Chapter V. The Descent of Loads

V.1. Definition

The aim of the load descent is to know the distribution and paths of the loads on all the load-bearing elements of the structure from the top to the foundations.

The values obtained make it possible to size the load-bearing elements and, in certain cases, to modify the structure.

There are three types of load transfer in a building:

- Horizontal Transmission (HT); through floors, beams, platforms…etc.
- Vertical Transmission (VT); through poles, walls, soles, etc.
- Inclined Transmission (IT); through inclined cross beams, slopes, etc.

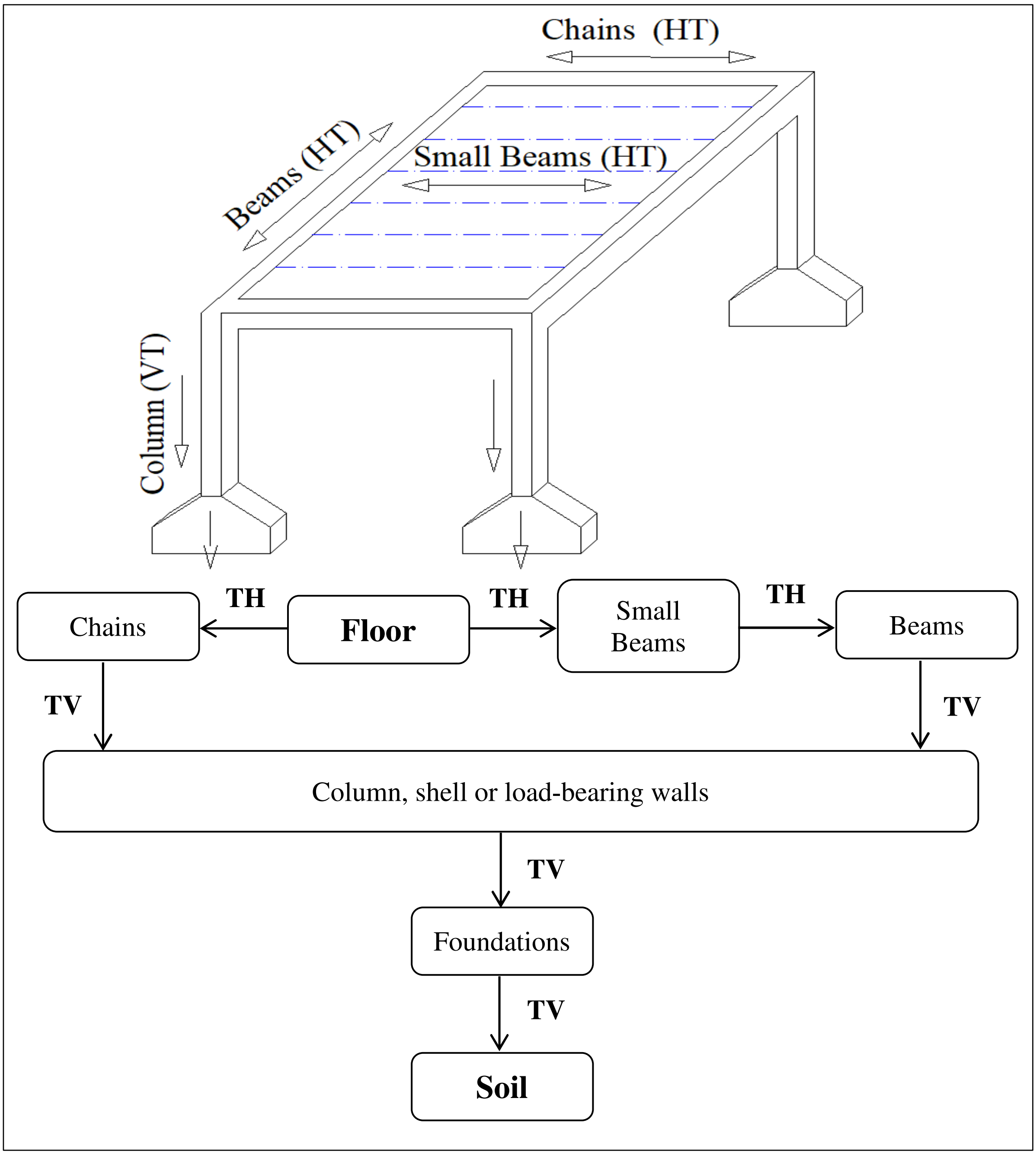

Figure V.1 - Example of load path in a reinforced concrete building

V.2 . Types of charges according to their nature

V.2.1. Permanent loads

They are the loads resulting from the self-weight of the immobile load-bearing and non-load-bearing elements of the structure (beams, floors, walls, tiles, coatings, etc.).
Permanent loads include not only the self-weight of the load-bearing elements, but also the weights of elements incorporated into the load-bearing elements such as: ceiling, floor, coatings and any coverings as well as those of the construction elements supported or supported by the load-bearing elements such as: fixed partitions, smoke pipes, ventilation ducts, etc. The value of such loads is calculated according to the volume of the materials and their greatest density under the conditions of use.
In order to facilitate the calculation of these loads, Table V.1 gives, for information purposes, average values of the volumetric weight of some construction materials. The values in Table V.1 are taken from the Regulatory Technical Document DTR-BC2.2 (Permanent loads and operating loads).

Materials	**Volumetric weight (kN / m^3)**
Steel	78.50
Font	72.50
Aluminum	27.00
Copper materials	89.00
Lead	114.00
Air dried coniferous wood	6.00
Air dried hardwood lumber	8.00
Tropical hardwoods	10.00
Sandstone	25.00
Compact limestone, marble, granite.	28.00
Limestone of medium hardness	22.00
Soft limestone	18.00
Unreinforced concrete	22.00
Reinforced concrete	25.00
Lightweight aggregate concrete (expanded clay or shale)	7.50 – 15.50
Masonry (*) in rubble	23.00
