \leq bp \leq 28}$**.**

So, we have: $\begin{cases} \boldsymbol{hp = 40cm}. \\ \boldsymbol{bp = 25cm}. \end{cases}$ **(bp,hp):** dimensions of the main beam.

❖ **Verification of RPA conditions:**

- bp =25cm>20cm , verified . Verify RPA.
- hp =40cm>30cm , verified.
- $\frac{\text{hp}}{\text{bp}}$ =1.6 <4 , verified.





Therefore, RPA conditions are met, so we take the dimensions of the secondary beams (s.b) [transverse] : (25×40)cm^2.

Figure II.7. The dimensions of the main beam and the secondary beam.

II.3.2. The Columns:

Columns are structural elements that transmit vertical loads to the foundations. They contribute to the overall or partial bracing of buildings.

The preliminary sizing of columns is done by verifying the strength of an initially chosen section with a reinforcement ratio of 1% of the concrete section under the action of the maximum axial load (the most heavily loaded column) determined by the load descent.

- **According to RPA99/version 2003:**

The dimensions of the cross-sectional area of the columns in zone 0 must satisfy the following conditions:

Zone 0:

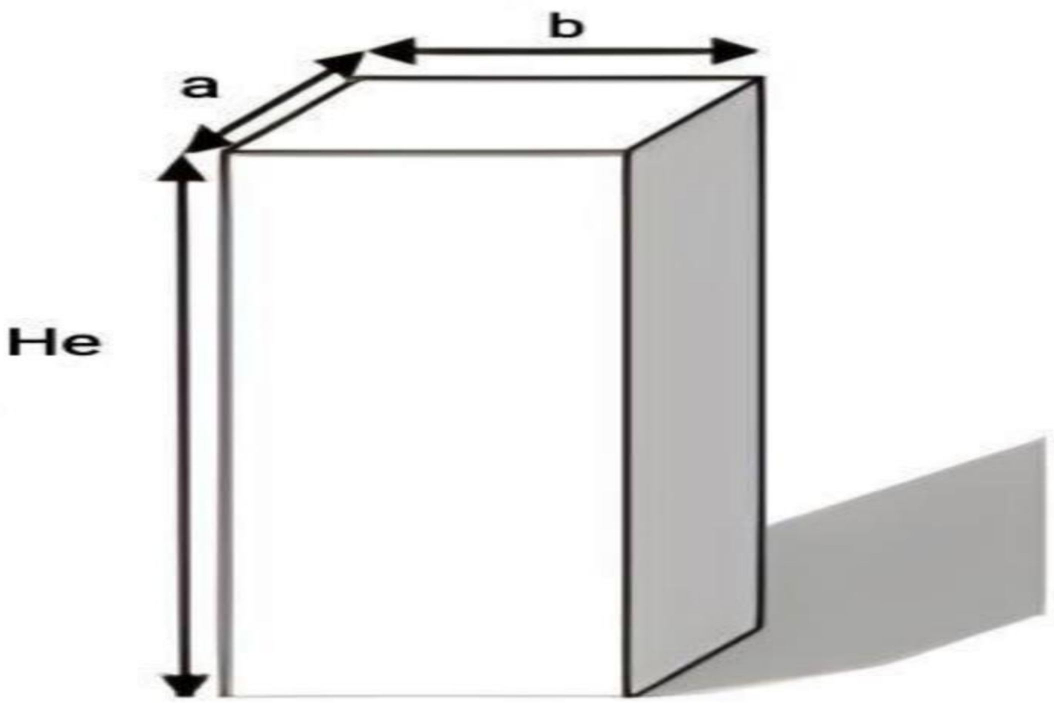


Figure II.8. Design of a column.

- **According to the BAEL (French Concrete Design Code):**

The ultimate axial force N_{ul} acting on a column (centrally applied compression) is given by the following formula:

$$Br \geq \frac{\beta \text{x}\, Nu}{\left[\frac{fbu}{0.9} + \frac{0.85\, X\, fe}{\gamma s(\frac{As}{Br})}\right]}.$$

With:

Br: reduced section of the column.

Br = (a-0.02)(b-0.02)m², for a rectangular section.

Br = (a-0.02)² m², for a square section.

N_{ul}: Maximum normal force at the ultimate limit state (Nu = 1.35G + 1.5Q).

fc28: Compressive strength of concrete at 28 days (here we assume fc28 = 25 MPa).

fe: Yield strength of steel (here we assume fe = 400 MPa).

As: Area of reinforcement in the column.

γb: Safety factor for concrete, where **γb =** 1.5 (for sustained or transient situations).

γs: Safety factor for steel, where **γs =** 1.15 (for sustained or transient situations).

α: Coefficient based on the slenderness of the column calculated by:

$$\begin{cases} for\, \lambda \leq 50 \;\; \alpha = \dfrac{0.85}{1 + 0.2\left(\dfrac{\lambda^2}{35^2}\right)}. \\ for 50 \leq \lambda \leq 70 \;\; \alpha = 0.6\left(\dfrac{50^2}{\lambda^2}\right). \end{cases}$$

Generally, the steel percentage is 1% of the section:

$\frac{As}{Br} = \frac{1}{100}$ ⇒ So:

Nu: Is determined based on the load descent.

$$Nu \leq \alpha.Br.\left[\frac{fc\,28}{0.9\, x\, \gamma\, b + fe\, 100\, x\, \gamma\, s}\right] \quad Br \geq \frac{\beta.Nu}{\frac{fbc}{0.9} + \frac{0.0085\, fe}{\gamma\, s}}.$$

$$Br = \frac{0.718\, x\, 570.71}{(14.17/\,0.9\,) + 0.0085\,(400\,/1.15)} = 21910 mm^2.$$

a = b = 148.02 mm.

According to the RPA, we assume that **B** is 25 x 25.

II.4. Conclusion:

In this chapter, it can be that we have performed load assessment. Additionally, we have calculated the preliminary cross-sections of the structural members. As for the lintels, we have used sections measuring (45*25) square centimeters and (25*40) square centimeters for the main lintels and the chains, respectively.

Chapter 03: STUDY OF SECONDARY ELEMENTS.

III.1. Introduction:

The secondary elements are elements that do not directly contribute to load-bearing and their design is independent of seismic effects. They are calculated according to the BAEL91 code, respecting all the specific regulations of the seismic design RPA99.

The secondary elements that are taken into account include:

- Floors .
- Balconies (or terraces) .
- Stairs .
- Partitions (or walls) .

III.2. Floor:

The floor is a horizontal element that separates two levels and transfers the applied loads and superimposed loads directly to the supporting elements, while also providing functions such as sound insulation, thermal insulation, and waterproofing of the extreme levels. The thickness of the floors is usually determined based on usage conditions rather than strength checks. Therefore, the thickness of the floors is derived from the conditions mentioned below at a later stage.

III.2.1. Hollow-core floor:

This type of floor is composed of hollow cores, beams, and a topping slab.

La hauteur du plancher est conditionnée par le critère de la flèche dicté par le CBA93.

$$\mathbf{ht} \geq \frac{\mathbf{Lmax}}{\mathbf{22.5}} \quad \boldsymbol{RPA\ ,Article\ B.6.8.4.2.4.}$$

With:

ht: Total height of the floor.

Lmax: The greatest span between supports in the direction of beam layout .

$\mathbf{Lmax} = 5 - 0.25 = 4.75 \text{ m} \Rightarrow \text{ht} \geq \frac{4.75}{22.5} = 21.11$

$\mathbf{ht} \geq \mathbf{2}4 \text{ cm}$

In that case, we opt for a floor [20 + 4] $\begin{cases} \boldsymbol{Hhollow\ core\ =\ 20\ cm.} \\ \boldsymbol{Hcompression\ slab\ =\ 4\ cm.} \\ \boldsymbol{Htotal\ =\ 24\ cm.} \end{cases}$

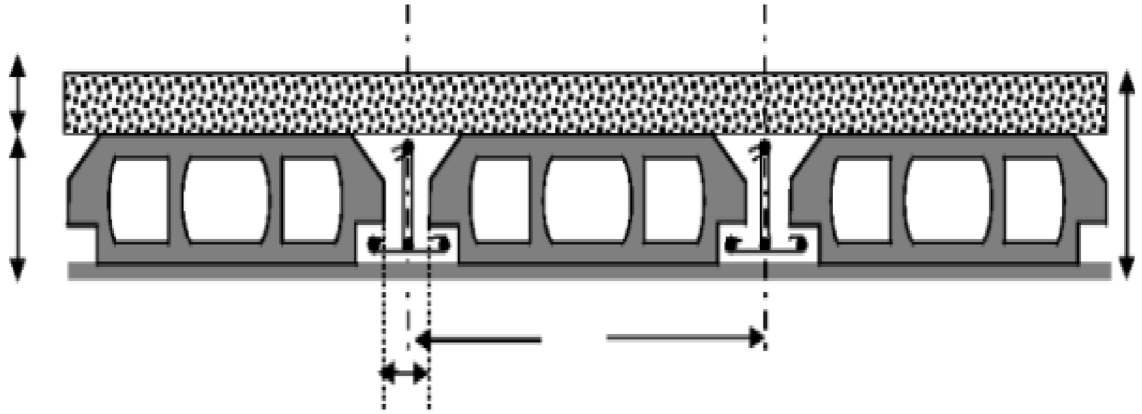


Figure III.1. Cross-section of a hollow-core floor.

III.2.1.1. Preliminary sizing of the joists:

These are precast or cast-in-place reinforced concrete elements designed to transfer vertical loads to the beams.

The beams are calculated as a T-section. The width of the compression slab to be considered is defined by:

$$\frac{b - b0}{2} \leq \min\left(\frac{Lx}{2}, \frac{Ly}{2}\right) \text{.. CBA93.}$$

With:

Lx: Distance between the centers of the joists.

Ly: Distance between the supports of the joists.

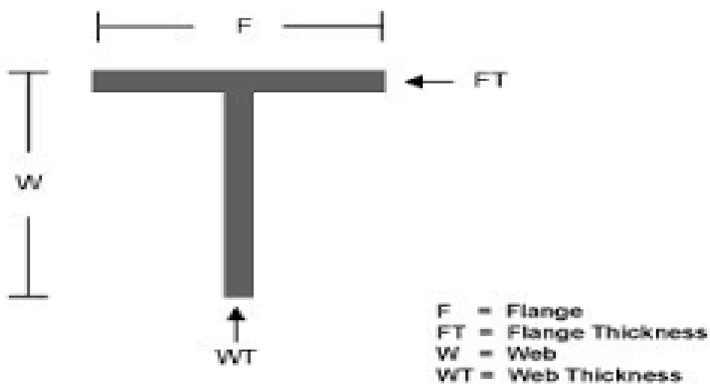


Figure III.2. Cross-section of a joists.

III.2.1.2. Calculation of reinforcement for the joists:

For the calculation, we use the maximum values of the moments (in mid-span and at supports). According to the results from **the ROBOT software**:

Table III.1. Maximum moments in the joists.

