CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF CIVIL ENGINEERING
DEPARTMENT OF BUILDING STRUCTURES

MASTER THESIS

DWELLING HOUSE – STRUCTURAL PROJECT

AUTHOR: Bc. JAVIER MARTÍNEZ PERAGÓN

SUPERVISOR: Doc. Ing. František Kulhánek CSC

Prague, January 2018

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Thákurova 7, 166 29 Prague 6, Czech Republic

DIPLOMA THESIS ASSIGNMENT FORM

I. PERSONAL AND STUDY DATA

Surname: Martínez Name: Javier Personal number: ________

Assigning Department: K124

Study programme: Civil Engineering

Branch of study: Building Structures

II. DIPLOMA THESIS DATA

Diploma Thesis (DT) title: Dwelling House – Structural project

Diploma Thesis title in English: Dwelling House – Structural project

Instructions for writing the thesis:

Study of structural system of a building-2 options (Spanish and Czech).
Preliminary static calculations for both the options.
Design of envelop structure.
Drawings (1:50) of ground floor,Typical floor,Roof,Two sections,Two elevations and Details.

List of recommended literature:

Procházka, J. - Štemberk, P.: Design Procedures for Reinforced Concrete Structures.
Concrete Structures - Euro-design Handbook.Editor: Josef Eibl, Ernst u.
Barritt C.M.H.: Advanced Building Construction, Vol 1 - 4, Longman 1991.

Name of Diploma Thesis Supervisor: doc.Ing. František Kulhánek,CSC

DT assignment date: 02.10.2017 DT submission date: 07.01.2018

______________________________ ______________________________
DT Supervisor's signature Head of Department's signature

III. ASSIGNMENT RECEIPT

I declare that I am obliged to write the Diploma Thesis on my own, without anyone's assistance, except for provided consultations. The list of references, other sources and consultants' names must be stated in the Diploma Thesis and in referencing I must abide by the CTU methodological manual "How to Write University Final Theses" and the CTU methodological instruction "On the Observation of Ethical Principles in the Preparation of University Final Theses".

______________________________ ______________________________
Assignment receipt date Student's name

Abstrakt:

Tato diplomová práce je duševním vlastnictvím studentá Javiera Martíneze. Výzkum pro diplomovou práci byl proveden v období od 27. září 2017 do 7. ledna 2018. Práce zahrnuje předběžný návrh betonové konstrukce, výzkum tepelné izolace, kalkulaci nosnosti a návrh rekonstrukce budovy na základě českých standardů a evropských standardů Eurocode. Předběžný design jednoho sloupu a nosníku indikuje, že prvky struktury mají vyhovující nosnost.

Abstract:

This thesis report is an original intellectual property of the student (Javier Martínez), the period of conducting this work is from 27th September 2017 -7th January 2018.
It encompasses a preliminary design, thermal insulation research, determination of design loads and refurbishment of the building according to the Czech Standards and Eurocode. A preliminary concrete design of one column and one beam indicates the members of the structure are adequate to carry design loads.

Keywords: bearing system, insulation, Czech standards, section, plan, details, optimize, drawings.

Statement

I declare that I have worked out this thesis independently assuming that the result of the result can also be used at the discretion of the supervisor of the thesis as co-author. I also agree with the potential publication of the results of the thesis or its substantial part, provided I will be listed as co-author.

In Prague: ___________________________ Signature: ______________________________

GENERAL INDEX

1. INTRODUCTION

1. INTRODUCTION

1.1 Preface

This thesis report is an original intellectual property of the student (Javier Martínez), the period of conducting this research work is from 27th September 2017 -7th January 2018.

Its main objective is to identify a challenge and propose a solution to that challenge, consisting in refurbish a building from only its initial architecture plans.

It encompasses a structural discussion, thermal insulation research, determination of design loads and spot checks and refurbishment of the building according to the Czech Standards and Eurocode. A preliminary design of one column and one beam indicates the members of the structure are adequate to carry design loads.

1.2 Architecture

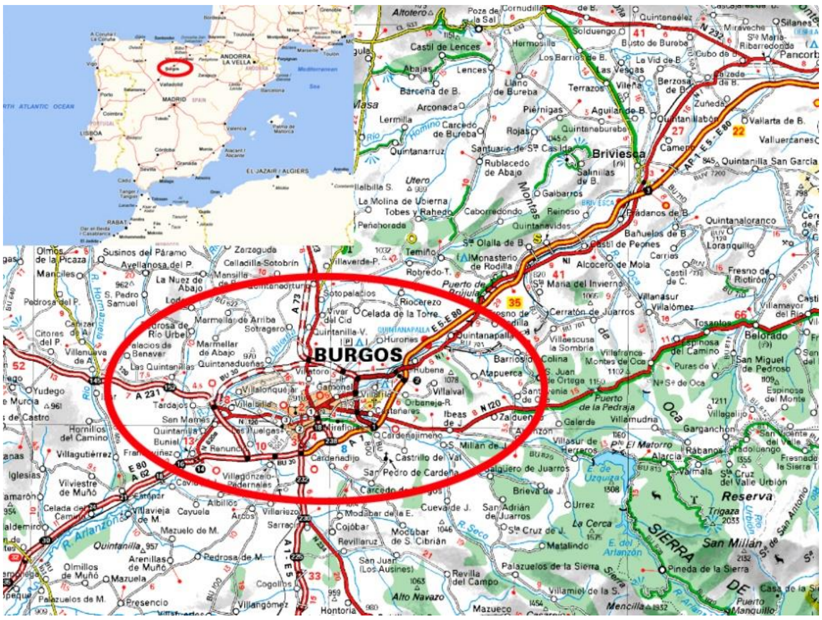
The project consists in a 5-story residential building with location in Burgos (Spain). It provides recreational facilities that include a lobby area, terraces, accessible roof and balcony spaces at every floor. Just like the interior, the exterior of the building is efficient in utilizing the available resources at the same time maintaining its aesthetic qualities.

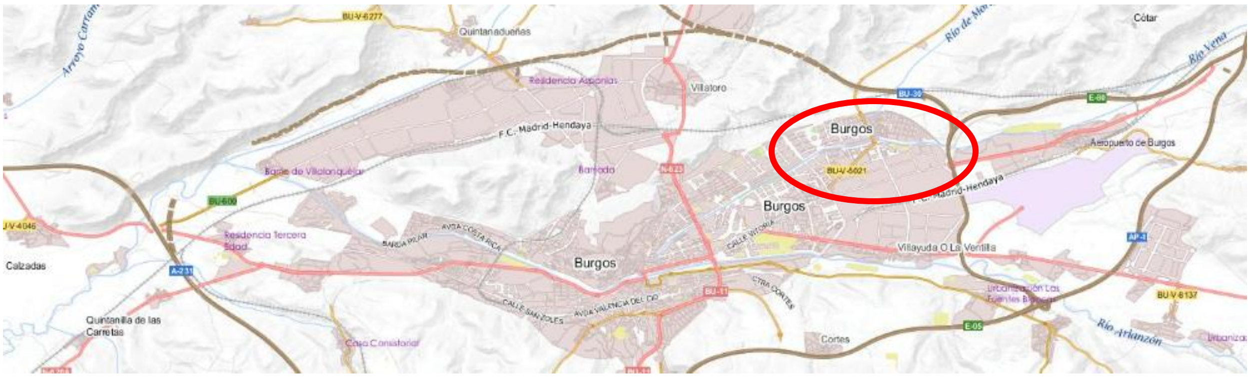
The envelope of the building is designed to fit into the fabric of the city which also becomes an important architectural feature of the building.

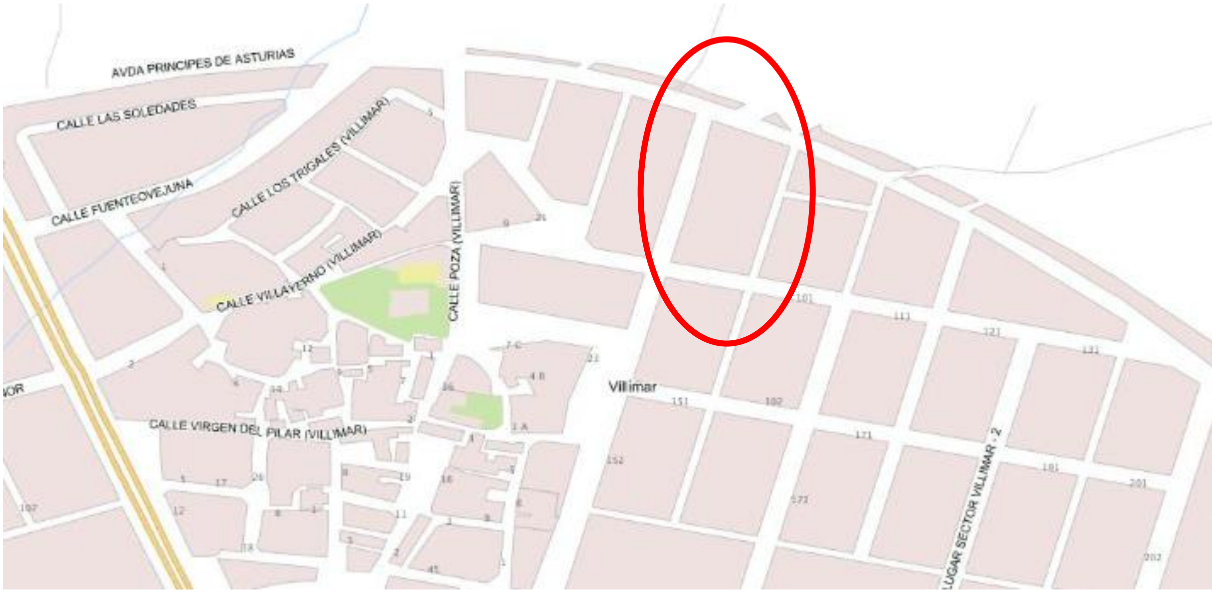
1.3 Location and site of the building

Burgos is a city in northern Spain and the historic capital of Castile, founded in 884 AC. It is situated on the confluence of the Arlanzón river tributaries, at the edge of the Iberian central plateau. It has about 180,000 inhabitants in the actual city and another 20,000 in the metropolitan area. It is the capital of the province of Burgos, in the autonomous community of Castile and León

Coordinates: 42°21′00″N 3°42′24″W
Area: 107.08 km^2
Elevation: 859 m







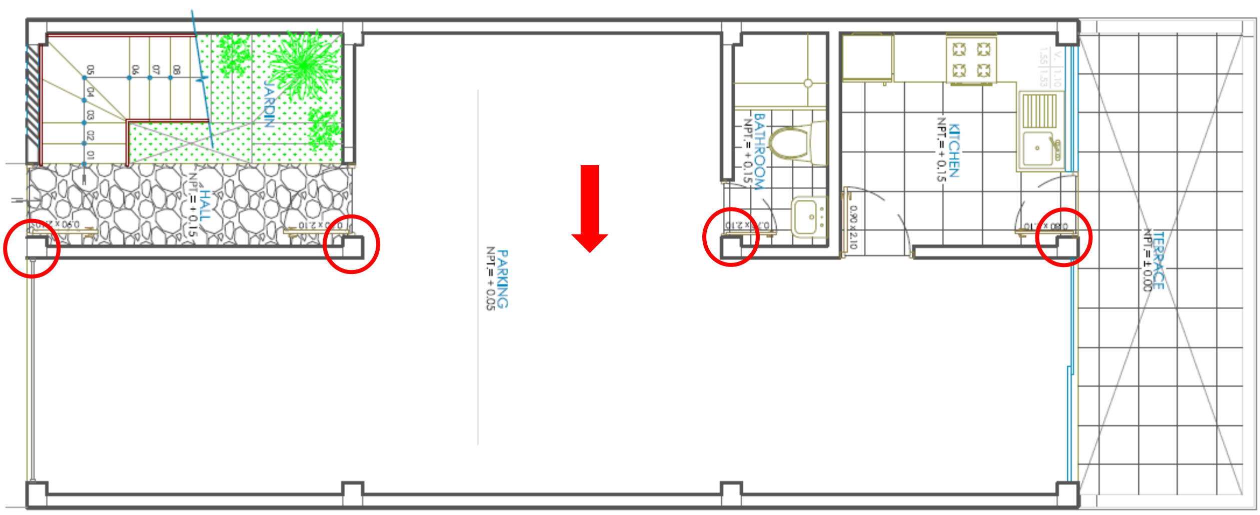
1.4 <u>Structural system</u>

It has been optimized to increase floor space area, to celebrate the architecture and economize the overall cost of the building. In order to achieve these goals, reinforced concrete was chosen as a prime material to design the structural members. It also facilitates design changes during construction. The structural system of the building consists of flat slabs supported by columns and shear walls located around the staircase, calculated everything as preliminary design according to Czech Standard.