Masonry (*) in solid bricks	19.00
Masonry (*) in perforated bricks	13.00
Masonry (*) in hollow bricks	9.00
Masonry (*) in solid concrete blocks in heavy aggregates	21
Masonry (*) in hollow concrete blocks in heavy aggregates	13
Masonry (*) in cut stone	27
Cork blocks	4
Plasterboards	10
Poured asphalt	18
Bituminous concrete	22
Glass	25

(*) : Not including the cost of the coatings.

Table V.1 - Example of permanent loads in a building (DTR-BC2.2)

V.2.2 . Variable charges

They are the loads that can be changed during the use of the building, they vary depending on the operation of the building, the nature of the loads and also their loading duration.
There are 03 types of variable charges:

V.2.2.1. Operating costs :

These are the charges resulting from the use of the building, they vary according to the use and operation of the structure, for example the charges of the people occupying the building, the charges of the mobile equipment, etc. This type of charge is subject to a degression law according to article 6.3 of DTR.B.C2.2, for buildings with several floors.
For information purposes, Table V.2 presents examples of operating loads in a building type construction (DTR-BC2.2).

No.	Nature of the premises	Charge (KN/m^2)
1	Accommodation in rooms, games rooms and rest of the cribs	1.5
2	Group accommodation (dormitories)	2.5
3	Dining rooms, cafes, canteens of reduced dimensions (number of places seats ≤100)	2.5
4	Offices proper	2.5
5	Meeting rooms with tables work	2.5
6	Various halls (stations, etc.) where the public moves	4.0
7	Exhibition rooms of less than 50 m^2	2.5
8	Exhibition rooms of 50 m² or more	3.5
9	Meeting rooms and Cuite locations with standing assistance (12)	5.0
10	Halls and stands of performance venues and sports with standing places (12)	6.0
11	Theatre halls, conference rooms, amphitheaters , stands and other places, with seats - not including bleachers - (without tables or desks) (12)	4.0
12	Community kitchens excluding the costs of large equipment taken into account independently (13)	2.5
13	Reading rooms of the libraries	4.0
14	Dance halls (14)	5.0
15	Shops and annexes	5.0
16	Garages and parking lots light vehicles, excluding maintenance and repair shops	2.5