	Support:		Mid-span:	
The moments (kN.m)	Ultimate Limit State (ULS)	Serviceability Limit State (SLS)	Ultimate Limit State (SLS)	Serviceability Limit State (SLS)
	-16.92	-12.37	15.37	11.23

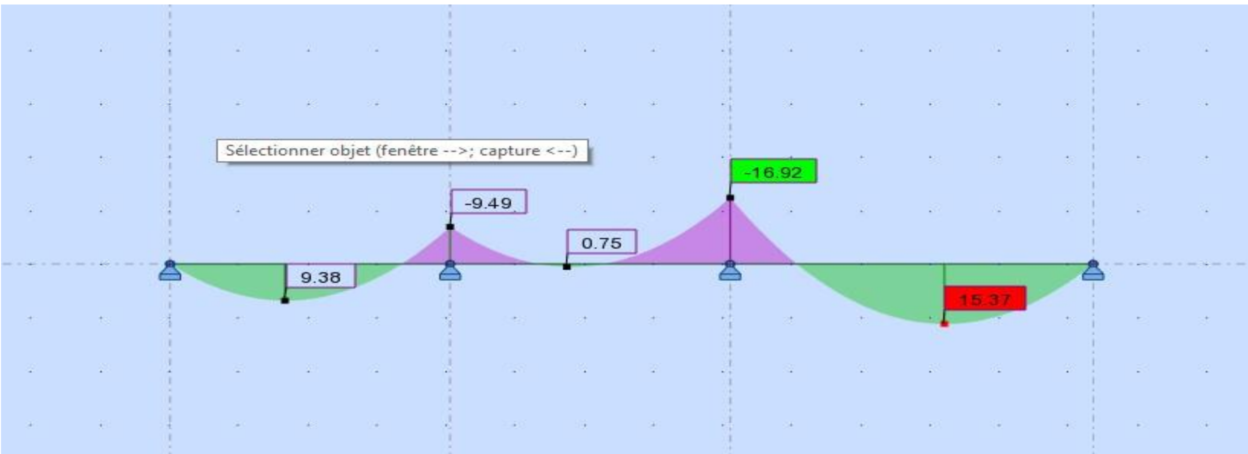


Figure III.3. Maximum moments in the joists at the ultimate limit state (ULS).

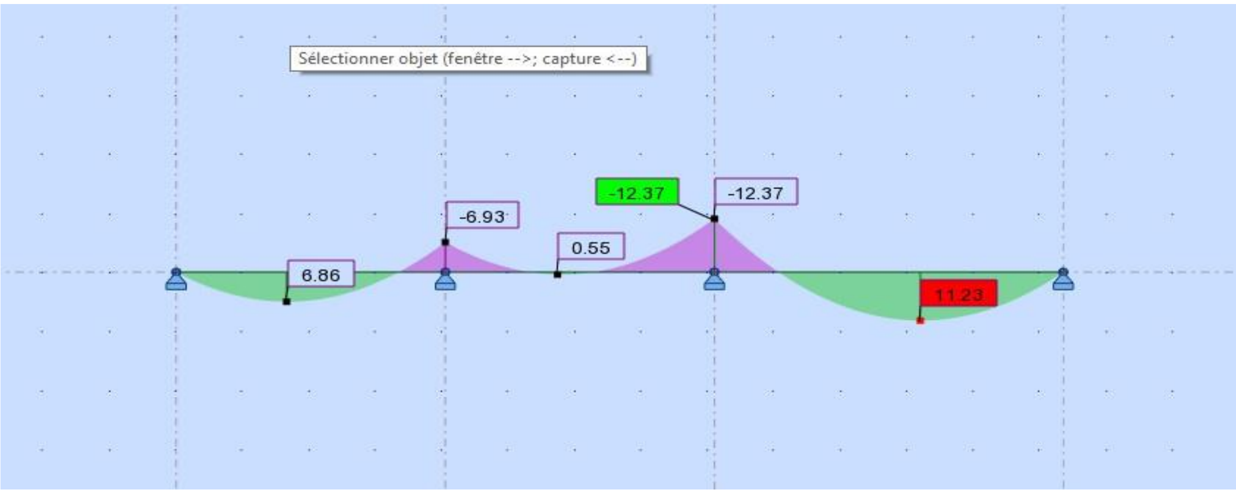


Figure III.4. Maximum moments in the joists at the Serviceability Limit State (SLS).

h_0 = 4cm ; h=24 cm ; b=60 cm ; b_0 = 12 cm ; d= 0.9h = 21.6 cm .

$fbu = \frac{0.85\ fc28}{\gamma\ b} = 14.17$ MPa ; $\frac{fe}{\gamma\ s}$ =347.82 MPa .

- **Support :**

$MT = bh_0(d - h_0/2)fbu$.

MT =0.066 MN.m .

If : Mu $\leq$ MT $\begin{cases} Yes \Rightarrow \ Rectangular\ section. \\ \quad No \ \Rightarrow T - section \ . \end{cases}$

0.0169 $\leq$ 0.066

- **Note:** The neutral axis will be inside the table. The reinforcement calculation is done as a rectangular section.

<u>Organizational Diagram for Simple Bending:</u>

$\mu \leq \mu L$ $\begin{cases} \textbf{Yes} \Rightarrow \ \textbf{As}' = \ \textbf{0}. \\ \textbf{No} \ \Rightarrow \ \textbf{As}' \neq \ \textbf{0}. \end{cases}$

$\mu = \frac{Mu}{b.d^2.fbu} = \frac{16.94*10\_3}{0.6 \times 0.216^2 \times 14.17} = 0.043 \leq 0.392$

$\alpha = 0.0549$; $\beta = 0.979$

$\varepsilon st = 3.5‰(\frac{1-\alpha}{\alpha}) = 3.5‰(\frac{1-0.0549}{0.0549}) = 60.25 \geq 1.739$; $\sigma st = 347.82$ MPA

$As = \frac{Mu}{\beta.d.\sigma st} = \frac{16.94 \times 10-3}{0.979 \times 0.216 \times 347.82} = 0.00023\ m^2 = 2.30\ cm^2$.

Therefore, we rely on: 3 HA12 = 3.39 cm^2.

Condition of non-fragility:

Ast min ≥ 0,23.b.d $\frac{ft28}{fe}$.

Ast min ≥ 0.23 × 0.6 × 0.216 × $\frac{2.1}{400}$

Ast min ≥ 1.56 cm².

Verification of SLS (Serviceability Limit State):

$\gamma = \frac{Mu}{Mser} = 1.37$ $\alpha \leq \frac{\gamma - 1}{2} + \frac{fc28}{100}$ AS Mser =12.37 KN.m

0.0549 $\leq$ 0.435……………………………………………………………………………….OK

- **In span:**

$$MT = bh_0(d - h_0/2)fbu\,.$$

MT =0.066 MN.m.

If : Mu $\leq$ MT $\begin{cases} Yes \Rightarrow \ Rectangular\ section. \\ \quad No \ \Rightarrow T - section\ . \end{cases}$

0.0154 $\leq$ 0.066

- **Note:** The neutral axis will be inside the table. The reinforcement calculation is done as a rectangular section.

$\mu \leq \mu L$ $\begin{cases} Yes \Rightarrow \ As' \ = \ 0 \\ No \ \Rightarrow \ As' \ \neq \ 0 \end{cases}$.

$$\mu = \frac{Mu}{b.d^2.fbu} = \frac{15.4*10\_3}{0.6 \text{ x } 0.216^2 \text{ x } 14.17} = 0.039 \ \leq 0.392$$

α = 0.049 ; β = 0.981

$$\varepsilon st = 3.5‰\left(\frac{1-\alpha}{\alpha}\right) = 3.5‰\left(\frac{1-0.049}{0.049}\right) = 67.25 \ \geq 1.739\,; \quad \sigma st = 347.82 \text{ MPa}\,.$$

$$As = \frac{Mu}{\beta.d.\sigma st} = \frac{15.4 \text{ x } 10-3}{0.981 \text{ x } 0.216 \text{ x } 347.82} = \ 0.000209 \ m^2 = 2.\ 09 \ cm^2\,.$$

Therefore, we rely on: **3 HA10 = 2.36 cm².**

Condition of non-fragility:

$$Ast\ min \geq 0{,}23.b.d\,\frac{ft28}{fe}\ .$$

$$Ast\ min \geq 0.23 \times 0.6 \times 0.216 \times \frac{2.1}{400}$$

$$Ast\ min \geq 1.56 \ \ cm^2.$$

Verification of the ELS (Environmental Limit State):

$\gamma = \frac{Mu}{Mser} = 1.37$ $\quad \alpha \leq \frac{\gamma-1}{2} + \frac{fc28}{100}$ **AS Mser =11.23 KN.m .**

0.049 $\leq$ 0.435……………………………………………………………………………ok

Table III.2. Reinforcement of joists.

	A min	As	A dopted cm^2
Support	1.56	2.30	3.39 (3HA12)
In span	1.56	2.09	3.39 (3HA12)

- **Verification of shear stress:**

For the shear force, checking shear will be sufficient. The most unfavorable case (Tu max =17.66 KN) needs to be verified, so it is necessary to check that:

$$\overline{\tau u} \leq \tau u \,.$$

Such as: $\tau u = \min[0.2 \times \frac{fc28}{\gamma b}, 4MPA] = 3.33\ MPa$ (non-detrimental cracking).

$$\tau u = \frac{TMAX}{bxd} = \frac{17.66}{0.6*0.216} \,.$$

$\tau u = 0.135\ MPA \leq \tau u = 3.33\ MPa$..ok

b) Transversale renforcement:

$$\emptyset l \leq \min\left(\frac{h}{35}, \frac{b}{10}, \emptyset\right) = \min\left(\frac{240}{35}, \frac{120}{10}, \emptyset\right) = 11.43\ mm = \min(6.86, 12, 12)$$

We will consider T6[$HA \rightarrow fe400\ MPa$].

At=2T6=1,01cm².

- **Spacing of transverse reinforcement:**

St1 ≤ min (0. 9 × d; 40cm) = 19.44cm .

$$St2 \leq \frac{At \times fe}{b0 \times 0.4} = \frac{1.01 \times 400}{12 \times 0.4} = 84.17\ cm\,.$$

St = min (St1, St2) = 19.44 cm

SO : **St = 15 cm**

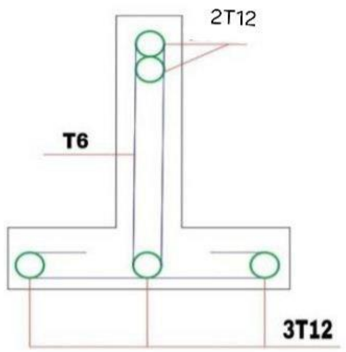


Figure III.5. Reinforcement diagram of supported joists.

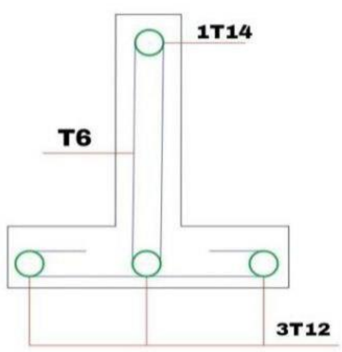


Figure III.6. Reinforcement diagram the joists in span.

III.3. Balcony :

III.3.1. Introduction :

The balcony is a secondary element in a building. It is often composed of a solid and reliable reinforced concrete slab that extends as a projection from the main structure. It is exposed to external elements and follows the contour of the building. The balcony plays an important role in architectural aesthetics and increasing the usable area.

The balcony is modeled as a cantilevered slab on one side.

The balcony is subjected to a permanent load G (self-weight), a concentrated load at the free end P (self-weight of the wall), and a live load Q.

III.3.2. Preliminary design:

The thickness of the solid slab will be determined based on the condition of flexural strength.

$$\frac{L}{30} < e < \frac{L}{10}$$

$L_1 = 1.00$m.......................3 .33 $< e < 10$...................... $e_1 = 15$cm.

$L_2 = 0.6$m............................$2 < e < 6$.........................$e_2 = 10$ cm.

III.3.3. Load evaluation:

The load G1:

1-Tiling……………………………………………………………………………. 0.44 kN/m².

2-Bedding mortar……………………………………………………………….. 0.60 kN/m².

3-Solid slab floor……………………………………………………………... 3 kN/m².

4-Plaster coating…………………………………………………………….... 0.24 kN/m².

G =4.28 KN/m².

The load G2:

1-Weight of walls……………………………………………..…………………… 0.9 KN/m².

2-Cement plaster ………………………….……………………………………....0.72 KN/m².

G = 1.62 KN/m².

The load Q = 3.5 KN/m².

III-3-4. Calculation of loads:

$Nu = 1.35G1 + 1.5Q = 1.35 \text{ x } 4.28 + 1.5 \text{ x } 3.5 = 11.03$.