The quality and the bearing capacity of the soil was assumed according to data provided from the council city (medium sand) which is also the most common in the Czech Republic.

2. INITIAL PLANS AND MAIN CHANGES MADE IN THEM

1st FLOOR



STRUCTURAL CHANGES

-All the columns in red has been removed because the distance between the columns in each side is <7m, therefore we don't need them. A column was added where the arrow is, in order to carry the weight of the open space located in the floors above.

-Initially the thickness of all vertical walls and partitions were given by default. By adapting the plan with the new dimensions, the area of all rooms has been slightly reduced and the staircase made new from the beginning. A lift was installed as well (explained below)

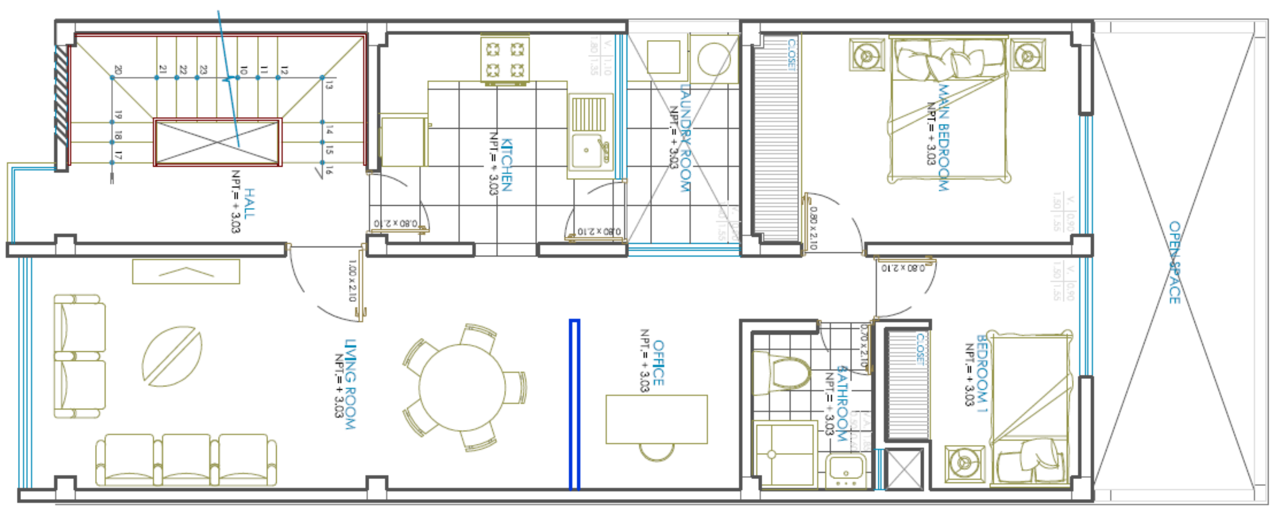
-The staircase is carried by a reinforced concrete wall instead of beams-columns.

ARCHITECTURAL CHANGES

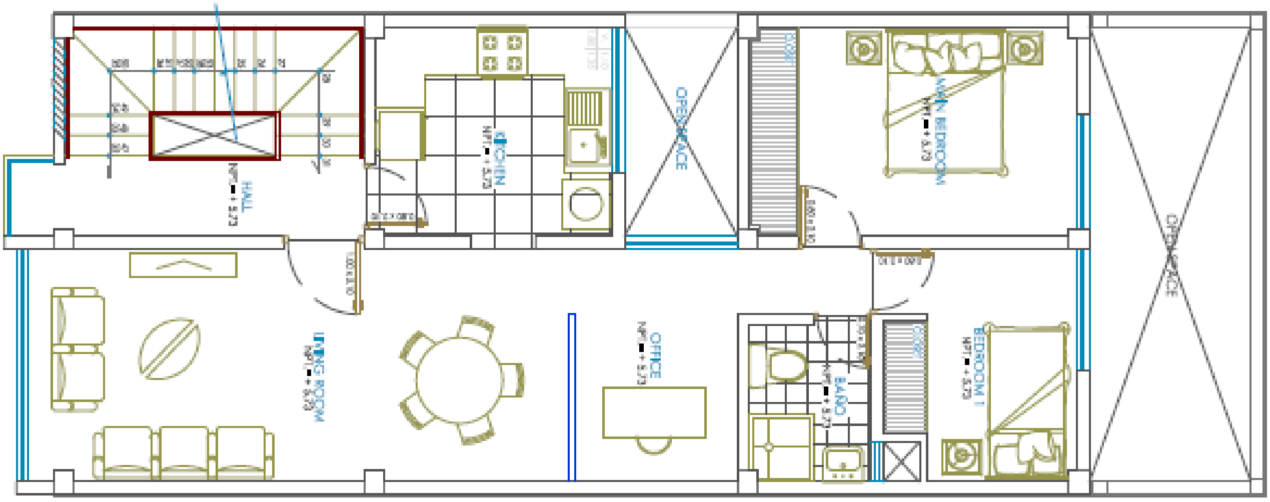
- Kitchen and bathroom have been removed in order to make a storage for all the owners.

-The purpose of the parking has been changed to lobby room because there was just space for one car. Nevertheless, a car can fit inside if needed.

2nd FLOOR



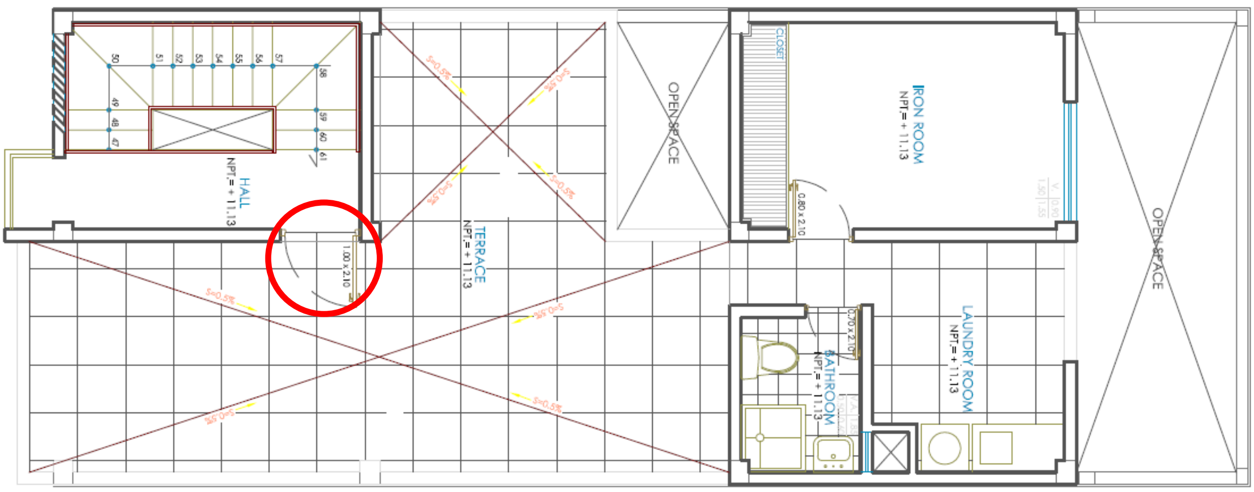
TYPE FLOOR: 3rd and 4th



ARCHITECTURAL CHANGES

- Redistribute the space of all rooms due to the column added and new thickness of cladding and partitions.

FLAT ROOF



STRUCTURAL CHANGES:

-Small staircase added in the roof (red circle) to balance the distance between hall and terrace.

-Slopes were calculated again with the correct position of sewers.

ARCHITECTURAL CHANGES

-All the rooms has been removed in order to make a passable terrace and garden terrace.

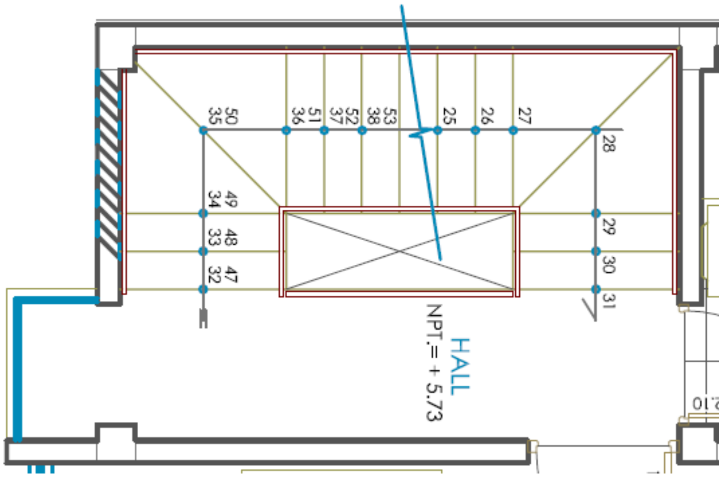
3. STAIRCASE AND LIFT

3.1 Preliminary design of staircase (Blondel's law)

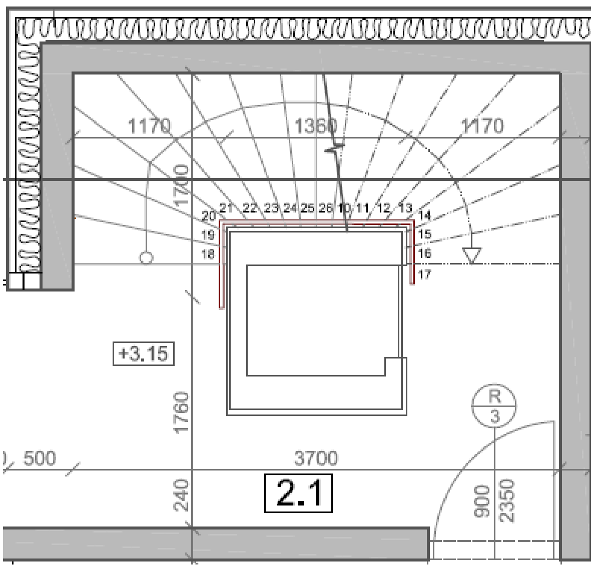
DATA:
Height: 3,05 m
Run length ≥ 28 cm -> 28 cm is taken for calculation
Riser height ≤ 21 cm -> 18 cm is taken for calculation

$\frac{305\ cm}{18\ cm} = 16{,}94 \approx 17\ steps$ -> RH= $\frac{305\ cm}{17\ steps} = 17{,}9\ cm$