Table V.2 - Example of operating loads in a building (DTR-BC2.2)

The law of degression of operating costs

Let Q_0 the operating load on the roof or terrace covering the building, Q_1, Q_2, Q_3 *and* Q_3 the respective operating loads of the floors of floors *1, 2, 3* and *n* numbered from the top of the building.

The following operating loads will be adopted for the calculation of the support points:

Terrace floor………………………….. Q_0

The last floor (floor 1)……………. $Q_0 + Q_1$

The sub-floor (floor 2)……………………. $Q_0 + 0.95\ (Q_1 + Q_2)$

The sub-floor (floor 3)…………………… $Q_0 + 0.90\ (Q_1 + Q_2 + Q_3)$

The sub-floor (floor 4)…………………… $Q_0 + 0.85\ (Q_1 + Q_2 + Q_3 + Q_4)$

(floor *n*)………………… $Q_0 + \frac{3+n}{2n}\ (Q_1 + Q_2 + Q_3 + Q_4 + \dots Q_n)$

The coefficient $\frac{3+n}{2n}$ was valid for n $\geq$ 5.

When the operating load is the same for all floors, the above degression law is equivalent to the usual rule in which the operating loads of each floor are reduced in the proportions indicated below:

Terrace floor………………………….. Q_0

The last floor (floor 1)……………. Q

The basement (floor 2)…………………… .0.90 Q

The basement (floor 3)…………………… 0.80 Q

and so on, reducing by 10% per floor down to 0.50 Q , a value retained for the lower floors.

Noticed

For more information and details on the different values of permanent and operating loads, please refer to DTR.BC2.2 (Permanent and operating loads). Appendix I gives the load tables taken from DTR.BC2.2.

V.2.2.2. Climatic loads

This type of load is caused by the external climate of the building, in particular snow loads, wind and temperature. Table V.3 gives some examples of wind speeds that can be applied to a building (zones I, II, III and IV are indicated in Annex II), the reference for this type of load is the snow and wind regulation "RNV" (DTR- C.2.4.7).

Zone	$V_{réf}$ (m/s)
I	25
II	27
III	29
IV	31

Table V.3 - Values of the reference wind speed according to the RNV version 2013

V.2.2.3. Special charges

A building may be subjected to particular loads which accidentally stress the structure, we can cite:

- Seismic loads,
- Explosion and shock loads,
- Vibrations due to rotating machines, etc.

V.2.3. Weightings

A building type structure must always be sized so that it is in a state of equilibrium in all normal situations, during use, while respecting the economic side and avoiding the waste of materials, time and human effort. For this reason the designer of a building must master the weightings of the loads that represent the relationships (combinations) between the different types of loads, in general, we have two types of combination:

- **Service Limit State (SLS)**

  It represents the limit state of use of a structure, for example a floor in a residential building must not have a significant (visual) deformation, so in this limit state the structure must not undergo deformations or cracks. In this state, the relationship between permanent and variable loads is given by:

  The load at ELS = the permanent load (G) + the variable load (Q), (i.e.: G+Q).

- **Ultimate Limit State**

  It represents the limit state of deformation of a structure, in this limit state the structure must be dimensioned in such a way that the applied loads can generate visual deformations, but without having a partial or total ruin of a load-bearing element of this structure. And of course ensure the safety of property and people.

  Permanent (G) and variable (Q) loads are weighted as follows:

  The load at ELU = 1.35 G + 1.50 Q.