$Pu = 1.35G2 = 1.35 \text{ x } 1.62 = 2.19$.

$Mu1 = -Pu.L1 - \frac{\text{Nu.L1 2}}{2} = -2.19 \text{ x } 1 - \frac{11.03 \text{ x } 1\ 2}{2} = -7.71\ KN.m$.

$Mu2 = -Pu.L2 - \frac{\text{Nu.L2 2}}{2} = -2.19 \text{ x } 0.6 - \frac{11.03 \text{ x } 0.6\ 2}{2} = -5.3 KN.m$.

$Tu = Nu \text{ x } L + Pu = 11.03 \text{ x } 1 + 2.19 = 13.22$.

$Tu = Nu \text{ x } L + Pu = 11.03 \text{ x } 0.6 + 2.19 = 8.81$.

$Mser1 = 1.62 \text{ x } 1 + \frac{7.78\text{x } 1\ 2}{2} = 5.51\ KN.m$.

$Mser1 = 1.62 \text{ x } 0.6 + \frac{7.78\text{x } 0.6\ 2}{2} = 2.37\ KN.m$.

III-3-5. Reinforcement :

- **The longitudinal reinforcement of loads 1:**

The reinforcement is carried out for simple bending for a beam with a width of b = 1m et d'épaisseur e = 15cm.

d = e – d' =15 – 1.5 = 13.5 cm .

Mu = 7.71 kN.m .

$u_{bu} = \frac{Mu}{bd^2 fbc} = \frac{7.71x10-3}{1\times(0.135)\ 2 \times 14.17} = 0.03 \leq u_L = 0.392$.

$A's = 0 \quad \beta = 0.985 ; \alpha = 0.038 ; \sigma st = 347.82$ MPa .

$As = \frac{Mu}{\beta d\sigma st} = \frac{7.71x10-3}{0.985 \times 0.135 \times 347.82} = 0.000167\ m^2 = 1.67\ cm^2$.

Also : 4HA8=2.01 cm^2.

Condition of non-fragility:

Ast min ≥ 0,23.b.d $ft28/\ fe$

Ast min ≥ 0.23 × 1 × 0.135 × 2.1 /400

Ast min ≥ 1,63 cm^2.

Verification of the serviceability limit state (ELS):

$\gamma = \frac{\text{Mser}}{\text{Mu}} = 1.69 \quad \alpha \leq \frac{\gamma - 1}{2} + \frac{\text{fc28}}{100}$ with: Mser = 5.51 KN.m .

0.038 ≤ 0.593……………………………………………………………………………OK

❖ **The transverse reinforcement:**

$$Ast = \frac{AS}{5} = \frac{5.5}{5} = 1.1cm^2$$

AST: Section of the transverse reinforcement.

The spacing between the bars.

- In the main direction **b = 1m :**

$$St = \frac{b}{5} = \frac{100}{5} = 20 \ .$$

- In the secondary direction:

$$St = \frac{L}{4} = \frac{100}{4} = 25 \text{ cm} \ .$$

Table III.3. Balcony reinforcement results.

	As longitudinal	As transverse	Amin (cm^2)	St main (cm)	St secondary (cm)
	1.67	1.1	1.63	20	25
We adopt (cm^2)	4HA8=2.01	4HA8=2.01			

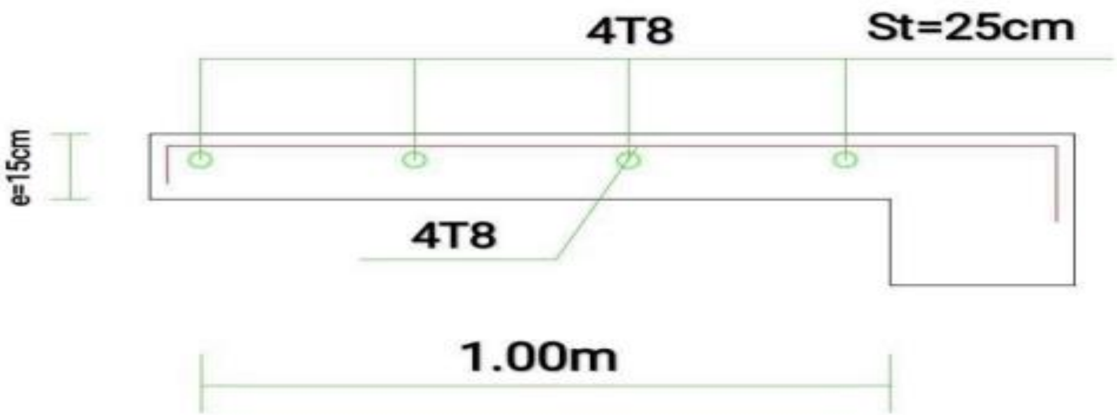


Figure III.7. Balcony reinforcement diagram.

- **The longitudinal reinforcement of loads 2:**

The reinforcement is carried out for simple bending for a beam with a width of b = m and a thickness of b = 1m et d'épaisseur e = 10cm.

d = e – d' =10– 1.5 = 8.5 cm

Mu = 5.3 kN.m

$u_{bu} = \frac{Mu}{bd^2fbc} = \frac{5.3x10-3}{1\times(0.085)\ 2\times 14.17} = 0.052 \leq u_L = 0.392$

$A's = 0 \quad \beta = 0.973\ ;\ \alpha = 0.0667\ ;\ \sigma st = 347.82$ MPA

$As = \frac{Mu}{\beta d\sigma st} = \frac{5.3x10-3}{0.973\times 0.085\times 347.82} = 0.000184\ m^2 = 1.84\ cm^2$

Also : 4HA8=2.01 cm^2

Condition of non-fragility:

Ast min ≥ 0,23.b.d $ft28/\ fe$

Ast min ≥ 0.23 × 1 × 0.085 × 2.1 /400

Ast min ≥ 1,01 cm^2.

Verification of the serviceability limit state (ELS):

γ = Mu/ Mser = 2.24

$\alpha \leq \frac{\gamma - 1}{2} + \frac{fc28}{100}$ AS Mser = 2.37 KN.m

0.038 ≤ 0.87………………………………………………………ز…………..………. ok

- **The transverse reinforcement:**

$$Ast = \frac{AS}{5} = \frac{3.3}{5} = 0.66cm^2 \,.$$

AST: Section of the transverse reinforcement.

The spacing between the bars.

- In the main direction **b = 1m** :

$$St = \frac{b}{5} = \frac{100}{5} = 20 \,.$$

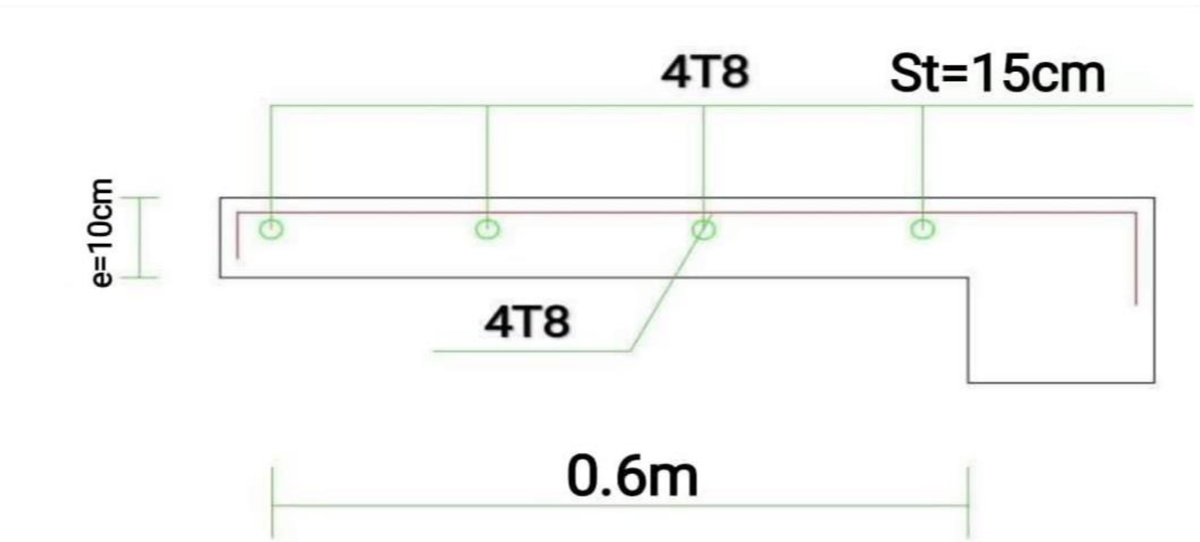
- In the secondary direction.

$$St = \frac{L}{4} = \frac{60}{4} = 15 \text{ cm.}$$

Table III.4. Balcony reinforcement results.

	As longitudinal	As transverse	Amin (cm^2)	St main (cm)	St secondary (cm)
	1.84	0.66	1.01	20	15
We adopt (cm^2)	4HA8=2.01	4HA8=2.01			

Figure III.8. Balcony reinforcement diagram.



III.4. Stairs:

III.4.1. Preliminary design:

The stairs are a series of steps that allow passage from one level to another. They can be made of reinforced concrete, metal, or wood. In our case, they are constructed using cast-in-place concrete. The various components of a staircase include.

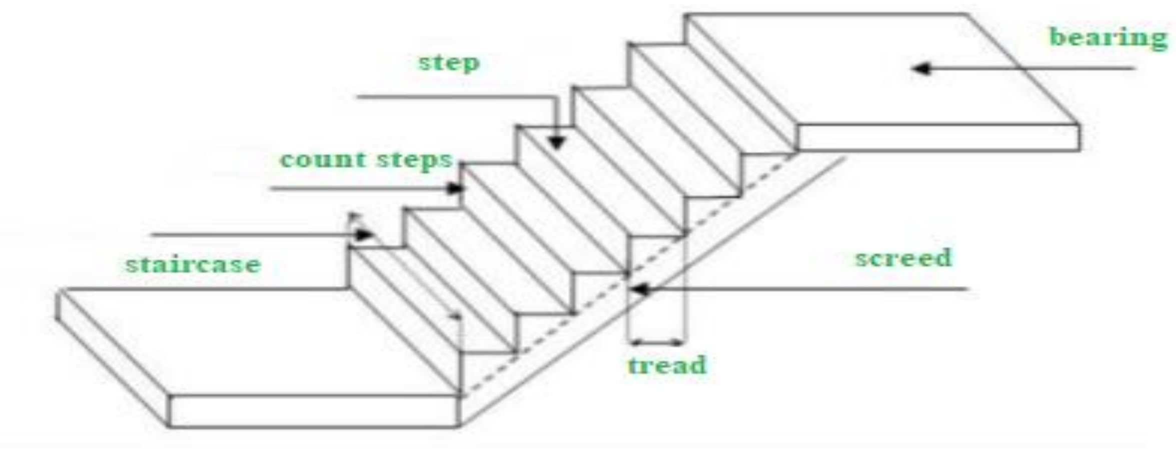


Figure III.9. Diagram of a staircase.

III.4.1.1. design :

In order for a staircase to fulfill its function with optimal comfort, the following conditions must be verified:

- The height (h) of the risers is situated between:

$$14\text{cm} \leq \boldsymbol{h} \leq 20 \text{ cm}.$$

- The width (g) is situated between:

$$25\text{cm} \leq \boldsymbol{g} \leq 32 \text{ cm}.$$

- The empirical formula of BLONDEL is:

$$\mathbf{60}\ \boldsymbol{cm} \leq \boldsymbol{m} \leq \mathbf{65}\ \boldsymbol{cm} \text{ with} \rightarrow \boldsymbol{m} = \boldsymbol{g} + \mathbf{2}\boldsymbol{h}.$$

We take:

- g =30 cm.
- h= 17cm.

For our construction, the stairs are straight with two flights.