$2 \cdot RH + 1 \cdot RL = 64$ cm
$2 \cdot 17{,}9 + 1 \cdot RL = 64$ cm;
RL= 28,2 cm



Initial staircase



Designed staircase

3.2 Lift

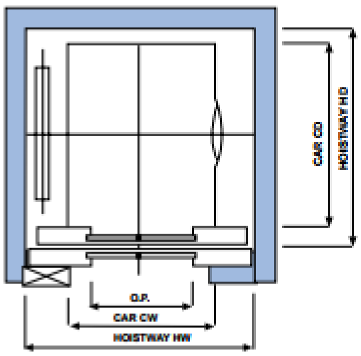
These are some of the featurings of the lift installed. **MODEL: OTIS GEN2 COMFORT**

DIMENSION	OTIS GEN2 COMFORT		
Load capacity	Car CW x CD (mm)	Hoistway HW (mm) x HD (mm)	Door opening (mm)
320 kg (4p)	840 x 1050	1350 x 1300	700

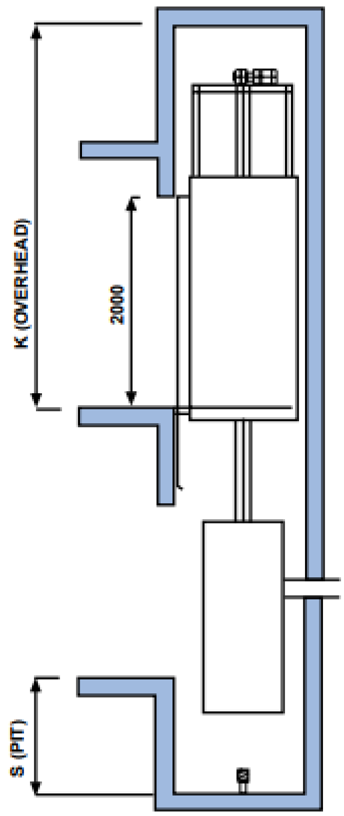
Floor sketch

1 entrance

Central Opening doors



Vertical section



4. HYGRO-THERMAL EVALUATION

BASIC HYGRO-THERMAL EVALUATION OF THE BUILDING CONSTRUCTION (1D HEAT AND MOISTURE TRANSFER)

according to EN ISO 13788, EN ISO 6946 and CSN 730540

Teplo 2014

Project name : **Wall**
User : Javier Martínez Peragón
Order : DT
Date : 30.11.2017

ASSEMBLY OF THE CONSTRUCTION AND BOUNDARY CONDITIONS:

Type of analysed construction : Ventilated external wall
Correction of U-value dU : 0.000 W/m2K

Assembly of the construction (from interior) :

No.	Name	D [m]	Lambda [W/(m.K)]	C [J/(kg.K)]	Ro [kg/m3]	Mi [-]	Ma [kg/m2]
1	Bayosan DP 85	0,0100	0,0700	850,0	240,0	8,0	0.0000
2	Lime-sand bric	0,2400	0,8600	960,0	1800,0	15,0	0.0000
3	Rockwool Airro	0,1800	0,0390	840,0	112,0	3,5	0.0000

Note: D is thickness of layer, Lambda is design thermal conductivity of layer, C is specific thermal capacity, Ro is bulk density of layer, Mi is vapor resistance factor of layer and Ma is initial built-in moisture in layer.

No.	Complete name of layer	Internal calculation of thermal conductivity
1	Bayosan DP 85	---
2	Lime-sand bricks 2 DF	---
3	Rockwool Airrock HD	---

Boundary conditions :

Internal surface thermal resistance Rsi : 0.13 m2K/W
dtto for calculation of temperature factor Rsi : 0.25 m2K/W
External surface thermal resistance Rse : 0.13 m2K/W
dtto for calculation of temperature factor Rse : 0.13 m2K/W

Design external temperature Te : -13.0 C
Design internal air temperature Tai : 21.0 C
Design relative humidity of external air RHe : 84.0 %
Design relative humidity of internal air RHi : 55.0 %

Month	Dur.[days]	Ti[C]	RHi[%]	Pi[Pa]	Te[C]	RHe[%]	Pe[Pa]
1	31	21.0	43.1	1071.3	-2.4	81.2	406.1
2	28	21.0	45.1	1121.0	-0.9	80.8	457.9
3	31	21.0	48.3	1200.5	3.0	79.5	602.1
4	30	21.0	52.7	1309.9	7.7	77.5	814.1
5	31	21.0	59.5	1478.9	12.7	74.5	1093.5
6	30	21.0	65.0	1615.6	15.9	72.0	1300.1
7	31	21.0	67.9	1687.7	17.5	70.4	1407.2
8	31	21.0	66.9	1662.9	17.0	70.9	1373.1
9	30	21.0	60.5	1503.8	13.3	74.1	1131.2
10	31	21.0	53.3	1324.8	8.3	77.1	843.7
11	30	21.0	48.2	1198.1	2.9	79.5	597.9
12	31	21.0	45.6	1133.4	-0.6	80.7	468.9

Note: Tai, RHi and Pi are mean monthly parameters of internal air (temperature, rel. humidity and partial vapor pressure) anf Te, RHe and Pe are mean monthly parameters in environment on external side (temperatur, rel. humidity and partial vapor pressure).

To increase the safety, internal relative humidity was increased for: 5.0 %

The first month of calculation was determined according to EN ISO 13788.
Number of calculated years : 1

RESULTS OF CALCULATION :

Thermal resistance and thermal transmittance according to EN ISO 6946 :

Thermal resistance of construction R : 5.037 m2K/W
Thermal transmittance of construction U : **0.189 W/m2K**

U-value of built-in construction U,kc : 0.21 / 0.24 / 0.29 / 0.39 W/m2K
These informational values are valid for various design level of thermal bridges expressed by means of increment according to clause B.9.2 in ČSN 730540-4.

Diffusion resistance and thermal accumulation:

Vapor diffusion resistance of construction ZpT : 2.3E+0010 m/s

Decrement factor of construction Ny* : 646.5
Time shift of temperature oscillation Psi* : 13.7 h

Internal surface temperature and temperature factor according to EN ISO 13788 :

Internal surface temperature for design conditions Tsi,p : 19.43 C
Temperature factor in design conditions f,Rsi,p : **0.954**

Month no.	Minimum required values for max. internal surface relative humidity --------- 80% ---------		-------- 100% ---------		Calculated values		
	Tsi,m[C]	f,Rsi,m	Tsi,m[C]	f,Rsi,m	Tsi[C]	f,Rsi	RHsi[%]
1	11.3	0.586	8.0	0.444	19.9	0.954	46.1
2	12.0	0.589	8.7	0.436	20.0	0.954	48.0
3	13.0	0.558	9.7	0.371	20.2	0.954	50.8
4	14.4	0.502	11.0	0.246	20.4	0.954	54.7
5	16.3	0.430	12.8	0.014	20.6	0.954	60.9
6	17.7	0.346	14.2	------	20.8	0.954	65.9
7	18.4	0.245	14.8	------	20.8	0.954	68.6
8	18.1	0.280	14.6	------	20.8	0.954	67.7
9	16.5	0.419	13.1	------	20.6	0.954	61.8
10	14.6	0.492	11.1	0.224	20.4	0.954	55.3
11	13.0	0.558	9.6	0.372	20.2	0.954	50.7
12	12.2	0.591	8.8	0.436	20.0	0.954	48.5

Note: RHsi is relative humidity at the internal surface, Tsi is int.surface temperature and f,Rsi is temp.factor.

Vapor diffusion in design conditions and annual balance according to CSN 730540:
(without influence of built-in moisture and sun radiation)

Pressure and temperature distribution in design conditions:

interface:	i	1-2	2-3	e
theta[C]:	20.2	19.2	17.5	-12.2
p [Pa]:	1367	1345	344	166
p,sat [Pa]:	2361	2230	1994	214

Note: theta is temperature on interfaces of layers, p is expected partial vapor pressure on interfaces of layers and p,sat is saturated partial vapor pressure on interfaces.

No condensation occurs in the design conditions.

Vapor diffusion flow rate Gd : 5.560E-0008 kg/(m2.s)

Annual moisture balance according to EN ISO 13788:

Annual cycle no. 1

No condensation occurs in the construction during the model year.

Note: Calculation of water vapor diffusion was performed with the assumption of 1D vapor flow through prevailing assembly of the construction. The result is just informational for components with significant thermal bridges. More exact values can be obtained using 2D analysis.

VYHODNOCENÍ VÝSLEDKŮ PODLE KRITÉRIÍ ČSN 730540-2 (2011)

Název konstrukce: Wall

Rekapitulace vstupních dat

Návrhová vnitřní teplota Ti: 20,0 C
Převažující návrhová vnitřní teplota TiM: 20,0 C
Návrhová venkovní teplota Tae: -13,0 C
Teplota na vnější straně Te: -13,0 C
Návrhová teplota vnitřního vzduchu Tai: 21,0 C
Relativní vlhkost v interiéru RHi: 50,0 % (+5,0%)

Skladba konstrukce

Číslo	Název vrstvy	d [m]	Lambda [W/mK]	Mi [-]
1	Bayosan DP 85	0,010	0,070	8,0
2	Lime-sand bricks 2 DF	0,240	0,860	15,0
3	Rockwool Airrock HD	0,180	0,039	3,55

I. Požadavek na teplotní faktor (čl. 5.1 v ČSN 730540-2)

Požadavek: f,Rsi,N = f,Rsi,cr = 0,753
Vypočtená průměrná hodnota: f,Rsi,m = 0,954

Kritický teplotní faktor f,Rsi,cr byl stanoven pro maximální přípustnou vlhkost na vnitřním povrchu 80% (kritérium vyloučení vzniku plísní).

Průměrná hodnota fRsi,m (resp. maximální hodnota při hodnocení skladby mimo tepelné mosty a vazby) není nikdy minimální hodnotou ve všech místech konstrukce. Nelze s ní proto prokazovat plnění požadavku na minimální povrchové teploty zabudované konstrukce včetně tepelných mostů a vazeb. Její převýšení nad požadavkem naznačuje pouze možnosti plnění požadavku v místě tepelného mostu či tepelné vazby.

II. Požadavek na součinitel prostupu tepla (čl. 5.2 v ČSN 730540-2)

Požadavek: U,N = 0,30 W/m2K
Vypočtená hodnota: U = 0,189 W/m2K
U < U,N ... POŽADAVEK JE SPLNĚN.

Vypočtený součinitel prostupu tepla musí zahrnovat vliv systematických tepelných mostů (např. krokví v zateplené šikmé střeše).