V.3. Types of loads according to the area of application

Depending on the area of application of the loads, three types of loading can be distinguished:

V.3.1. Surface charge

It is a load applied to a surface area, such as floors, platforms, rafts, soils, etc., this type of load is expressed in units of weight divided by units of surface area, for example (kN/m^2).

V.3.2. The linear load

It is a load applied to a linear area, such as beams, walls, joists, soffits, etc., this type of load is expressed in units of weight divided by units of length, for example (kN /m).

V.3.3. The point (concentrated) charge

It is a load applied to a specific area, such as posts, nodes, footings, etc., this type of load is expressed in units of weight, for example (kN).

V.4 . Example of load descent

Consider a residential building with R+6 floors and an inaccessible terrace, the floors of this building are shown in Figure V.2, the height of each floor is equal to 3.06m, the types of floors used in this building are hollow body floors, the details of the floors are shown in Figures V.3 and V.4.

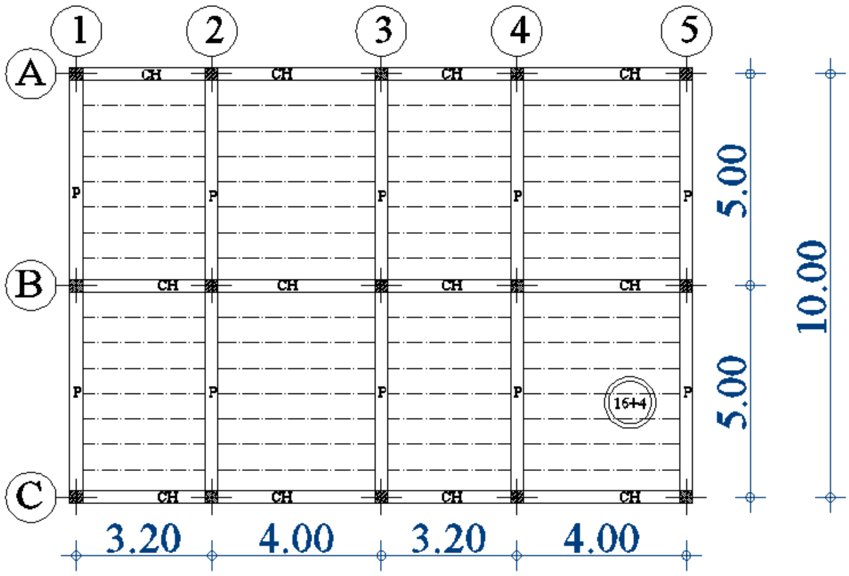

Figure V.2- Plan view of a Floor (units in m)

Dimensions of the posts: - Ground floor………………… .(60x60) cm
- 1st floor……………………………………………..… …(50x50) cm
- 2nd floor ……………………………………………...… ...(40x40) cm
- 3rd , 4th , 5th and 6th floor ………………………………..…(30x30) cm
Dimensions of the beams: - Main beam ………………..… ..(30x50) cm
- Secondary beams (chains)………. ……………………..…(30x30) cm