III.4.1.2. Verification of Blondel's formula:

60 cm ≤ m ≤ 65 cm ⇒ m = g + 2 × h = 30 +2 × 17 = 64 cm .

60 cm ≤ 64 cm ≤ 65 cm ....ok

- **The stairs (two flights) for the ground floor are:**

The flights are designed in the same shape.

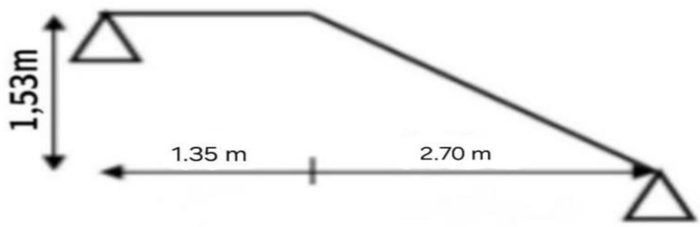


Figure III.10. Diagram of flight 1 of the ground floor.

L0 = 2.7m , **H =** 1.53m , **Lp =** 1. 35m.

- **Number of risers "Nc":**

$$Nc=\frac{hv}{h\ step} = \frac{153}{17} = 9 .$$

- **Number of Steps "Nm":**

$$Nm = Nc - 1 = 8 \text{ steps} .$$

- **The inclination:**

$$\tan(\alpha) = \frac{h}{l0} \Rightarrow \frac{1.35}{2.7} = 0.566 \Rightarrow \alpha=30°.$$

- **The length of the screed:**

$$L = \frac{l0}{\cos(\alpha)} = \frac{2.7}{\cos(30)} = 3.10 \text{ m} .$$

- **The thickness of the screed:**

$$e = \frac{l0}{20} \Rightarrow = \frac{l0}{20} = 0.135 \text{ m} = 13.5 \text{ cm} .$$

Therefore, the thickness: ***e*=13.5cm.**

Permanent load G:

$$Gv=\frac{(25\times0.21)}{(COS(30))} + 0.84 = 6.90 \text{ KN/m} .$$

Gp=(0.135×25)+0.84=4.215 KN/m .

Ultimate Limit State (ULS):

G = 6.9 KN/m . Q = 2.5KN/m .

Qu.v =1.35G+1.5Q . Qs.v = G + Q .

Quv=13.065 KN/m . Qsv=9.4 KN/m .

G=4.215KN/m . Q= 2.5KN/m .

Qu.p=9.44 KN/m . Qs.p=6.715 KN/m .

$Mvu = \frac{qL^2}{8} = 11.95$KN.m . $Mvs = \frac{qL^2}{8} = 8.57$ KN.m .

$Mpu = \frac{qL^2}{2} = 8.6$ KN.m . $Mps = \frac{qL^2}{2} = 6.12$ KN.m .

- **In support:**

Longitudinal reinforcement:

The calculation of reinforcements is primarily done concerning simple bending for a strip 1 meter long, with a section (b×h) = (100×15) cm².

d = e - 2.5 = 12.5 cm , b = 100 cm , h = 15 cm , d' = 2.5 cm .

$f_{bu} = \frac{(0.85\, fc28)}{\gamma b} = 14.17$ MPa with: $f_{c28} = 25$ MPa ; $\gamma b = 1.5$

$f_{t28} = 0.6 + 0.06\, f_{c28} = 2.1$ MPa ; $\gamma s = 1.15$.

$\mu \leq \mu_L$: $\begin{cases} \textbf{oui} \Rightarrow \textbf{As}' = \textbf{0}. \\ \textbf{Non} \Rightarrow \textbf{As}' \neq \textbf{0}. \end{cases}$

$\mu = \frac{Mu}{bd^2fbc} = \frac{8.6 \times 10-3}{1 \times (0.125)^2 \times 14.17} = 0.039 \leq uL = 0.392$ YES.

So: A's = 0 .

$\beta = 0.981$, $\alpha = 0.0497$, $\sigma_{st} = \frac{fe}{\gamma s} = 347.82$ MPa.

$As = \frac{Mu}{\beta d\sigma st} = \frac{8.6 \times 10^{-3}}{0.981 \times 0.125 \times 347.82} = 2.02\ cm^2$.

So we adopt: 5HA10=2.51 cm² .

- **In Span :**

$\mu \leq \mu_L$: $\begin{cases} \textbf{oui} \Rightarrow \textbf{As}' = \textbf{0}\ . \\ \textbf{Non} \Rightarrow \textbf{As}' \neq \textbf{0}\ . \end{cases}$

$U_{bu} = \frac{Mu}{bd^2fbc} = \frac{11.95 \times 10-3}{1 \times (0.125)^2 \times 14.17} = 0.054 \leq uL = 0.392$……………………………………..ok

So: **A's** = **0** .

$\beta = 0.972$, $\alpha = 0.0694$, $\sigma_{st} = \frac{fe}{\gamma s} = 348$MPa.

$As = Mu / (\beta d \sigma st) = \frac{11.95 \times 10-3}{0.972 \times 0.125 \times 348} = 2.83\ cm^2$.

So we adopt: 4HA10=3.14 cm^2.

Table III.5. Reinforcement of Stairs.

	A (cm^2)	A (cm^2)
support	2.02	5HA8=2.51
Span	2.83	4HA10=3.14

- **Verifications:**

a) Condition of non-fragility:

Ast min $\geq$ 0,23.b.d $\frac{ft28}{fe}$.

Ast min $\geq 0.23 \times 1 \times 0.125 \times \frac{2.1}{400}$.

Ast min $\geq 1.51\ cm^2$.

- **Verification of shear stress:**

Tu Max =16.56 KN .

$\tau u \leq \tau u$.

Such as: $\tau u = \min[0.2 \text{ x} \frac{fc28}{\gamma b}, 4MPA] = 3.33$ MPa(non-detrimental cracking) .

$\tau u = \frac{TMAX}{bxd} = \frac{16.56}{1 * 0.125}$.

$\tau u = 0.132$ MPA $\leq \tau u = 3.33$ MPA..ok

- **Spacing of transverse reinforcement:**

St1$\leq$ min (3 h ; 33) = 33 cm .

SO : St = 25 cm .

b) Verification of the serviceability limit state (ELS):

Table III.6. Reinforcement of Verification of the serviceability.

	α	$\gamma = \frac{Mu}{Mser}$	$\alpha \leq \frac{\gamma - 1}{2} + \frac{fc28}{100}$	$\alpha \leq \frac{\gamma - 1}{2} + \frac{fc28}{100}$
In support:	0.0497	1.39	0.45	ok
In Span:	0.0694	1.40	0.45	ok

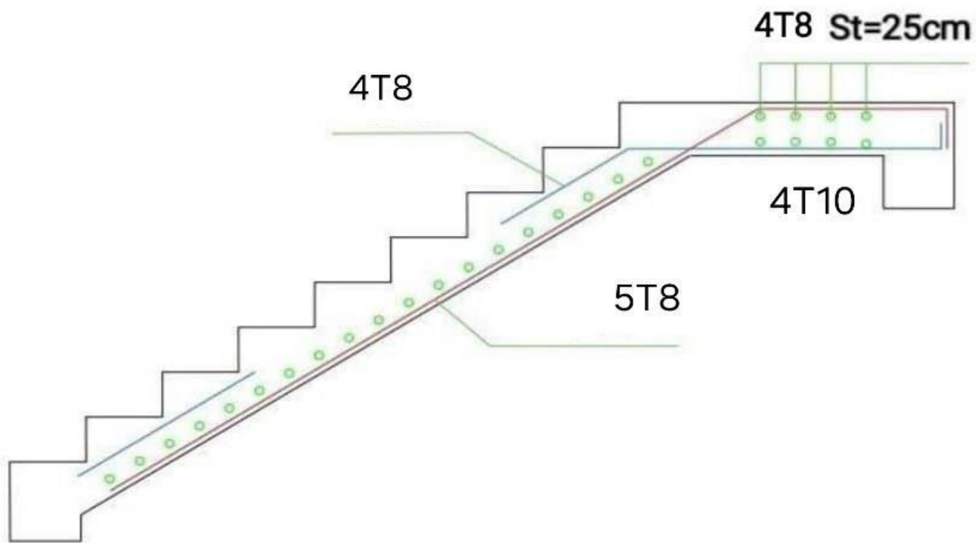


Figure III.11. Stairs reinforcement diagram.

III.5. The parapet :

The parapet is an element surrounding the building at the level of the last floor. It will be calculated as a cantilever beam at the level of the terrace floor beam.

It will be subjected to its own weight and a lateral thrust of 1 KN/m due to the handrail; the calculation will be done for 1 m of length.

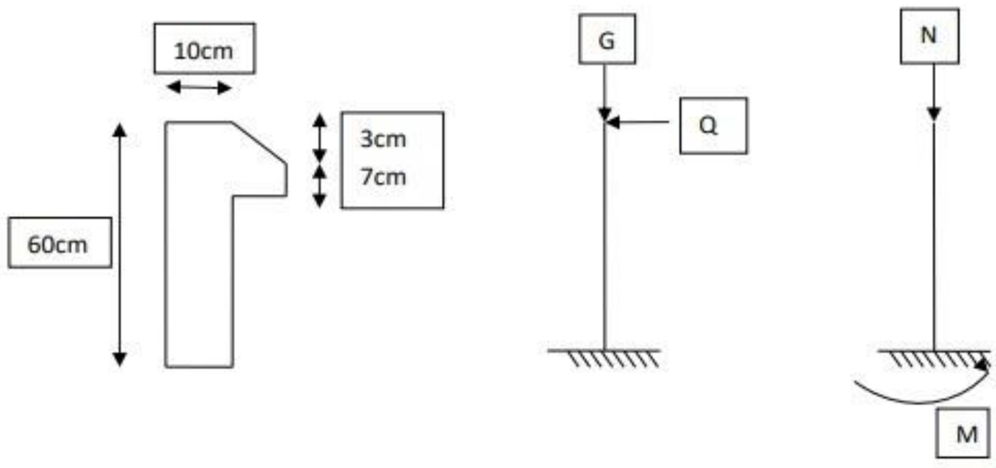


Figure III.12. Cross-sectional view of the parapet.

III.5.1. Calculation Method:

1) Permanent load G:

$$g = 0.6 \times 0.1 \times 25 + 0.1 \times 0.07 \times 25 + 0.03 \times \frac{0.1}{2} \times 25 = 1.712 \text{ KN/m} .$$

- ✓ **Cement render:**

$g' = 0.18$ KN/m .

$G = g + g' = 1.712 + 0.18 = 1.8925$ KN/m .

2) Operational load Q:

Q = 150 Kg/ml = 1.5 KN/ml.

Ultimate Limit State (ULS):

Nu = G×1.35 = 2.55 KN/ml .

Mu = 1.5 ×Q× h = 1.5 ×1.5 x 0.6 = 1.35 KN.m .

Tu = 1.5 ×1 .5 = 2 .25 KN.

Serviceability Limit State(SLS):

Ns = G = 1.8925 KN/ml.

Ms = Q x h = 1.5 x 0.6 = 0.9 KN.m.

Ts = Q = 150 Kg = 1.5 KN.

III.5.2. Reinforcement Calculation:

- ➢ **Calculation of longitudinal reinforcement:**

The parapet is an element that works under compound bending and from which we have certain data:

Mu = 1.35 KN.m , Nu = 1.8925 KN/ml.

b = 100 cm ; h = 10 cm ; d' =2.5 cm ; d = 7.5 cm .

(0.337h - 0.81d') x b x h x fbu ≤ Nu (d - d') - M1

M1 = Mu + Nu $(d - \frac{h}{2})$ M1 = 0.007725 Mn.m .

(0.337h - 0.81d') x b x h x fbu ≤ Nu (d - d') - M1

0.0567 ≤ -1.2225. $Non \Rightarrow$ RPA

$f_{bu} = \frac{0.85\ f_{c28}}{\gamma b} = 14.17$ MPa with f_{c28} = 25 MPA ; $\gamma b = 1.5$.