III. Požadavky na šíření vlhkosti konstrukcí (čl. 6.1 a 6.2 v ČSN 730540-2)

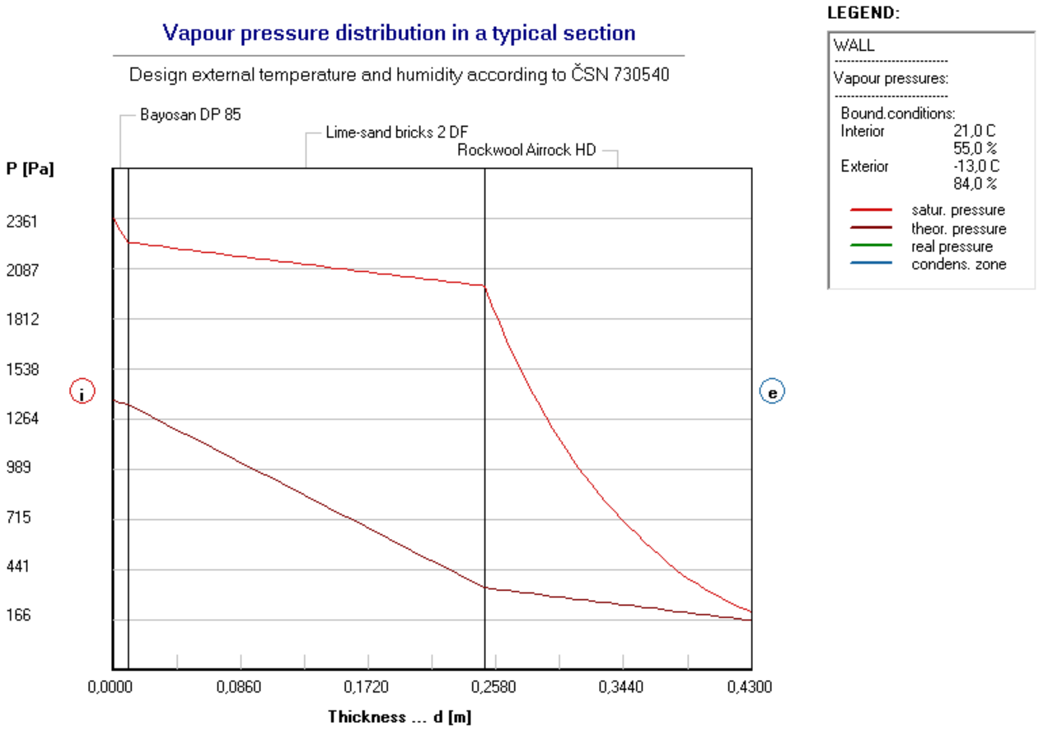
Požadavky:
1. Kondenzace vodní páry nesmí ohrozit funkci konstrukce.
2. Roční množství kondenzátu musí být nižší než roční kapacita odparu.
3. Roční množství kondenzátu Mc,a musí být nižší než 0,5 kg/m2.rok, nebo 5-10% plošné hmotnosti materiálu (nižší z hodnot).

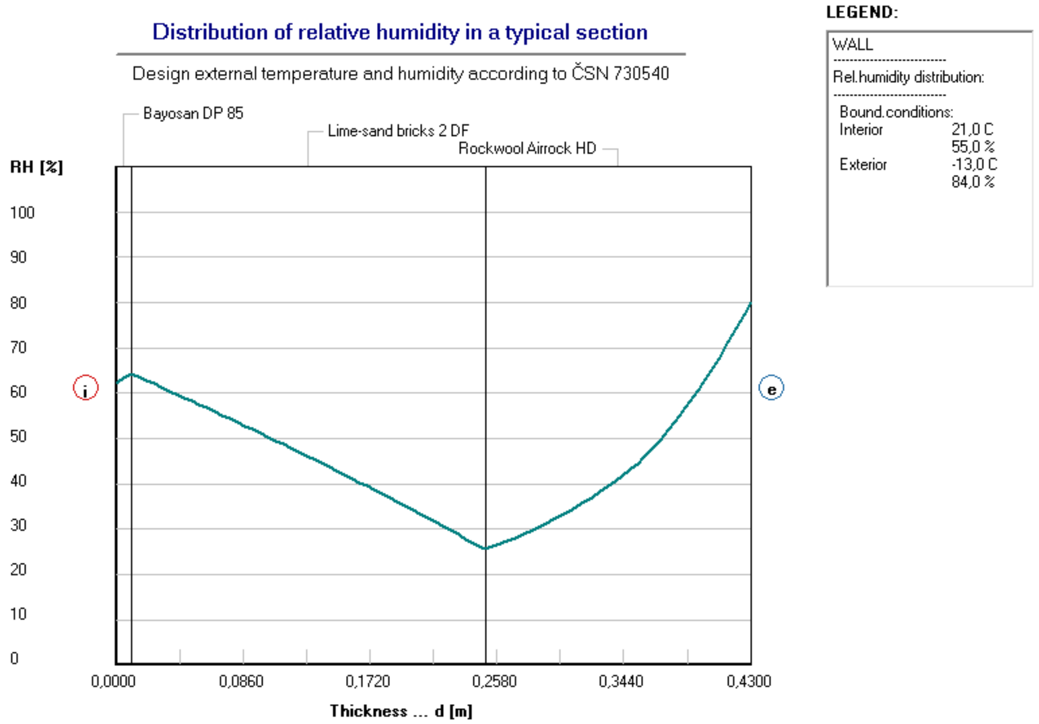
Vypočtené hodnoty: V kci nedochází při venkovní návrhové teplotě ke kondenzaci.

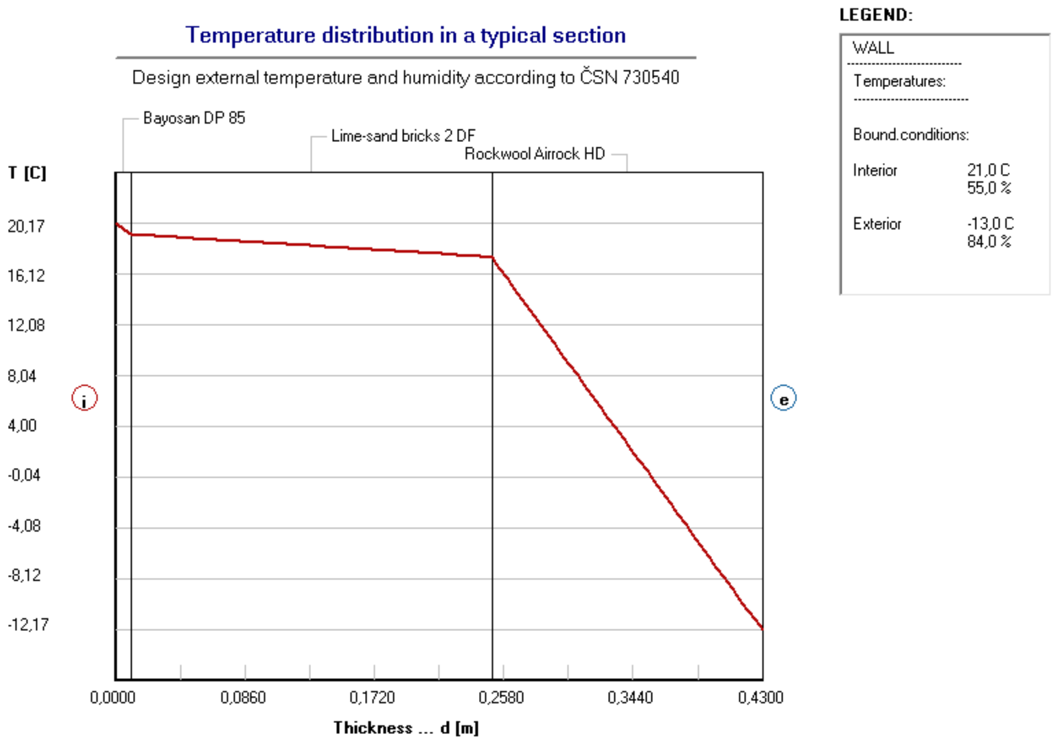
V konstrukci nedochází během modelového roku ke kondenzaci.

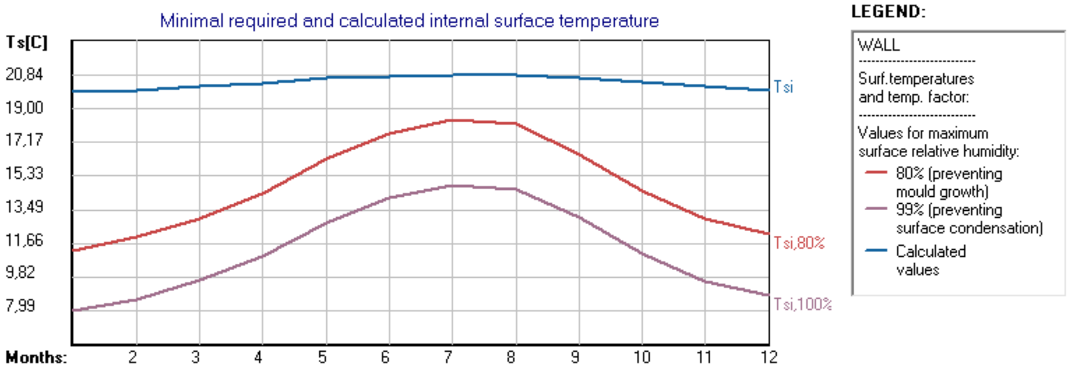
POŽADAVKY JSOU SPLNĚNY.

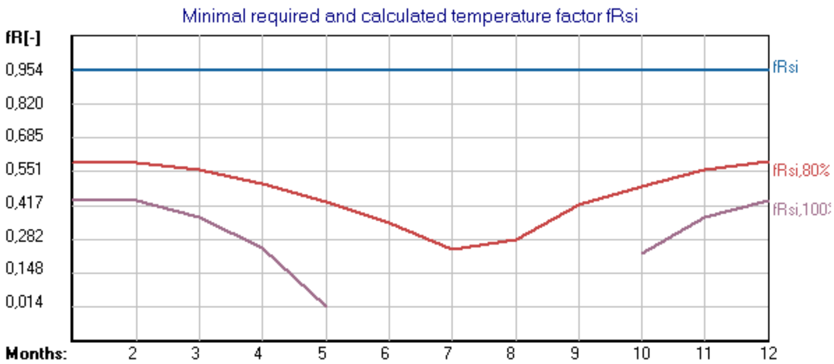
LINE GRAPHS

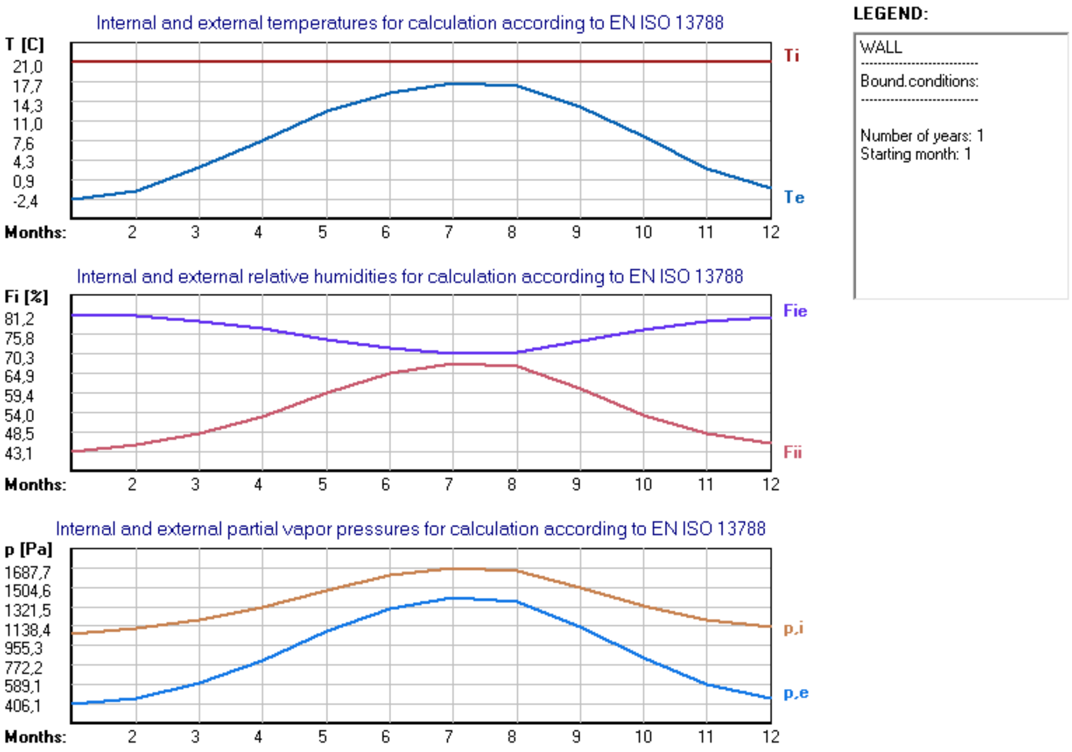





Temperature distribution in a typical section
Design external temperature and humidity according to ČSN 730540
Bayosan DP 85
Lime-sand bricks 2 DF
Rockwool Airrock HD
T [C]
20,17
16,12
12,08
8,04
4,00
-0,04
-4,08
-8,12
-12,17
i
e
0,0000
0,0860
0,1720
0,2580
0,3440
0,4300
Thickness ... d [m]
LEGEND:
WALL
Temperatures:
Bound.conditions:
Interior
21,0 C
55,0 %
Exterior
-13,0 C
84,0 %