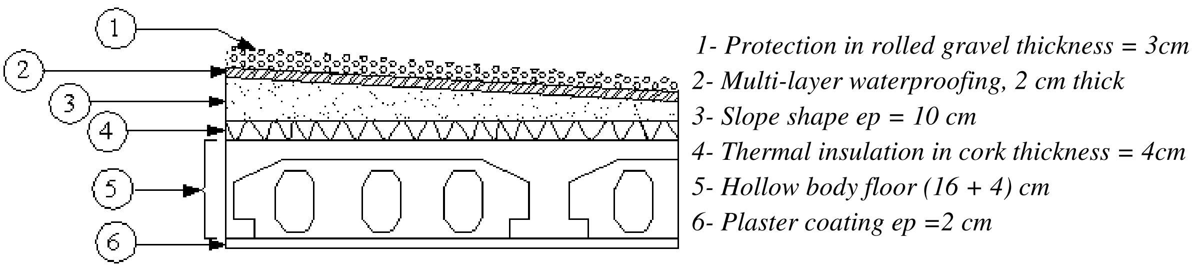

Figure V.3- Terrace Floor

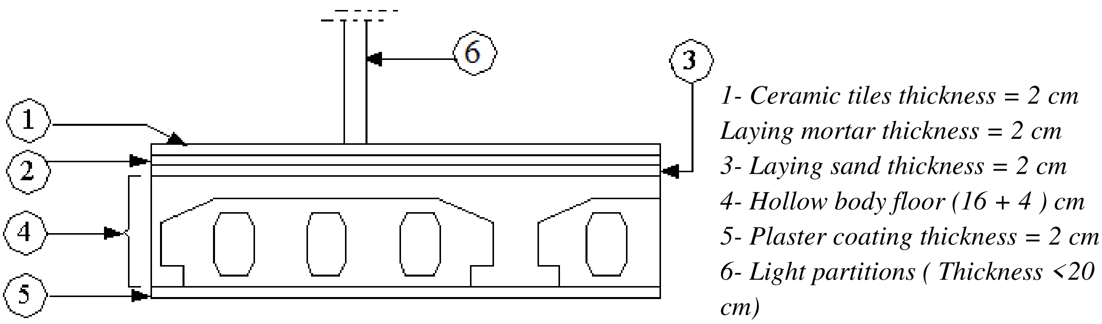

Figure V.4 - Ground floor and current floors

Work requested

1- Calculate the surface load on each type of floor?
2- Calculate the linear load applied to the beam [(A-2)-(B-2)] at the level of a current floor at the ELU and ELS?
3- Calculate the point load applied to the column (B-2) at the level of the base of the building (foundation) at the ELU and ELS?

Solution

1- Calculation of surface loads for each type of floor:

According to DTR.BC2.2 and Annex I, we have:

Terrace Floor

1- Protection in rolled gravel, thickness = 3 cm 0.20 x 3 = 0.60 (kN /m²).
2- Multi-layer waterproofing, thickness 2 cm 0.12 (kN /m²).
3- Slope shape ep = 10 cm 22 x 0.1 = 2.20 (kN /m²).
4- Thermal insulation in cork ep = 0.04m 4 x 0.04 = 0.16 (kN /m²).
5- Hollow body floor (16 + 4) 2.85 (kN /m²).
6- Plaster coating thickness = 2 cm 0.10 x 2 = 0.20 (kN /m²).

Permanent load: **G = 6.13** (kN /m²).
Operating load : **Q = 1.00** (kN /m²).

Floor Current floor

1- Ceramic tiles thickness = 2 cm 0.20 x 2 = 0.40 (KN/m²).
2- Setting mortar thickness = 2 cm 22 x 0.02 = 0.44 (KN/m²).
sand thickness = 2 cm 17 x 0.02 = 0.34 (KN/m²).
4- Hollow body floor (16 + 4) 2.85 (KN/m²).
5- Plaster coating thickness = 2 cm 0.10 x 2 = 0.20 (KN/m²).
6- Lightweight partitions 1.00 (KN/m²).

Permanent load: **G = 5.23** (kN /m²).
Operating load : **Q = 1.50** (kN /m²).

2- Calculation of the linear load applied to the beam [(A-2)-(B-2)] at the level of a current floor:

In a standard floor we have: G= 5.23 kN /m² and Q=1.50 kN /m²

to the ELU :

The ultimate charge Pu = 1.35 G + 1.50 Q …………(1)

$$(1) \Rightarrow Pu = 1{,}35\left[5{,}23\left(\frac{3{,}20}{2}+\frac{4}{2}\right)\right] + 1{,}50\left[1{,}50\left(\frac{3{,}20}{2}+\frac{4}{2}\right)\right]$$

$\Rightarrow Pu = 33{,}52\ kN/m$ **THE ELECTED ONE**

at the ELS :