$e_0 = \frac{Mu}{Nu} = 0.6$ m ; e_a = max (2 ; 60/ 250) = 0.02 m .

$e_2 = \frac{3\, lf^2}{h\, 104}$ $(2+\alpha\, Ø) = 0.00864$ m As $\begin{cases} Ø = 2l = 1.2\text{m}. \\ \alpha = 0. \\ lf = 2 \text{ x } 0.6 = 1.2\text{m}. \end{cases}$

$e' = e_0 + e_a + e_2 = 0.63$ m .

Nu' = Nu =2.55 KN.m .

Mu' = Nu' x e' = 1.603KN.m .

M1' = Mu' + Nu' (d - $h/2$) =1.46625 KN.m .

Organizational Diagram for Simple Bending:

$\mu \leq \mu L$ $\begin{cases} yes \Rightarrow As' = 0. \\ \text{Now} \Rightarrow As' \neq 0. \end{cases}$

$\mu = \frac{M1'}{b.d^2.fbu} = 0.017 \leq 0.392$

$\alpha = 0.0214$; $\beta = 0.992$; $\varepsilon_{st} = 10‰ \geq \varepsilon_L = 1.739$.

$\sigma_{st} = fe / \gamma s = 347.82$ MPA As $= \frac{M1'}{\beta.d.\sigma st} = 0.52$ cm^2 .

Condition of non-Fragility :

As= 4HA6 =1.13cm^2 .

Verification of Ultimate Limit State:

γ = Mu /Mser = 1.5 .

$\alpha \leq \frac{\gamma - 1}{2} + \frac{fc28}{100}$ AS Mser = 0.6 KN.m .

0.3434 ≤ 0.5…………………………………………………………………………… OK

- **Calculation of transverse reinforcement:**

$Ar = \frac{As}{4} = \frac{1.13}{4} = 0.28$ cm^2.

Ar=3HA6=0.85 cm^2 .

The distance between the bars:

$St = \min\{\frac{h}{35}, \frac{b}{10}, \frac{\emptyset}{10}\} = \min\{0.28, 10, 0.6\}$.

St= 0.28cm.

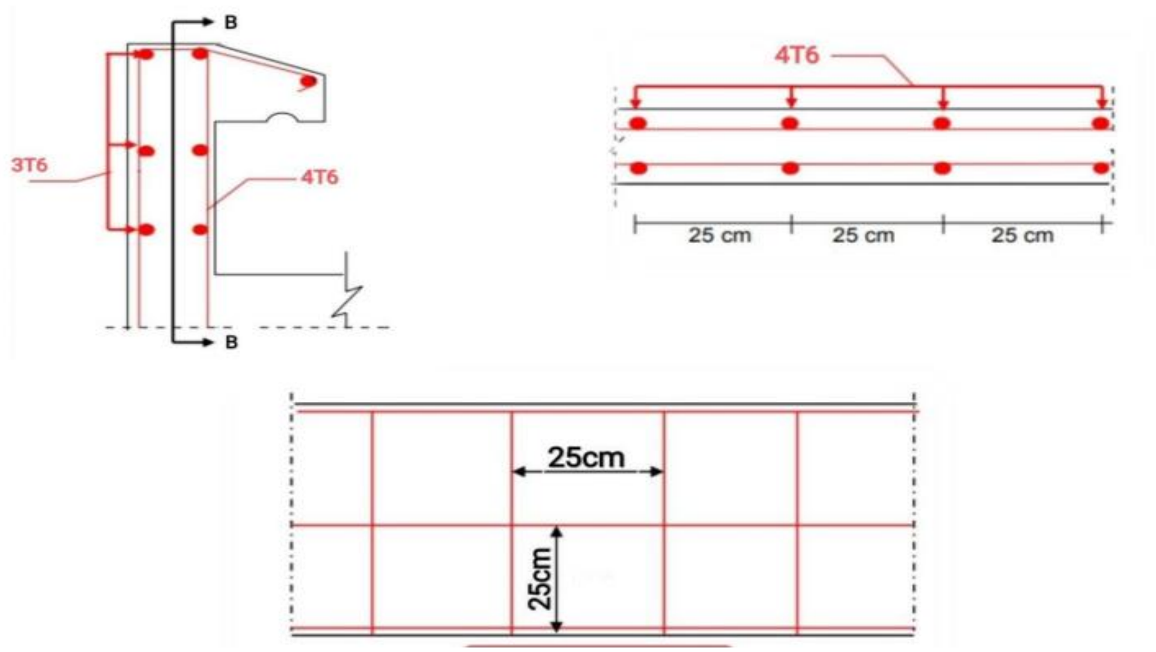


Figure III.13 Parapet reinforcement diagram .

III.6. Conclusion:

L'importance de ces éléments secondaires réside effectivement dans l'aspect esthétique du bâtiment, en plus d'offrir un confort à ses occupants. Le respect des normes BAEL 91 (Béton Armé aux États Limites) et RPA99/version2003 (Règles de Calcul des Structures en Béton Armé) est essentiel pour garantir la sécurité, la durabilité et la qualité de ces éléments.

Chapter 04: STUDY OF STRUCTURAL ELEMENTS .

IV.1.Introduction:

The superstructure is the part that is located above the ground. It consists of the bracing elements: frames (columns-beams) and shear walls. These elements are made of reinforced concrete, and their role is to ensure the resistance and stability of the structure before and after an earthquake. However, they must be well reinforced and properly arranged in order to withstand and resist all types of loads.

IV.2. Study of Columns:

Les poteaux sont des éléments verticaux conçus pour supporter et transmettre les charges (forces normales et moments de flexion) à la base de la structure. Leur armature est réalisée en flexion combinée selon les combinaisons de charges les plus défavorables appliquées, cette étude est d'après le **BAEL.**

- **1.35 G + 1.5 Q.**

The reinforcement is determined based on the following load conditions:

- Maximum axial force and corresponding moment: **(Nmax Mcorr).**

- Maximum moment and corresponding axial force: **(Mmax Ncorr).**

- Minimum axial force and corresponding moment: **(Nmin Mcorr).**

IV2.1. Reinforcement Calculation:

- **Longitudinal reinforcement:**

❖ **The Max case:**

Normal maximum effort and the corresponding moment:

Nmax = 570.71 KN .

$L\ max = \left(\frac{5.25+4.05}{2}\right) = 4.65\ m$.

Qu =(1.35G +1.5 Q)×4.65 =51.86 KN/m .

Qs =37.90 KN/m .

L = 3.06 m .

$Mu = \frac{51.86 * (3.06)2}{12} = 40.47$ KN.m . $Ms = \frac{37.90 * (3.06)2}{12} = 29.57$ KN.m .

b = 25 cm ; h = 25 cm ; d' = 2.5 cm ; d = 22.5 cm .

$(0.337h - 0.81d') \times b \times h \times fbu \leq Nu\ (d - d') - M1 \quad \begin{cases} \text{YES} \Rightarrow \text{RPA} \\ \text{Now} \Rightarrow \text{RPA} \end{cases}$

$M1 = Mu + Nu\ (d - \frac{h}{2})$

M1 = 0.086 Mn.m .

(0.337h - 0.81d') x b x h x fbu ≤ Nu (d - d') - M1

0.0567 ≤ 0.027 NO ⇒ RPA

$fbu = \frac{0.85\ fc28}{\gamma b}$ =14.17 MPa As fc_{28} = 25 MPA ; $\gamma\ \mathbf{b}$ =1.5 .

$e_0 = \frac{Mu}{Nu}$ = 0.07m ; e_a= max (2 ; $\frac{3.06}{250}$) = 0.02 m .

$e_2 = \frac{3\ lf^2}{h\ 104}(2+\alpha\ \emptyset)$ = 0.01 m As $\begin{cases} \emptyset = 2 . \\ \alpha = 0 . \\ lf = 3.06\ x\ 0.7 = 2.14 . \end{cases}$

e' = $e_0+e_a+e_2$ = 0.1 m .

Nu' = Nu

Mu' = Nu' x e' = 0.057 Mn.m .

M1' = Mu' + Nu' (d - $\frac{h}{2}$) = 0.114 Mn.m .

Organizational Diagram for Simple Bending:

$\mu \le \mu L \begin{cases} yes \Rightarrow As' \neq 0 . \\ \text{No} \Rightarrow As' = 0 . \end{cases}$

$\mu = \frac{M1}{b.d^2.fbu}$ = 0.636 ≤ 0.392 .

$M_L=\mu_L bd^2F_{bu}$ =0.060MN.m .

$\varepsilon_{sc}=(\frac{\frac{d'}{d}}{\alpha L})$3.5 ‰ = 0.58 .

$\varepsilon_{sc} \ge \varepsilon_L$.

$\sigma_{sc} = E_s\varepsilon_{sc}$ = 116.0 Mpa .

$\sigma st = fe/\gamma s$ = 347.82 Mpa .

$As' = \frac{Mu-ML}{\sigma sc(d-d')}$ = 2.33 cm² .

$As = \frac{ML}{\beta L.d.\sigma st} - As'\frac{\sigma sc}{\sigma st}$ = 9.69cm² .

So : (As'+ As) = 12.02 cm² = 6HA16 = 12.06 cm² .

Condition of non-brittleness :

Ast min $\geq$ 0,23.b.d $\frac{ft28}{fe}$.

Ast min $\geq$ 0.68 cm^2 .

Vérification of ELS :

$\sigma_{bc} \leq \sigma_{bc}$

σ_{bc} =0.6 f_{c28} = 15 MPa

D= 15 (As +As')/b = 7.21 cm .

E= 30(As.d +As'.d')/b = 268.62 cm^2 .

Y_1= - D +$\sqrt{D2+E}$ = 10.70 cm .

I = $\frac{by1^3}{3}$ +15 As(d-y_1)^2+15 As'(y_1-d') = 42268.25 cm^3 .

K= M_s/I =0.7 .

σ_{bc} = K.y_1=7.48 MPa .

$\sigma_{bc} \leq \sigma_{bc}$

7.48 $\leq$ 15 MPa .

Calculation of the section of the transverse reinforcements:

Choice of diameter:

$\emptyset t \geq \frac{1}{3}\,\emptyset l \rightarrow$ So : $\emptyset t \geq \frac{1}{3} \times 16 =$ 5.33 $mm \rightarrow$ **Øt = 8 mm.**

We adopt frames: **T8**

Spacing between frames:

St Min (15Øl ; 40 cm ; a + 10 cm) .

St Min ([15 × 1,6] ; 40 cm ; 35 cm)=24 cm → Soit : St = 15 cm .