Minimal required and calculated internal surface temperature
Ts[C]
20,84
19,00
17,17
15,33
13,49
11,66
9,82
7,99
Tsi
Tsi,80%
Tsi,100%
Months:
2
3
4
5
6
7
8
9
10
11
12
LEGEND:
WALL
Surf.temperatures and temp. factor:
Values for maximum surface relative humidity:
80% (preventing mould growth)
99% (preventing surface condensation)
Calculated values


Minimal required and calculated temperature factor fRsi
fR[-]
0,954
0,820
0,685
0,551
0,417
0,282
0,148
0,014
fRsi
fRsi,80%
Months:
2
3
4
5
6
7
8
9
10
11
12



BASIC HYGRO-THERMAL EVALUATION OF THE BUILDING CONSTRUCTION (1D HEAT AND MOISTURE TRANSFER)

according to EN ISO 13788, EN ISO 6946 and CSN 730540

Teplo 2014

Project name : **Roof**
User : Javier
Order : DT
Date : 30.11.2017

ASSEMBLY OF THE CONSTRUCTION AND BOUNDARY CONDITIONS:

Type of analysed construction : Roof, ceiling - heat flow upwards
Correction of U-value dU : 0.000 W/m2K

Assembly of the construction (from interior) :

No.	Name	D [m]	Lambda [W/(m.K)]	C [J/(kg.K)]	Ro [kg/m3]	Mi [-]	Ma [kg/m2]
1	Bayosan DP 85	0,0100	0,0700	850,0	240,0	8,0	0.0000
2	Reinforced con	0,2000	1,5800	1020,0	2400,0	29,0	0.0000
3	Austrotherm 70	0,0800	0,0300	2060,0	45,0	200,0	0.0000
4	Sarnafil G 476	0,0015	0,1500	960,0	1600,0	15000,0	0.0000
5	Austrotherm 70	0,1400	0,0300	2060,0	45,0	200,0	0.0000

Note: D is thickness of layer, Lambda is design thermal conductivity of layer, C is specific thermal capacity, Ro is bulk density of layer, Mi is vapor resistance factor of layer and Ma is initial built-in moisture in layer.

No.	Complete name of layer	Internal calculation of thermal conductivity
1	Bayosan DP 85	---
2	Reinforced concrete 2	---
3	Austrotherm 70 XPS-G/030	---
4	Sarnafil G 476	---
5	Austrotherm 70 XPS-G/030	---

Boundary conditions :

Internal surface thermal resistance Rsi : 0.10 m2K/W
 dtto for calculation of temperature factor Rsi : 0.25 m2K/W
External surface thermal resistance Rse : 0.04 m2K/W
 dtto for calculation of temperature factor Rse : 0.04 m2K/W

Design external temperature Te : -13.0 C
Design internal air temperature Tai : 21.0 C
Design relative humidity of external air RHe : 84.0 %
Design relative humidity of internal air RHi : 55.0 %

Month	Dur.[days]	Ti[C]	RHi[%]	Pi[Pa]	Te[C]	RHe[%]	Pe[Pa]
1	31	21.0	43.1	1071.3	-4.4	81.2	342.9
2	28	21.0	45.1	1121.0	-2.9	80.8	387.4
3	31	21.0	48.3	1200.5	1.0	79.5	521.8
4	30	21.0	52.7	1309.9	5.7	77.5	709.4
5	31	21.0	59.5	1478.9	10.7	74.5	958.1
6	30	21.0	65.0	1615.6	13.9	72.0	1142.9
7	31	21.0	67.9	1687.7	15.5	70.4	1239.1
8	31	21.0	66.9	1662.9	15.0	70.9	1208.4
9	30	21.0	60.5	1503.8	11.3	74.1	991.8
10	31	21.0	53.3	1324.8	6.3	77.1	735.7
11	30	21.0	48.2	1198.1	0.9	79.5	518.1
12	31	21.0	45.6	1133.4	-2.6	80.7	396.8

Note: Tai, RHi and Pi are mean monthly parameters of internal air (temperature, rel. humidity and partial vapor pressure) anf Te, RHe and Pe are mean monthly parameters in environment on external side (temperatur, rel. humidity and partial vapor pressure).

Mean monthly external temperature Te was decreased by 2 C according to EN ISO 13788 (influence of radiation heat exchange between roof and sky vault).

To increase the safety, internal relative humidity was increased for: 5.0 %

The first month of calculation was determined according to EN ISO 13788.
Number of calculated years : 1

RESULTS OF CALCULATION :

Thermal resistance and thermal transmittance according to EN ISO 6946 :

Thermal resistance of construction R : 7.613 m2K/W
Thermal transmittance of construction U : **0.129 W/m2K**

U-value of built-in construction U,kc : 0.15 / 0.18 / 0.23 / 0.33 W/m2K
These informational values are valid for various design level of thermal bridges expressed by means of increment according to clause B.9.2 in ČSN 730540-4.

Diffusion resistance and thermal accumulation:

Vapor diffusion resistance of construction ZpT : 3.8E+0011 m/s

Decrement factor of construction Ny* : 1505.9
Time shift of temperature oscillation Psi* : 14.8 h

Internal surface temperature and temperature factor according to EN ISO 13788 :

Internal surface temperature for design conditions Tsi,p : 19.92 C
Temperature factor in design conditions f,Rsi,p : **0.968**

Month no.	Minimum required values for max. internal surface relative humidity				Calculated values		
	--------- 80% ---------		-------- 100% ---------				
	Tsi,m[C]	**f,Rsi,m**	**Tsi,m[C]**	**f,Rsi,m**	**Tsi[C]**	**f,Rsi**	**RHsi[%]**
1	11.3	0.618	8.0	0.488	20.2	0.968	45.3
2	12.0	0.623	8.7	0.483	20.2	0.968	47.3
3	13.0	0.602	9.7	0.434	20.4	0.968	50.2
4	14.4	0.567	11.0	0.345	20.5	0.968	54.3
5	16.3	0.541	12.8	0.205	20.7	0.968	60.7
6	17.7	0.530	14.2	0.038	20.8	0.968	65.9
7	18.4	0.520	14.8	------	20.8	0.968	68.6
8	18.1	0.520	14.6	------	20.8	0.968	67.7
9	16.5	0.539	13.1	0.182	20.7	0.968	61.7
10	14.6	0.561	11.1	0.330	20.5	0.968	54.8
11	13.0	0.602	9.6	0.435	20.4	0.968	50.1
12	12.2	0.625	8.8	0.484	20.3	0.968	47.7

Note: RHsi is relative humidity at the internal surface, Tsi is int.surface temperature and f,Rsi is temp.factor.

Vapor diffusion in design conditions and annual balance according to CSN 730540:
(without influence of built-in moisture and sun radiation)

Pressure and temperature distribution in design conditions:

interface:	i	1-2	2-3	3-4	4-5	e
theta[C]:	20.6	19.9	19.4	7.7	7.6	-12.8
p [Pa]:	1367	1366	1270	1004	631	166
p,sat [Pa]:	2419	2328	2249	1049	1046	201

Note: theta is temperature on interfaces of layers, p is expected partial vapor pressure on interfaces of layers and p,sat is saturated partial vapor pressure on interfaces.

No condensation occurs in the design conditions.

Vapor diffusion flow rate Gd : 3.318E-0009 kg/(m2.s)

Annual moisture balance according to EN ISO 13788:

Annual cycle no. 1

No condensation occurs in the construction during the model year.

Note: Calculation of water vapor diffusion was performed with the assumption of 1D vapor flow through prevailing assembly of the construction. The result is just informational for components with significant thermal bridges. More exact values can be obtained using 2D analysis.

VYHODNOCENÍ VÝSLEDKŮ PODLE KRITÉRIÍ ČSN 730540-2 (2011)

Název konstrukce: Roof

Rekapitulace vstupních dat

Návrhová vnitřní teplota Ti:	20,0 C
Převažující návrhová vnitřní teplota TiM:	20,0 C
Návrhová venkovní teplota Tae:	-13,0 C
Teplota na vnější straně Te:	-13,0 C
Návrhová teplota vnitřního vzduchu Tai:	21,0 C
Relativní vlhkost v interiéru RHi:	50,0 % (+5,0%)

Skladba konstrukce

Číslo	Název vrstvy	d [m]	Lambda [W/mK]	Mi [-]
1	Bayosan DP 85	0,010	0,070	8,0
2	Reinforced concrete 2	0,200	1,580	29,0
3	Austrotherm 70 XPS-G/030	0,080	0,030	200,0
4	Sarnafil G 476	0,0015	0,150	15000,0
5	Austrotherm 70 XPS-G/030	0,140	0,030	200,0

I. Požadavek na teplotní faktor (čl. 5.1 v ČSN 730540-2)

Požadavek: f,Rsi,N = f,Rsi,cr = 0,753
Vypočtená průměrná hodnota: f,Rsi,m = 0,968

Kritický teplotní faktor f,Rsi,cr byl stanoven pro maximální přípustnou vlhkost na vnitřním povrchu 80% (kritérium vyloučení vzniku plísní).

Průměrná hodnota fRsi,m (resp. maximální hodnota při hodnocení skladby mimo tepelné mosty a vazby) není nikdy minimální hodnotou ve všech místech konstrukce. Nelze s ní proto prokazovat plnění požadavku na minimální povrchové teploty zabudované konstrukce včetně tepelných mostů a vazeb. Její převýšení nad požadavkem naznačuje pouze možnosti plnění požadavku v místě tepelného mostu či tepelné vazby.

II. Požadavek na součinitel prostupu tepla (čl. 5.2 v ČSN 730540-2)

Požadavek: U,N = 0,24 W/m2K
Vypočtená hodnota: U = 0,129 W/m2K
U < U,N ... POŽADAVEK JE SPLNĚN.

Vypočtený součinitel prostupu tepla musí zahrnovat vliv systematických tepelných mostů (např. krokví v zateplené šikmé střeše).