The load at the serviceability limit state, Pser = G + Q ………..(2)

$$(2) \Rightarrow Pser = \left[5{,}23\left(\frac{3{,}20}{2}+\frac{4}{2}\right)\right]+\left[1{,}50\left(\frac{3{,}20}{2}+\frac{4}{2}\right)\right]$$

$\Rightarrow Pser = 24{,}23\ kN/m$ **at the ELS**

3- Calculation of the point load applied to the post (B-2) at the base of the building:

Calculation of the related areas:

a) relevant surface for permanent loads:

$S_{f1} = (5-0{,}3)\times\left[\left(\frac{3{,}2}{2}-0{,}15\right)+\left(\frac{4}{2}-0{,}15\right)\right] = \mathbf{15,51\ m^2}$

b) area relating to operating costs:

$S_{f2} = 5\times\left(\frac{3{,}2}{2}+\frac{4}{2}\right) = \mathbf{18\ m^2}$

Calculation of permanent loads of floors

Terrace floor: $P_{LTG} = 15{,}51\times 6{,}13 = \mathbf{95,08\ kN}$

Current floor level: $P_{LEG} = 15{,}51\times 5{,}23 = \mathbf{81,12\ kN}$

Calculation of floor operating loads

Terrace floor: $P_{LTQ} = 18\times 1 = \mathbf{18\ kN}$

Current floor level: $P_{LEQ} = 18\times 1{,}50 = \mathbf{27\ kN}$

Building in R+6, therefore *n* =7 > 5 ➔we must reduce operating costs.

Calculation of permanent loads of beams, chains and posts

Beams: $P_P = (5-0{,}30)\times 0{,}30\times 0{,}50\times \mathbf{25} = \mathbf{17,63\ kN}$

Chains: $P_{CH} = \left[\left(\frac{3{,}2}{2}+\frac{4}{2}\right)-0{,}30\right]\times 0{,}30\times 0{,}30\times \mathbf{25} = \mathbf{7,43\ kN}$

Post (30x30) : $P_{(30\times30)} = 0{,}30\times 0{,}30\times 3{,}06\times \mathbf{25} = \mathbf{6,89\ kN}$

Post (40x40) : $P_{(40\times40)} = 0{,}40\times 0{,}40\times 3{,}06\times \mathbf{25} = \mathbf{12,24\ kN}$

Post (50x50) : $P_{(50\times50)} = 0{,}50\times 0{,}50\times 3{,}06\times \mathbf{25} = \mathbf{19,13\ kN}$

Post (60x60) : $P_{(60\times60)} = 0{,}60\times 0{,}60\times 3{,}06\times \mathbf{25} = \mathbf{27,54\ kN}$

Load descent by level

- **Terrace Floor**

  Permanent normal effort at the terrace level:

  $N_{GT} = P_{LTG} + P_P + P_{CH} = 95{,}08 + 17{,}63 + 7{,}43 = \mathbf{120,14\ kN}$

  Normal operating effort at terrace level:

  $N_{QT} = P_{LTQ} = \mathbf{18\ kN}$

- **Upper floor of the 5th floor**

  Permanent normal force at the level of the upper floor 5th floor :

  $$N_{G5} = \boldsymbol{N_{GT}} + P_{LEG} + P_P + P_{CH} + P_{(30\times30)}$$
  $$= 120{,}14 + 81{,}12 + 17{,}63 + 7{,}43 + 6{,}89 = \mathbf{233,21\ kN}$$

  Normal operating effort at the upper floor level 5th floor :

  $N_{Q5} = N_{QT} + P_{LEQ} = 18 + 27 = \mathbf{45\ kN}$

- **Upper floor of the 4th floor**

Permanent normal force at the level of the upper floor 4th floor :

$$N_{G4} = \boldsymbol{N_{G5}} + P_{LEG} + P_P + P_{CH} + P_{(30\times30)}$$
$$= 233{,}21 + 81{,}12 + 17{,}63 + 7{,}43 + 6{,}89 = \mathbf{346{,}28\ kN}$$