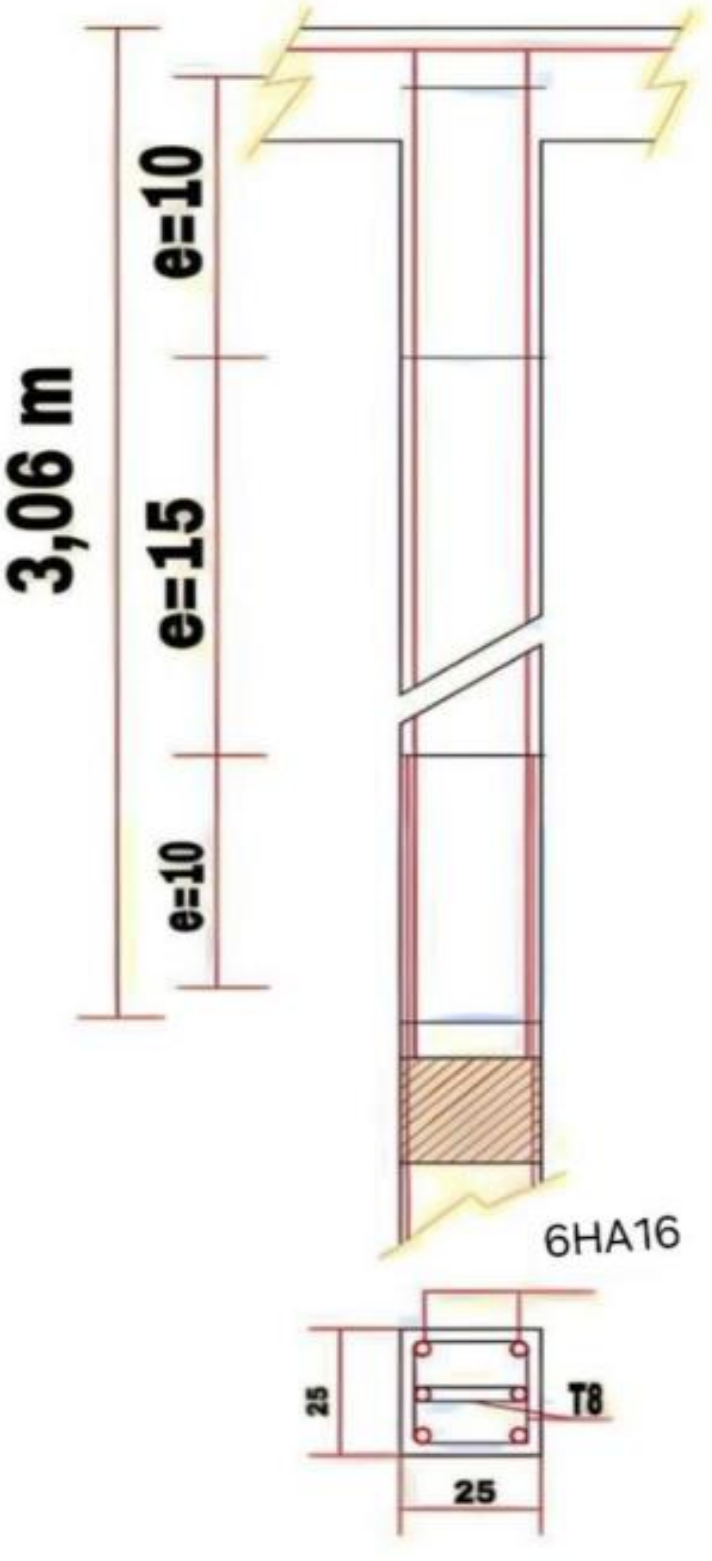


Figure IV.1. Reinforcement diagram of the column**.**

IV.3. Study of beams:

Beams are structural elements subjected to bending moments and shear forces. Their reinforcement is designed based on the most unfavorable load conditions in both directions for the following cases.

IV.3.1. Load combinations:

Depending on the type of requests, we distinguish the following different combinations:

- **Ultimate limit state:**

Exceeding these ultimate limit states can lead to severe disorders up to the collapse of the structure. The combination of ultimate limit states is determined by:

1,35G+1,5Q.

- **Serviceability limit state:**

This state is used to verify the durability of the structure. It corresponds to the mode of operation of the structure under normal conditions. The combination of loads is determined by the following relationship:

G+Q.

So, the beams will be reinforced according to the combination:

1.35G + 1.5Q............. According to the BAEL91 .

Table IV.1. Reinforcement Calculation Data for Beams.

	γs	γb	$\boldsymbol{\sigma}$s(MPa)	fbu(MPa)	$fc28$(MPa)
Sustainable situation.	1.15	1.5	347.82	14.17	25

IV.3.2. Reinforcement of Longitudinal Beams (25×45).

For the calculation, we use the maximum values of moments (in span and at supports). According to the results from the ROBOT software:

- ✓ **The main beam:**

b = 25 cm ; h = 45 cm ; d’ = 2.5 cm ; d = 42.5 cm .

1_In Support

- **Terrace Floor**:

L max= $(\frac{5.25+4.05}{2})$=4.65 m

Qu =(1.35G +1.5 Q)* 4.65 =51.86 KN/m

Qs = 37.90 KN/m

L = 5 m

Mu = 108.04 KN.m

MS = 78.96 KN.m

$\mu \leq \mu L \begin{cases} \text{yes} \Rightarrow As' = 0 \\ \text{Now} \Rightarrow As' \neq 0 \end{cases}$

$\mu = \frac{Mu}{b.d^2.fbu} = 0.168 \leq 0.392$

$\alpha = 0.2314$; $\beta = 0.907$; $\varepsilon st = 3.5‰(\frac{1-\alpha}{\alpha}) = 11.63 \geq \varepsilon L = 1.739$; $\sigma st = \frac{fe}{\gamma s} = 347.82$ MPA

$As = \frac{Mu}{\beta.d.\sigma st} = 8.00\ cm^2$

So : 6HA14 = 9.24 cm²

Vérification of ELS :

$\gamma = \frac{Mu}{Mse} = 1.37$ $\alpha \leq \frac{\gamma-1}{2} + \frac{fc28}{100}$

$0.1071 \leq 0.435$……………………………………………………………………ok

2_ In Span

- **Terrace Floor**:

L max= $(\frac{5.25+4.05}{2})$=4.65 m

Qu =(1.35G +1.5 Q)* 4.65 =51.86 KN/m

Qs = 37.90 KN/m

L = 5 m

Mu = 54.02 KN.m

MS = 39.48 KN.m

$\mu \leq \mu L \begin{cases} \text{yes} \Rightarrow As' = 0 \\ \text{Now} \Rightarrow As' \neq 0 \end{cases}$

$\mu = \frac{Mu}{b.d^2.fbu} = 0.084 \leq 0.392$

$\alpha = 0.1071$; $\beta = 0.956$; $\varepsilon st = 3.5‰(\frac{1-\alpha}{\alpha}) = 29.18 \geq \varepsilon L = 1.739$; $\sigma st = \frac{fe}{\gamma s} =$ 347.82 MPA

$As = \frac{Mu}{\beta.d.\sigma st} = 3.82\ cm^2$

So : 5HA12 = 5.65 cm^2.

Verification of the SLS (Serviceability Limit State):

$\gamma = \frac{Mu}{Mse} = 1.37$ $\alpha \leq \frac{\gamma-1}{2} + \frac{fc28}{100}$

0.1071 ≤
0.435……….………………………………………………………………………ok

Condition of non-brittleness :

Ast min $\geq 0{,}23.b.d\ \frac{ft28}{fe}$.

Ast min ≥ 1.28 cm^2 .

Verification of shear stress:

Tu Max =114.15 KN
$\overline{\tau u} \leq \tau u$.

Such as: $\tau u = \min[0.2\ x\frac{fc28}{\gamma b}, 4MPA] = 3.33$ MPa (non-detrimental cracking).

$\tau u = \frac{TMAX}{bxd} = \frac{114.15}{25 \times 0.425}$.
$\tau u = 1.074$ MPa $\leq \tau u = 3.33$ MPa .

$\emptyset l \leq \min (h/35 , b/10 , \emptyset)$

$\emptyset l \leq \min (450/35 , 250/10 , \emptyset) = 12.86$ mm

$\emptyset l = 8$ mm ; $At = 2.01\ cm^2$

Spacing of transverse reinforcement:

St1 ≤ min (0.9 d ; 40) = 38.25 cm .

St2 $\leq \frac{2.01*400}{0.4*25} = 80.4$ cm .

St3 $\leq \frac{0.8*400*2.01}{25(1.074*(0.3*2.1*1)}$ =31.69 cm .

St ≤ min (**St**1 ;2 ; **St**3) =31.69 cm .

St = 15 cm .

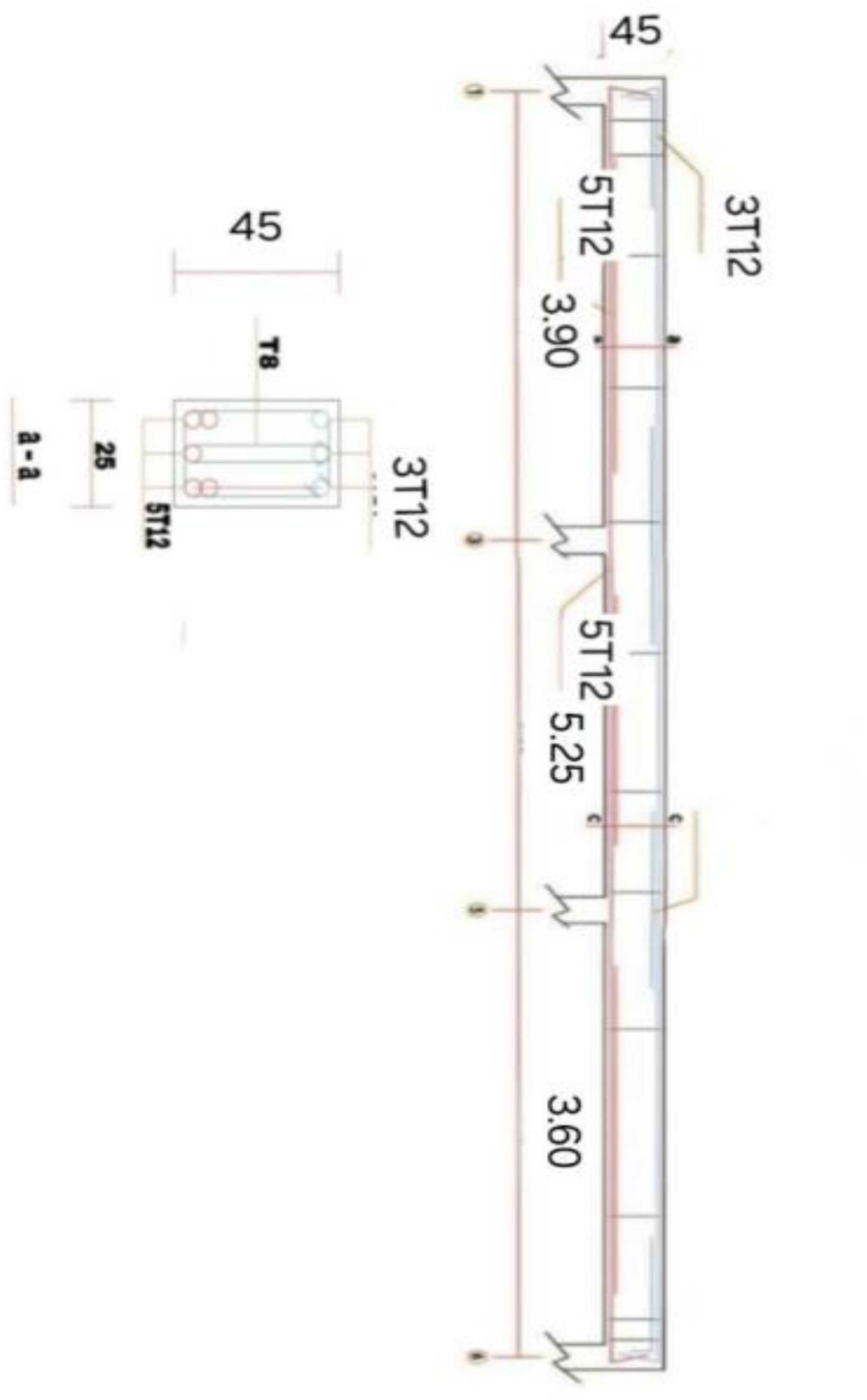


Figure IV.2. Reinforcement diagram of the main beam .

- ✓ **The Secondary beam:**

b = 25 cm ; h = 40 cm ; d' = 2.5 cm ; d =37.5 cm .