III. Požadavky na šíření vlhkosti konstrukcí (čl. 6.1 a 6.2 v ČSN 730540-2)

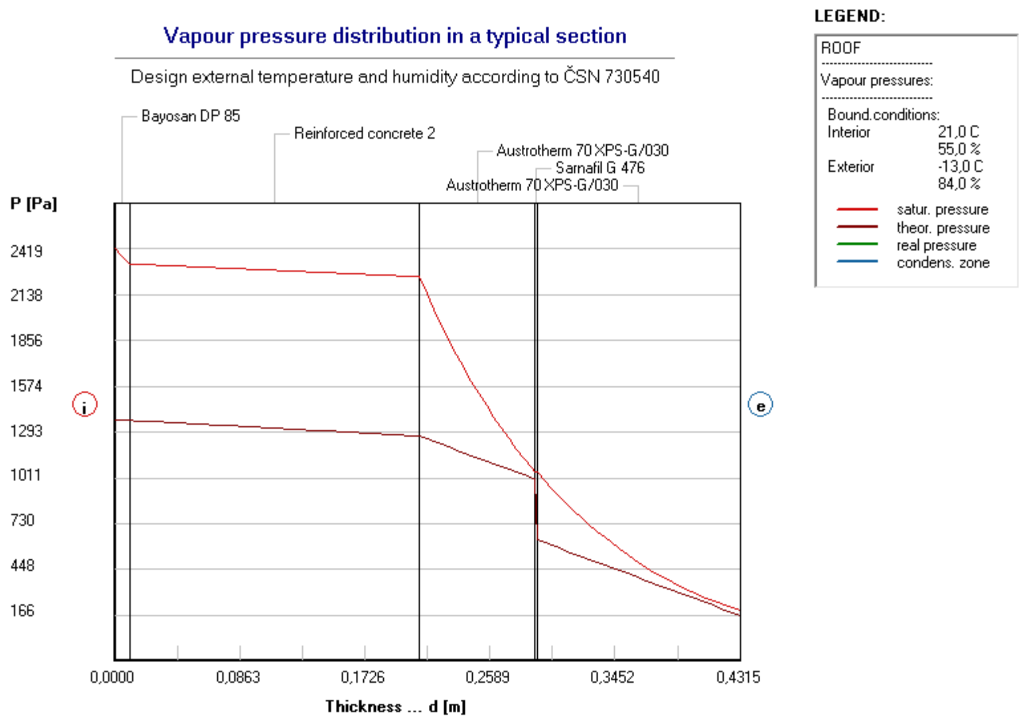
Požadavky:
1. Kondenzace vodní páry nesmí ohrozit funkci konstrukce.
2. Roční množství kondenzátu musí být nižší než roční kapacita odparu.
3. Roční množství kondenzátu Mc,a musí být nižší než 0,1 kg/m2.rok, nebo 3-6% plošné hmotnosti materiálu (nižší z hodnot).

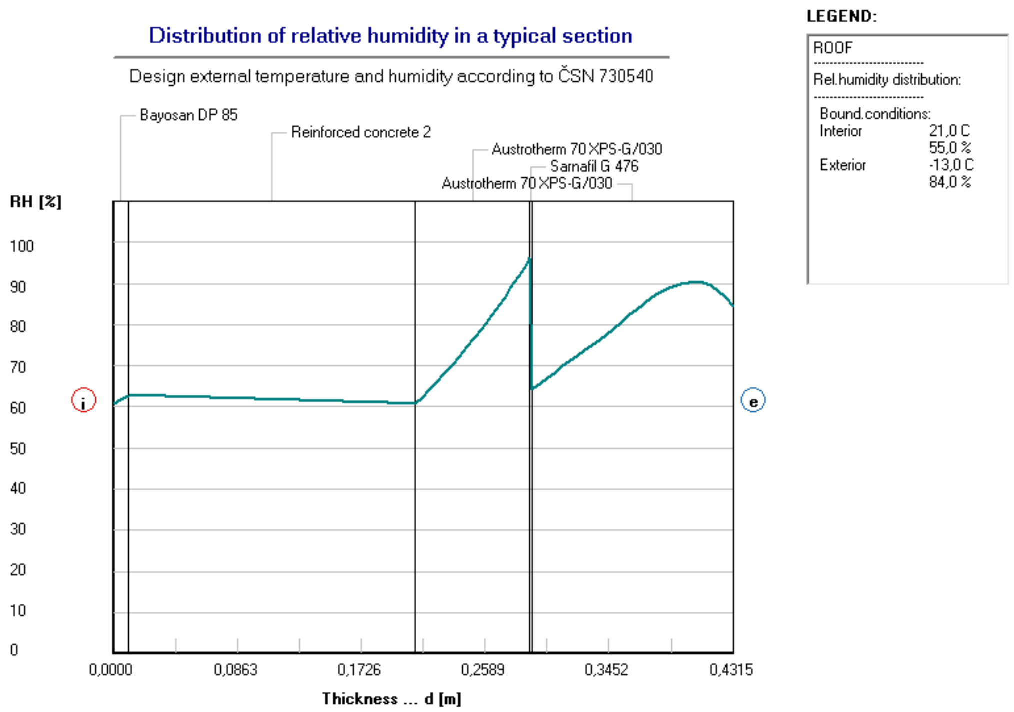
Vypočtené hodnoty: V kci nedochází při venkovní návrhové teplotě ke kondenzaci.

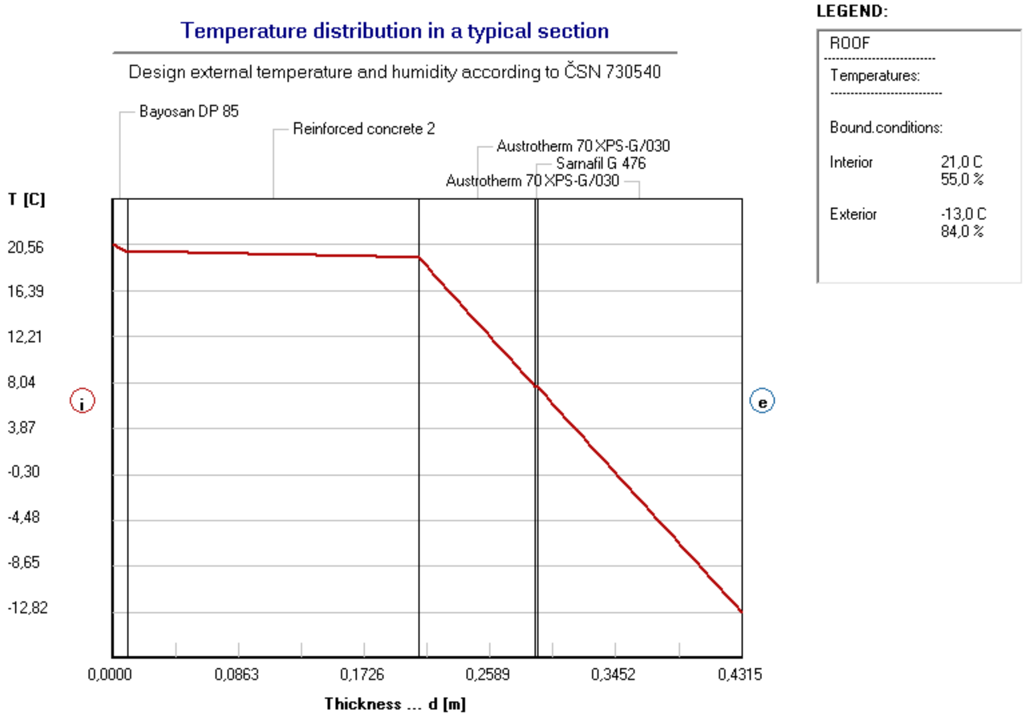
V konstrukci nedochází během modelového roku ke kondenzaci.

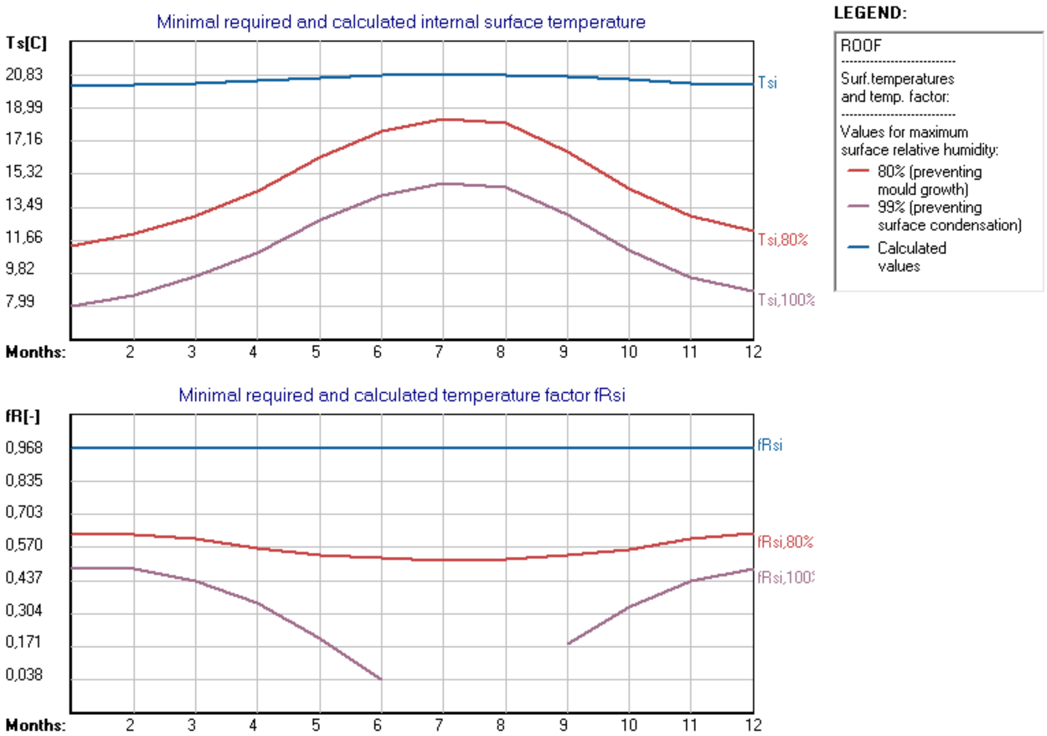
POŽADAVKY JSOU SPLNĚNY.

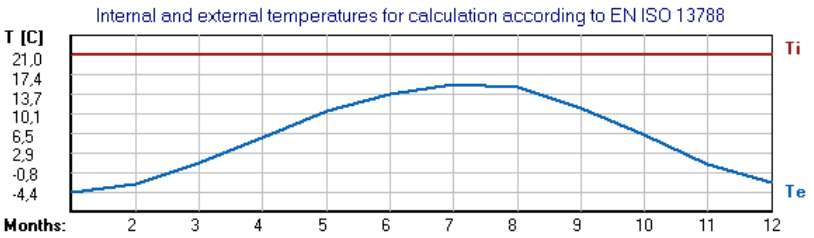
LINE GRAPHS

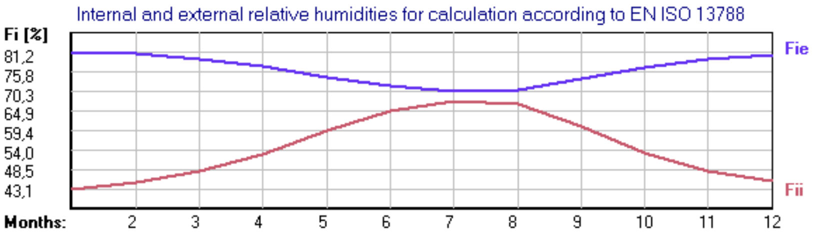

Vapour pressure distribution in a typical section
Design external temperature and humidity according to ČSN 730540
Bayosan DP 85
Reinforced concrete 2
Austrotherm 70 XPS-G/030
Sarnafil G 476
Austrotherm 70 XPS-G/030
P [Pa]
2419
2138
1856
1574
1293
1011
730
448
166
i
e
0,0000
0,0863
0,1726
0,2589
0,3452
0,4315
Thickness ... d [m]
LEGEND:
ROOF
Vapour pressures:
Bound.conditions:
Interior 21,0 C
55,0 %
Exterior -13,0 C
84,0 %
satur. pressure
theor. pressure
real pressure
condens. zone