Normal operating effort at the upper floor level 4th floor :

$$N_{Q4} = N_{QT} + 0{,}95(2 \times P_{LEQ}) = 18 + 0{,}95(2 \times 27) = \mathbf{69{,}30kN}$$

- **Upper floor of the 3rd floor**

Permanent normal force at the level of the upper floor 3rd floor :

$$N_{G3} = \boldsymbol{N_{G4}} + P_{LEG} + P_P + P_{CH} + P_{(30\times30)}$$
$$= 233{,}21 + 81{,}12 + 17{,}63 + 7{,}43 + 6{,}89 = \mathbf{459{,}35\ kN}$$

Normal operating effort at the upper floor level 3rd floor :

$$N_{Q3} = N_{QT} + 0{,}90(3 \times P_{LEQ}) = 18 + 0{,}90(3 \times 27) = \mathbf{90{,}90kN}$$

- **Upper floor of the 2nd floor**

Permanent normal force at the level of the upper floor 2nd floor :

$$N_{G2} = \boldsymbol{N_{G3}} + P_{LEG} + P_P + P_{CH} + P_{(30\times30)}$$
$$= 459{,}35 + 81{,}12 + 17{,}63 + 7{,}43 + 6{,}89 = \mathbf{572.42\ kN}$$

Normal operating effort at the upper floor level 2nd floor :

$$N_{Q2} = N_{QT} + 0{,}85(4 \times P_{LEQ}) = 18 + 0{,}85(4 \times 27) = \mathbf{109{,}80\ kN}$$

- **Upper floor of the 1st floor**

Permanent normal force at the level of the upper floor 1st floor :

$$N_{G1} = \boldsymbol{N_{G2}} + P_{LEG} + P_P + P_{CH} + P_{(40\times40)}$$
$$= 572{,}42 + 81{,}12 + 17{,}63 + 7{,}43 + 12{,}24 = \mathbf{690{,}84\ kN}$$

Normal operating effort at the upper floor level 1st floor :

$$N_{Q1} = N_{QT} + 0{,}80(5 \times P_{LEQ}) = 18 + 0{,}80(5 \times 27) = \mathbf{126\ kN}$$

- **Upper floor of the ground floor**

Permanent normal effort at the level of the upper ground floor:

$$N_{GRDC} = \boldsymbol{N_{G1}} + P_{LEG} + P_P + P_{CH} + P_{(50\times50)}$$
$$= 690{,}84 + 81{,}12 + 17{,}63 + 7{,}43 + 19{,}13 = \mathbf{816{,}15\ kN}$$

Normal operating effort at the upper ground floor level:

$$N_{QRDC} = N_{QT} + 0{,}75(6 \times P_{LEQ}) = 18 + 0{,}75(6 \times 27) = \mathbf{139{,}50\ kN}$$

- **The base (foundation)**

Permanent normal effort at the base:

$$N_{Gbase} = \boldsymbol{N_{GRDC}} + P_{(60\times60)} = 816{,}15 + 27{,}54 = \mathbf{843{,}69\ kN}$$

Normal operating effort at base level:

$$N_{Qbase} = N_{QT} + 0{,}71(7 \times P_{LEQ}) = 18 + 0{,}71(7 \times 27) = \mathbf{152{,}19\ kN}$$

Ultimate normal force (ULF) at base level for column (B-2):

$$N_u = 1{,}35\ N_{Gbase} + 1{,}50\ N_{Qbase} = 1{,}35(843{,}69) + 1{,}50(152{,}19) = \mathbf{1367{,}27kN}$$

Normal service force (SSF) at base level for column (B-2):

$$N_u = N_{Gbase} + N_{Qbase} = (843{,}69) + (152{,}19) = \mathbf{998{,}88\ kN}$$