1_In Support

- **** Terrace Floor**:

Qu =1.35G +1.5 Q=11.15 KN/m

Qs = 8.15 KN/m

L = 5 m

Mu = $qL^2/12$= 23.23 KN.m

MS =$qL^2/12$ = 16.97 KN.m

$\mu \le \mu L \quad \begin{cases} \text{yes} \Rightarrow As' = 0 \\ \text{Now} \Rightarrow As' \neq 0 \end{cases}$

$\mu = \frac{Mu}{b.d^2.fbu} = 0.029 \le 0.392$

$\alpha = 0.0568$; $\beta = 0.986$; $\varepsilon st = 3.5‰(\frac{1-\alpha}{\alpha}) = 58.12 \ge \varepsilon L = 1.739$; $\sigma st = \frac{fe}{\gamma s} = 347.82$ MPA

$As = \frac{Mu}{\beta.d.\sigma st} = 1.81\ cm^2$

So : 3HA12 = 3.39 cm^2

2_ In Span

- **Terrace Floor**:

Qu =1.35G +1.5 Q=11.15 KN/m

Qs = 8.15 KN/m

L = 5 m

Mu = 11.615 KN.m

MS = 8.49 KN.m

$\mu \le \mu L \quad \begin{cases} \text{yes} \Rightarrow As' = 0 \\ \text{Now} \Rightarrow As' \neq 0 \end{cases}$

$\mu = \frac{Mu}{b.d^2.fbu} = 0.0145 \le 0.392$

$\alpha = 0.0176$; $\beta = 0.993$; $\varepsilon st = 3.5‰(\frac{1-\alpha}{\alpha}) = 195.36 \ge \varepsilon L = 1.739$; $\sigma st = \frac{fe}{\gamma s} = 347.82$ MPA

$As = \frac{Mu}{\beta.d.\sigma st} = 0.90\ cm^2$

So : 2HA12 = 2.26 cm^2

Verification of the SLS (Serviceability Limit State):

$\gamma = \frac{Mu}{Mse} = 1.38 \quad \alpha \leq \frac{\gamma - 1}{2} + \frac{fc28}{100}$

0.0962 ≤ 0.44..OK

Condition of non-brittleness :

Ast min ≥ 0,23.b.d $ft28/fe$

Ast min ≥ 1.13 cm²

Verification of shear stress:
Tu Max =114.15 KN
$\overline{\tau u} \leq \tau u$ **.**
Such as: $\tau u = \min[0.2 \, x\frac{fc28}{\gamma b}, 4MPA] = 3.33$ **MPa** (non-detrimental cracking).

$\tau u = \frac{TMAX}{bxd} = \frac{114.15}{.25*0.425}$
$\tau u = 1.074$ MPa $\leq \tau u = 3.33$ MPa...............

$\emptyset l \leq \min(h/35, b/10, \emptyset)$.

$\emptyset l \leq \min(400/35, 250/10, \emptyset) = 11.43$ mm .

$\emptyset l = 8$ mm ; $At = 2.01$ cm^2 .

Spacing of transverse reinforcement:

St1 ≤ min (0.9 d ; 40) = 33.75 cm

St2 $\leq \frac{2.01*400}{0.4*25} = 80.4$ cm

St3 $\leq \frac{0.8*400*2.01}{25(1.074*(0.3*2.1*1)}$ =31.69 cm .

St ≤ min (**St**1 ;2 ; **St**3) =31.69 cm .

St = 15 cm .

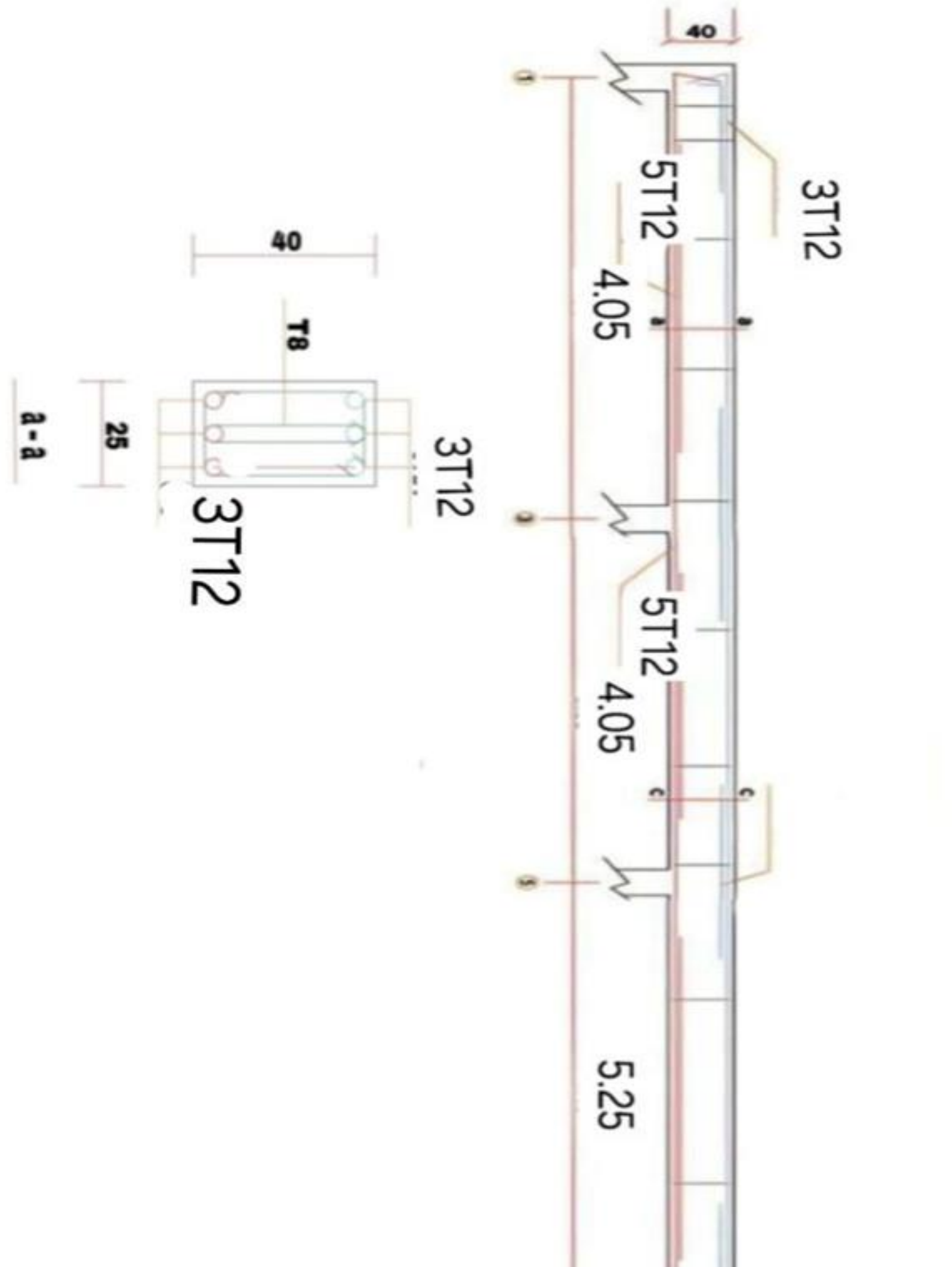


Figure IV. 3. Reinforcement diagram of the Secondary beam .

IV.4. Infrastructure (Foundation Study):

The foundation elements are designed to transmit the loads applied by the superstructure elements (such as columns, walls, panels) to the ground. This transmission can be direct, as in the case of footings resting on the ground or raft foundations, or it can be achieved through the use of other elements (for example, in the case of pile foundations where footings are supported by piles).

The determination of foundation types is done based on the strength and settlement conditions associated with the physical and mechanical characteristics of the soil.

The topics addressed in this chapter pertain to the determination of the dimensions and reinforcement of foundation elements as reinforced concrete elements.

In the most general case, a structural element can transmit to its foundation (assumed to be horizontal):

- A normal effort.
- A horizontal force, resulting, for example, from the action of an earthquake.
- A couple that can have variable magnitude and act in different planes.

IV.4.1. Choice of foundation type:

The choice of foundation type essentially depends on the following factors:

With a soil bearing capacity of 2 bars, it is appropriate to initially design shallow foundations of the isolated footing type.

a) Vérification des semelles isolées :

Since the columns have rectangular sections, we will choose rectangular footings. The verification to be done is as follows: $\frac{Nu}{S} \leq \bar{\sigma}_{\text{sol}}$.

N: Normal force at the base of the column, obtained from the ROBOT software.

$\bar{\sigma}_{\text{sol}}$ = 200 KN/m² . s = (A×B) $\geq \frac{Nu}{\bar{\sigma}\,\text{sol}}$ (m^2) .

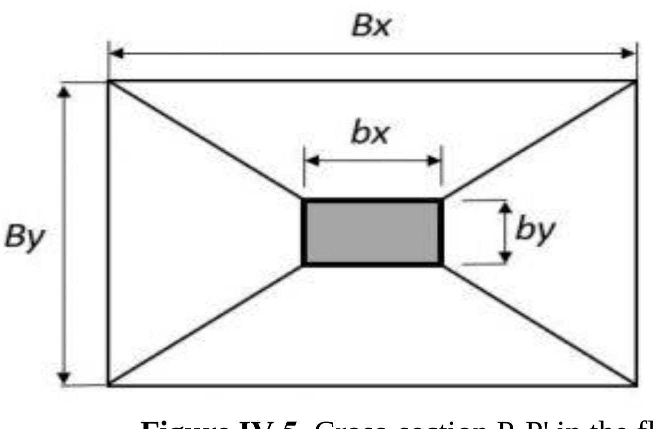


Figure IV.4. Plan view of the footing.

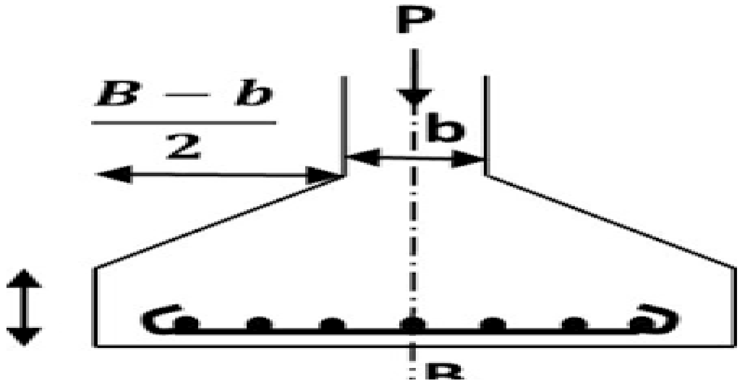


Figure IV.5. Cross-section P-P' in the flange.

Table IV.2. Summary of footing calculation.

Summary	N(KN)	S(m^2)	Summary	N(KN)	S(m^2)
A6	112.4182	0.562091	D3	88.70256	0.443513
B6	224.5284	1.122642	E3	104.4103	0.522052
C6	257.7918	1.288959	A2	285.2034	1.426017
E6	145.6816	0.728408	B2	570.7147	2.853574
A5	275.9635	1.379818	C2	514.6596	2.573298
B5	551.927	2.759635	E2	214.6725	1.073363
C5	520.5116	2.602558	A1	121.658	0.60829
E5	188.8009	0.944005	B1	243.3161	1.21658
D4	93.32249	0.466612	C1	286.4354	1.432177
E4	104.4103	0.522052	E1	157.6934	0.788467

✓ **Note:**

Based on the results obtained from ROBOT, we have divided the footings into groups.

IV.4.2. Dimensioning of the footing:

The surface area of the footing is given by: $S \geq \frac{Nu}{\sigma sol}$.

Nu: the maximum force on group 1 footings.

$\boldsymbol{\sigma_{sol}}$ **= 0.2 MPa .**

$K = \frac{a}{b} = \frac{A}{B}$

with: $\begin{cases} a = \textit{The width of the post} . \\ b = \textit{The length of the post} . \end{cases}$ $\begin{cases} A = \textit{The width of the footing} . \\ B = \textit{The length of the footing} . \end{cases}$

So we take k = 1.

a. Footing 1 (group 1):

$S \geq \frac{Nu}{\bar{\sigma}\ sol}$ with : $N1$=570.71kN .