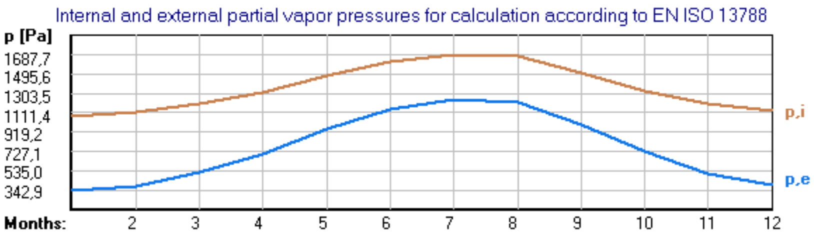

Distribution of relative humidity in a typical section
Design external temperature and humidity according to ČSN 730540
Bayosan DP 85
Reinforced concrete 2
Austrotherm 70 XPS-G/030
Sarnafil G 476
Austrotherm 70 XPS-G/030
RH [%]
100
90
80
70
60
50
40
30
20
10
0
i
e
0,0000
0,0863
0,1726
0,2589
0,3452
0,4315
Thickness ... d [m]
LEGEND:
ROOF
Rel.humidity distribution:
Bound.conditions:
Interior 21,0 C
55,0 %
Exterior -13,0 C
84,0 %


Temperature distribution in a typical section
Design external temperature and humidity according to ČSN 730540
Bayosan DP 85
Reinforced concrete 2
Austrotherm 70 XPS-G/030
Sarnafil G 476
Austrotherm 70 XPS-G/030
T [C]
20,56
16,39
12,21
8,04
3,87
-0,30
-4,48
-8,65
-12,82
i
e
0,0000
0,0863
0,1726
0,2589
0,3452
0,4315
Thickness ... d [m]
LEGEND:
ROOF
Temperatures:
Bound.conditions:
Interior 21,0 C 55,0 %
Exterior -13,0 C 84,0 %


Minimal required and calculated internal surface temperature
Ts[C]
20,83
18,99
17,16
15,32
13,49
11,66
9,82
7,99
Tsi
Tsi,80%
Tsi,100%
Months: 2 3 4 5 6 7 8 9 10 11 12
Minimal required and calculated temperature factor fRsi
fR[-]
0,968
0,835
0,703
0,570
0,437
0,304
0,171
0,038
fRsi
fRsi,80%
fRsi,100%
Months: 2 3 4 5 6 7 8 9 10 11 12
LEGEND:
ROOF
Surf.temperatures and temp. factor:
Values for maximum surface relative humidity:
80% (preventing mould growth)
99% (preventing surface condensation)
Calculated values







LEGEND:

ROOF

Bound.conditions:

Number of years: 1
Starting month: 1

5. PRELIMINARY DESIGN OF CONCRETE COLUMN-BEAM SYSTEM

5.1 Reinforced concrete slab

5.1.1 Effective depth of cross-section

$$d_s \geq \frac{l}{k_{c1} \cdot k_{c2} \cdot k_{c3} \cdot \lambda_{d,TAB}}$$

l	Maximum length of span = 5,94m
k_{c1}	Coefficient of rectangular cross-sections = 1,0
k_{c2}	Coefficient of span (l <7m) = 1,0
k_{c3}	Coefficient of stress in tensile reinforcement = 1,2
$\lambda_{d,TAB}$	Interior span of continuous beam in two-way spanning continuous slab (Strengh class C30/37, reinforcement radio 0,5%) = 30,8

$$d_s \geq \frac{5,94}{1,0 \cdot 1,0 \cdot 1,2 \cdot 30,8} = 0,1607 \text{ m}$$

5.1.2 Cross-section depth

$$h_s = d_s + \text{c} + \frac{\emptyset}{2}$$

d_s	Effective depth of cross-section = 0.1607 m
c	Concrete cover (20-25 cm) =0,023 m
$\emptyset$	Assumed bar diameter for slab =12mm

$$h_s = 0,1607 + 0,023 + \frac{0,012}{2} = 0.1897 \text{ m} \approx \textbf{200 mm}$$

5.2 Reinforced concrete beam

5.2.1 Dimensions of cross-section

$$\text{h}_b = \left(\frac{1}{12} \div \frac{1}{8}\right) \cdot l_b$$

$$\text{w}_b = \left(\frac{1}{3} \div \frac{1}{2}\right) \cdot h_b$$

l_b	Beam span
h_b	Cross-section depth
w_b	Cross-section width

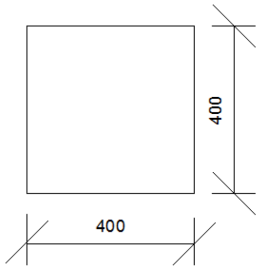
$$h_{b1} = \frac{1}{12} \cdot 5,94 \text{ m} = 0,495 \text{ m} ; \quad h_{b2} = \frac{1}{8} \cdot 5,94 \text{ m} = 0,7425 \text{ m} \rightarrow h_b = 550\text{mm}$$

$$w_{b1} = \frac{1}{3} \cdot 0,55 = 0,1833 \text{ m} ; \quad w_{b2} = \frac{1}{2} \cdot 0,55 = 0,275 \text{ m} \rightarrow w_b = 200\text{mm}$$

$I = \frac{b \cdot h^2}{12} = \frac{0{,}20 \cdot 0{,}55^2}{12} = 5{,}04 \cdot 10^{-3}\ \mathrm{m}^3$

Assuming 0,40x0,40 m as dimensions for the beam:

$5{,}04 \cdot 10^{-3} = \frac{1}{12} \cdot 0{,}40 \cdot h^2$; $h = 0{,}388\ m \approx$ **400 mm**



5.2.2 Load acting in the beam

- *Dead load (DL)*

Flooring (1 cm) -------------- 18 kN/m^3 ; 18 · 0,01	0,18
Concrete layer (4 cm) ------ 22 kN/m^3 ; 22 · 0,04	0,88
Insulation (2 cm) ------------ 0,02 kN/m^3 ; 0,02 · 0,02	0,0004
	1,060 kN/ m^2

Self-weight of the slab = 0,20 · 25 kN/m^3= 5 kN/ m^2

DL (g_k)= 1,060 + 5 = 6,060 kN/ m^2

DL (g_d)= 6,060 · 1,35= 8,181 kN/ m^2

- *Live load (LL)*

Apartments purpose= 2,5 kN/ m^2 (q_k)

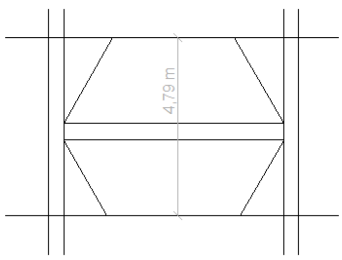
LL (q_d)= 2,5 · 1,5 = 3,75 kN/ m^2

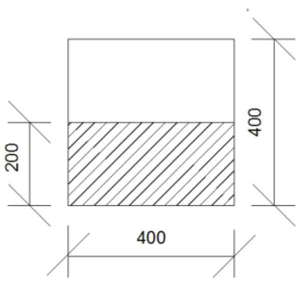
- *Total load (TL)*

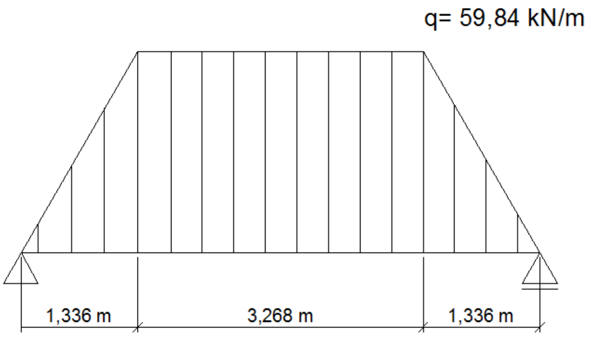
TL= (DL + LL) · b + self-weight of the beam;

TL= [(8,181kN/ m^2 + 3,75kN/ m^2) · 4,79m] + [0,40m · (0,40m – 0,20m) · 25kN/m^3] · 1,35

TL= 59,84 kN/m







$M = \frac{q}{24}(3l^2 - 4a^2) = \frac{59,84}{24}(3 \cdot 5.94^2 - 4 \cdot 1,336^2)$= 246,11 kN·m

R $= \frac{1}{2} q(l - a)$ = 0,5 · 59,84 (5,94 - 1,336) = 137.75 kN

5.2.3 Verification according to maximum bending moment

$$d_b = h_b - c - \emptyset_{sw} - \frac{\emptyset}{2}$$

f_{cd}	Design value of compressive concrete strength = $\frac{40}{1,5}$ = 26,6
c	Concrete cover = 25 mm
$\emptyset$	Assumed flexural reinforcement diameter = 18mm
$\emptyset_{sw}$	Assumed stirrups diameter = 10 mm

$$d_b = h_b - c - \emptyset_{sw} - \frac{\emptyset}{2} = 400 - 25 - 10 - \frac{18}{2} = 356 \text{ mm}$$

$$\mu = \frac{M_{Ed,max}}{w_b \cdot d_{b^2} \cdot f_{cd}} = \frac{246{,}11 \cdot 10^6}{400 \cdot 356^2 \cdot 26{,}6} = 0{,}182$$

Using the table, I determine ξ (ξ should be in a range 0,15 – 0,4):

ξ = 0,250 √

5.2.4 Verification according to shear force

$$v_{RD,max} = v \cdot f_{cd} \cdot w_b \cdot \zeta \cdot d_b \cdot \frac{\cot\theta}{1+\cot^2\theta}$$

v	$0{,}6\ (1\text{-}\frac{f_{ck}}{250}) = 0{,}6\ (1\text{-}\frac{40}{250}) = 0{,}504$
f_{cd}	Design value of compressive concrete strength $= \frac{40}{1{,}5} = 26{,}6\ \frac{N}{mm^2}$
ζ	0,900 (from the table)
$cot\ \theta$	Assumed flexural reinforcement diameter = 18mm

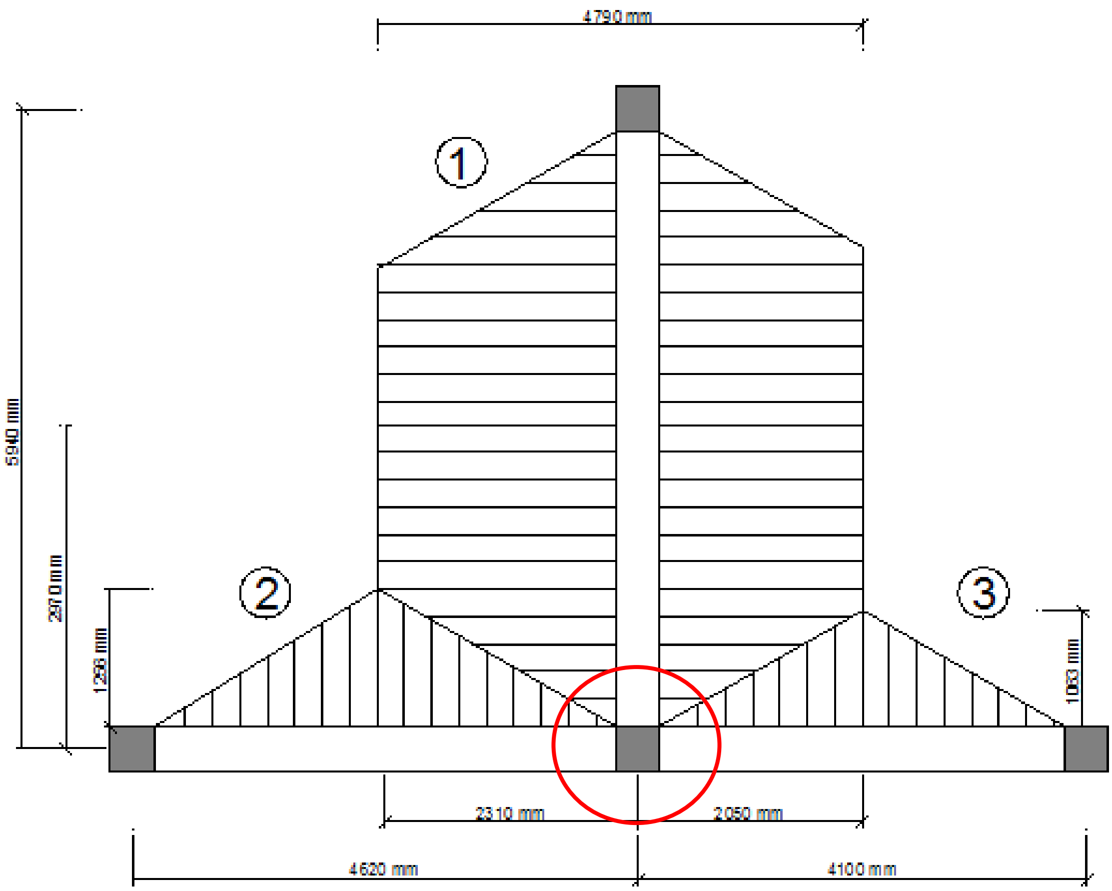
$v_{RD,max} = 0{,}504 \cdot\ 26{,}6 \cdot\ 400 \cdot\ 0{,}900 \cdot\ 400 \cdot\ \frac{1{,}3}{1+1{,}3^2} = 932960\ \text{N} = 932{,}96\ \text{kN}$