$S = \frac{570.71 \times 10^{-3}}{0.2} = 2.853\ m^2$.

$\sqrt{2.8530}$=168.91cm². → *on trend*: (A=1.7 m ; B=1.7 m) .

The height of the footing:

$H \geq d + 0.05\ m$; $d \geq \max\left(\frac{A-a}{4}; \frac{B-b}{4}\right) = \frac{1.7-0.25}{4} = 0.3625\ m$.

$H = 0.36\ m \approx 0.4\ m$.

$Ax = Ay = \frac{N\times(A-a)}{8\times(h-c)\sigma s} = \frac{570.71\times10-3\times(1.70-0.25)}{8\times(0.40-0.05)\times347.82} = 8.5\ cm^2$.

Donc on Adopte : $6HA14$=9.24 cm².

b. Footing 2 (group 2):

$S \geq \frac{Nu}{\bar{\sigma}\ sol}$ with : N1=415.72kN .

$S = \frac{286.43\times10^{-3}}{0.2} = 1.43215 m^2$.

$\sqrt{14321.5} = 119.67 cm^2$. → $on\ trend$: (A=1.2m ; B=1.2 m).

The height of the footing:

$H \geq d + 0.05\ m$; $d \geq \max\left(\frac{A-a}{4}; \frac{B-b}{4}\right) = \frac{1.2-0.25}{4} = 0.2375\ m$.

$H = 0.2375\ m \approx 0.25 m$

$Ax = Ay = \frac{N\times(A-a)}{8\times(h-c)\sigma s} = \frac{286.43\times10-3\times(1.2-0.25)}{8\times(0.25-0.05)\times347.82} = 4.89\ cm^2$.

Donc on Adopte : 5HA12=**5.65 cm²**.

c. Footing 3 (group 3):

$S \geq \frac{Nu}{\bar{\sigma}\ sol}$ with : N1=157.6 kN.

$S = \frac{157.6\times10^{-3}}{0.2} = 0.788 m^2$.

$\sqrt{7880} = 88.77\ cm$. → $on\ trend$: A=0.90 m; B=0.90m)

The height of the footing:

$H \geq d + 0.05\ m$; $d \geq \max\left(\frac{A-a}{4}; \frac{B-b}{4}\right) = \frac{0.9-0.25}{4} = 0.225\ m$.

$H = 0.225 \approx 0.25\ m$.

$Ax = Ay = \frac{N\times(A-a)}{8\times(h-c)\sigma s} = \frac{157.6\times10-3\times(0.9-0.25)}{8\times(0.25-0.05)\times347.82} = 1.84 cm^2$

Donc on Adopte : 4HA10=3.14 cm².

Table IV.3. Results of footing reinforcement calculation.

The Groups	N_{max} (KN)	Formwork:				Reinforcement:		Form:		Reinforce:	
		A (cm)	B (cm)	ht (cm)	H (cm)	Acal (cm^2)	Choice (cm^2)	a (cm)	B (cm)	A_L	C
Group 1	570.71	170	170	/	40	8.5	6HA14	25	25	6HA16	T10
Group 2	286.43	120	120	/	25	4.89	5HA12	25	25	6HA16	T10
Group 3	157.6	90	90	/	25	1.84	4HA10	25	25	6HA16	T10

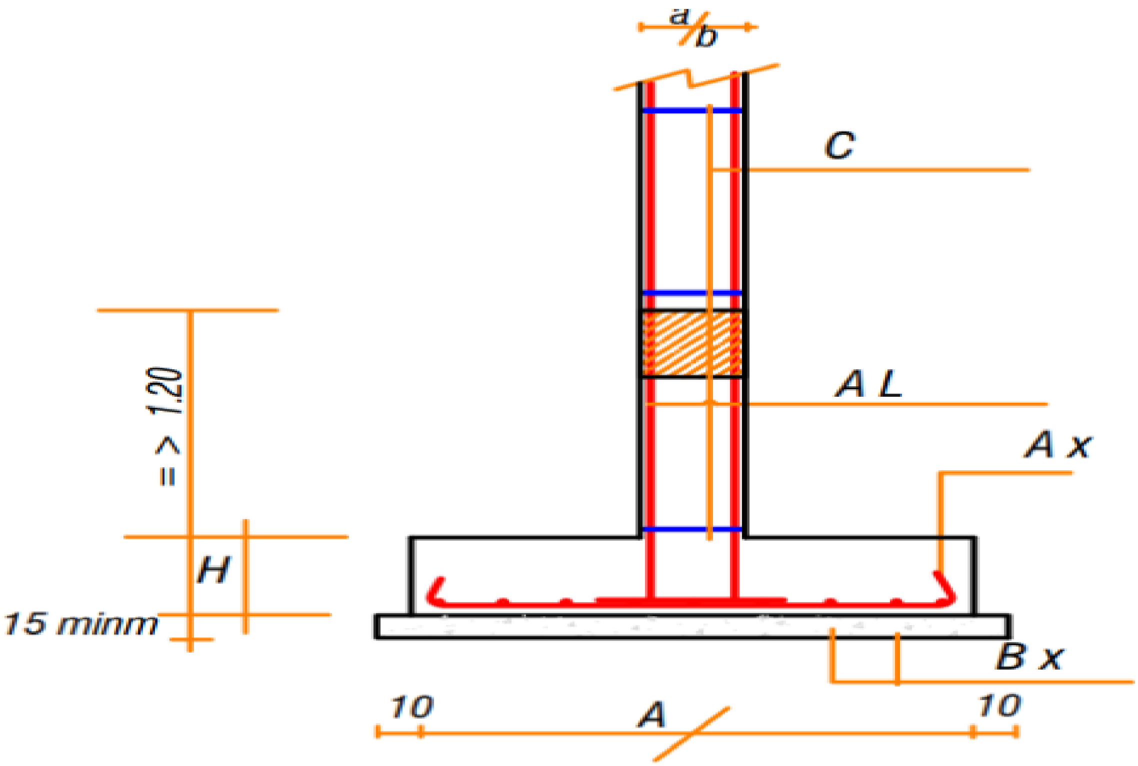


Figure IV.6. Footing reinforcement diagram.

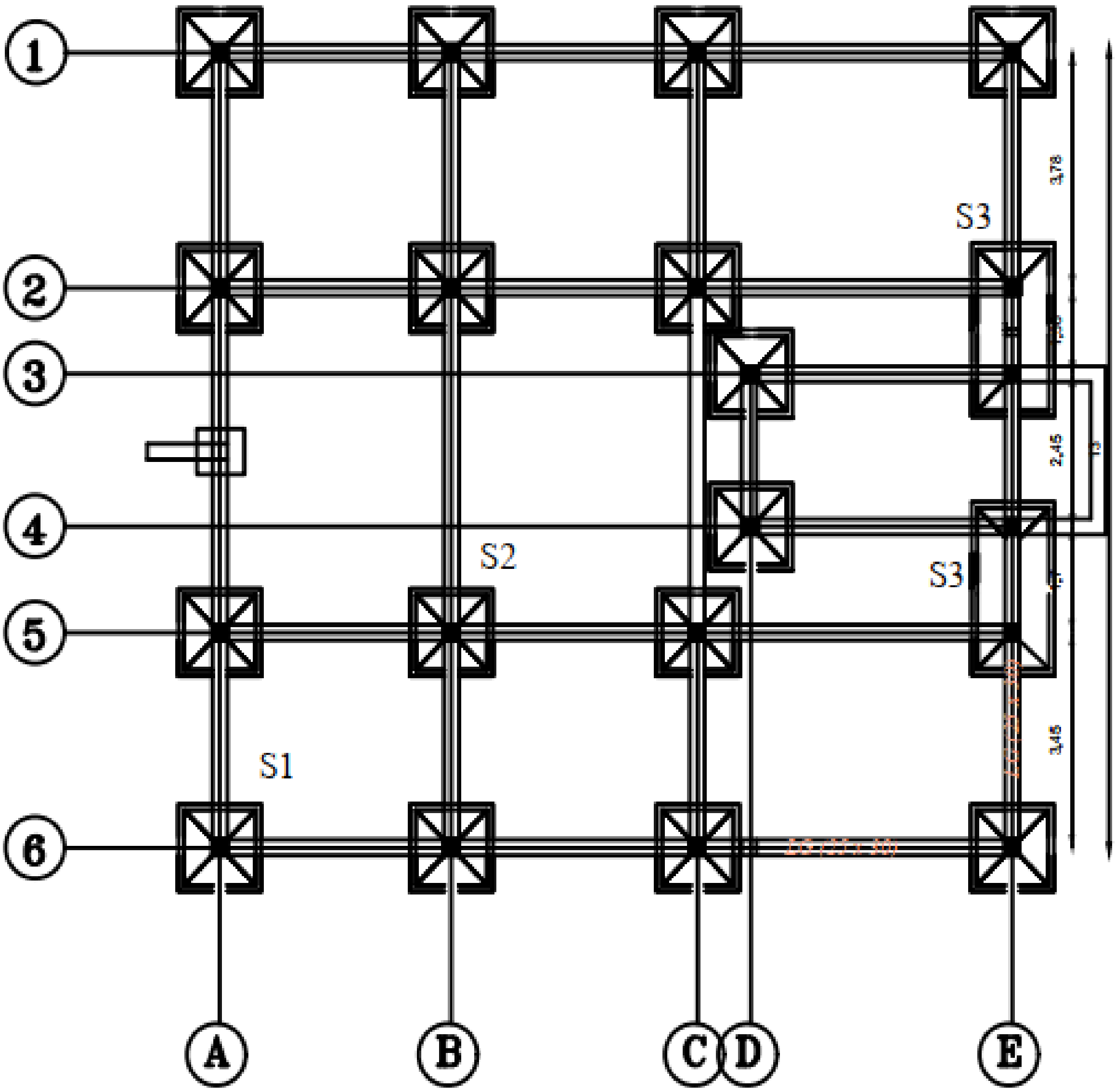


Figure IV.7. Foundation formwork plan.

IV.5. Conclusion:

The essential elements play a crucial role in bearing and transmitting loads. Therefore, it is essential to properly size and reinforce them. When determining the reinforcement for various main elements, the reinforcement requirements defined by the current seismic standards in Algeria, as well as the calculation rules of the French Association for Earthquake Engineering (BAEL), have been taken into account.

General Conclusion:

General Conclusion:

This end-of-studies project allowed us to apply the theoretical knowledge we acquired during our studies to the analysis and study of a real building project. We have understood the importance of thoroughly analyzing a structure before calculating it.

Based on this study, we can conclude that the structural integrity of a building depends primarily on its foundations. Therefore, it is necessary to carefully study the chosen soil for construction and its influence on the design of the infrastructure. For the sizing and calculation of foundations, stability, durability, and safety of the structure in the short and long term must be ensured.

To determine the appropriate dimensions and reinforcement of structural elements, the following steps need to be taken:

- Determine the loads and surcharges that each structural element can withstand.
- Calculate the dimensions of columns and beams using standardized methods and then verify the results obtained with the conditions of the R.P. A 99 version 2003 (presumably a reference or code).
- Determine the reinforcement requirements for each structural element.

The study of this building has been beneficial as it has allowed us to enhance our theoretical knowledge regarding the sizing and reinforcement of different elements. Lastly, we hope that this work serves as a useful reference document for future cohorts and as a starting point for other projects.

Table of Contents:

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REGULATIONS:

- Algerian Seismic Regulations RPA99/version2003.
- Design and Calculation Rules for Reinforced Concrete Structures CBA 93.
- Calculation Rules for Reinforced Concrete at Ultimate Limit State BAEL91.

Course Topics:

- Reinforced Concrete Design.
- Strength of Materials.
- Construction Materials.

Software Tools:

- Microsoft Word 2010.
- AutoCAD 2016.
- Autodesk Robot Structural Analysis Professional 2018.