$v_{ED,max}\ \leq\ v_{RD,max}\ ;$

$137{,}75\ kN\ \leq\ 932{,}96\ kN\ \surd$

5.3 Reinforced concrete column

5.3.1 Determination of maximum point load



- *Self-weight*

Column ----- (0,3m · 0,3m · 3,05m · 25 kN/m^3) x 4 floors = 27,45 kN

Beam 1 ----- Already included and calculated before

Beam 2 ----- (0,4m · 0,4m · 2,310m · 25 kN/m^3) x 4 floors = 36,96 kN

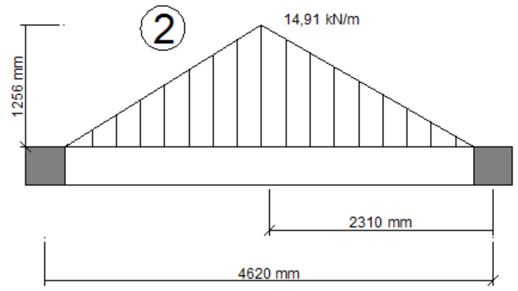
Beam 3 ----- (0,4m · 0,4m · 2,050m · 25 kN/m^3) x 4 floors = 32,8 kN

97,21 kN

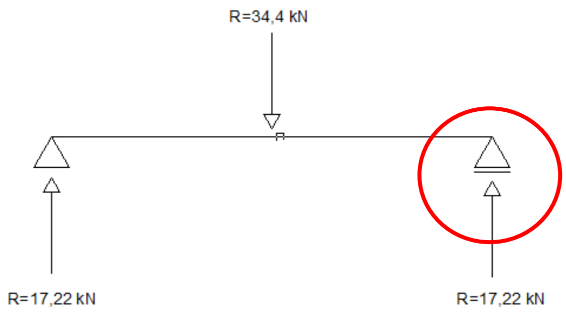
- *Load acting on the column from beams*

1- The reaction was calculated above: R=137,75 kN
Total for 4 floors: 137,75 · 4 = 551 kN

2- $(DL + LL) \cdot b = (8,181\ kN/m^2 + 3,75\ kN/m^2) \cdot 1,256\ m = 14,91\ kN/m$

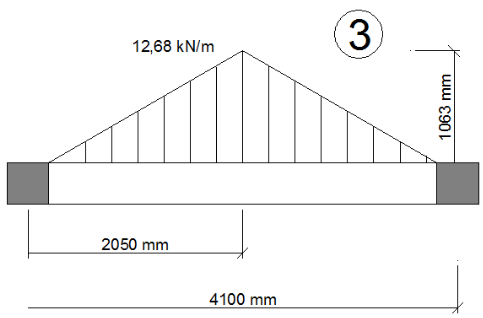


$(14,91\ kN/m \cdot 4,62\ m)\ /\ 2 = 34,4\ kN$

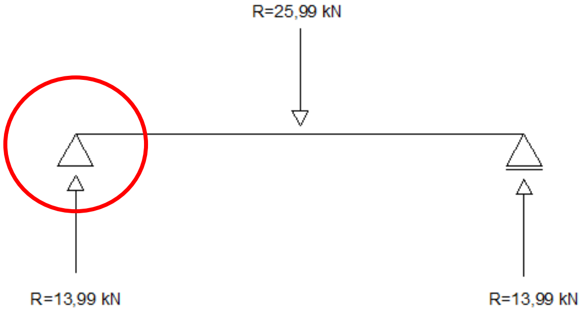


Total for 4 floors = 68,88 kN

3- $(DL + LL) \cdot b = (8,181\ kN/m^2 + 3,75\ kN/m^2) \cdot 1,063\ m = 12,68\ kN/m$



$$(12{,}68\ kN/m \cdot 4{,}1m)\ /\ 2 = 25{,}99\ kN$$



Total for 4 floors = 103,96 kN

- *TOTAL LOADING ACTING IN THE COLUMN* (N_{ed})
  Selfweight + 1 + 2 + 3 =97,21 + 551 + 68.88 + 103.96 =723.84 kN

5.3.2 Verification

$$\frac{N_{Ed}}{(0{,}8 \cdot\ f_{cd} +\ \rho \cdot \sigma_s)} \leq Ac$$

N_{Ed}	Maximum point load acting on proposed column = $723.84 \cdot 10^3$ N
f_{cd}	Design value of compressive concrete strength = $\frac{40}{1{,}5} = 26{,}6$
A_c	Cross-section area = $0{,}09\ m^2$
ρ	Reinforcement ratio (1-3%) = 3%
σ_s	Stress in reinforcement = 400 MPa

$$\frac{723{,}84 \cdot 10^3 N}{(0{,}8 \cdot\ 26{,}6 \cdot 10^6 +\ 0{,}03 \cdot 400 \cdot 10^6)} \leq 0{,}09$$

$0{,}021\ \leq 0{,}09$ √

As we have a column 30x30 cm we will change the cross-section of the beam from 40x40 to 30x40 cm. We will make sure that the verification is OK.

5.4 Verifications

5.4.1 Verification according to maximum bending moment (beam)

$$d_b =\ h_b - c - \emptyset_{sw} - \frac{\emptyset}{2}$$

f_{cd}	Design value of compressive concrete strength = $\frac{40}{1{,}5} = 26{,}6$
c	Concrete cover = 25 mm
$\emptyset$	Assumed flexural reinforcement diameter = 18mm
$\emptyset_{sw}$	Assumed stirrups diameter = 10 mm

$d_b = h_b - c - \emptyset_{sw} - \frac{\emptyset}{2} = 400 - 25 - 10 - \frac{18}{2} = 356$ mm

$\mu = \frac{M_{Ed,max}}{w_b \cdot d_{b^2} \cdot f_{cd}} = \frac{246{,}11 \cdot 10^6}{300 \cdot 356^2 \cdot 26{,}6} = 0{,}243$

Using the table, we determine ξ (ξ should be in a range 0,15 – 0,4):

ξ = 0,352 √

5.4.2 Verification according to shear force

$$v_{RD,max} = v \cdot f_{cd} \cdot w_b \cdot \zeta \cdot d_b \cdot \frac{\cot\theta}{1+\cot^2\theta}$$

v	$0{,}6\ (1-\frac{f_{ck}}{250}) = 0{,}6\ (1-\frac{40}{250}) = 0{,}504$
f_{cd}	Design value of compressive concrete strength $= \frac{40}{1{,}5} = 26{,}6\ \frac{N}{mm^2}$
ζ	0,861 (from the table)
$cot\ \theta$	Assumed flexural reinforcement diameter = 18mm

$v_{RD,max} = 0{,}504 \cdot 26{,}6 \cdot 300 \cdot 0{,}861 \cdot 356 \cdot \frac{1{,}3}{1+1{,}3^2} = 595768$ N = 595,768 kN

$v_{ED,max} \leq v_{RD,max}$;

$137{,}75\ kN \leq 595{,}768\ kN$ √

5.5 Preliminary design of foundation

Soil bearing capacity:

Type of Soil / Rock	Safe Bearing Capacity (kg/cm²)
Rock	32.40
Soft rock	4.40
Coarse sand	4.40
Medium sand	2.45
Fine sand	4.40
Soft shell / Stiff clay	1.00
Soft clay	1.00
Very soft clay	0.50

$$A = \frac{N_{ed}}{SBC} = \frac{723{,}84\ kN}{245\ kN/m^2} = 2{,}95\ m^2$$

Square footings will be the system used for our foundation. Each side will measure: $\sqrt{2{,}95} = 1{,}71\ m$

5.6 Flexural reinforcement (negative moment)

5.6.1 Data specification

$M_{Ed} = 246{,}11 \cdot 10^6 N$ *(design value of bending moment)*

$b = 300\ mm$ *(beam width)*

$h_b = 400\ mm\ (cross - section\ depth)$

$c = 25\ mm\ (concrete\ cover)$

$\emptyset_{sw} = 10\ mm\ (\ stirrups\ diameter)$

$f_{yk} = 500\ MPa\ (characterisctic\ yield\ strength\ of\ reinforcement)$

$f_{yd} = 434\ MPa\ (design\ yield\ strength\ of\ reinforcement)$

$f_{cd} = 26{,}6\ MPa\ (design\ compression\ strength\ of\ concrete)$

$f_{ctm} = 2{,}80\ MPa\ (mean\ tensile\ strength\ of\ concrete)$

5.6.2 Preliminary design

$d = h_b - c - \emptyset_{sw} - \frac{\emptyset}{2} = 400 - 25 - 10 - \frac{18}{2} = 356$ mm (effective cross – section depth)

$\mu = \frac{M_{Ed,max}}{b \cdot d^2 \cdot f_{cd}} = \frac{246{,}11 \cdot 10^6}{300 \cdot 356^2 \cdot 26{,}6} = 0{,}243$

Using the table, we determine ζ:

$\zeta = 0.861$ √

$A_{s,req} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{246{,}11}{0{,}861 \cdot 0{,}356 \cdot 434 \cdot 10^3} = 0{,}001850\ m^2 = 1850\ mm^2$

$$A_{s,min} = max \begin{cases} 0{,}26 \cdot \frac{f_{ctm}}{f_{yk}} \cdot b \cdot d = 0{,}26 \cdot \frac{2{,}80}{500} \cdot 300 \cdot 356 = 155{,}50\ mm^2 \\ 0.0013 \cdot b \cdot d = 0{,}0013 \cdot 300 \cdot 356 = 138{,}84\ mm^2 \end{cases}$$

$A_{s,min} = 155{,}50\ mm^2$

$A_{s,max} = 0{,}04 \cdot b \cdot d = 0{,}04 \cdot 300 \cdot 356 = 4272\ mm^2$

$$S_{a,max} = min \begin{cases} 2 \cdot h_b = 2 \cdot 400 = 800\ mm \\ 250\ mm \end{cases}$$

$S_{a,max} = 250\ mm$ (axial spacing of rebars)

$$S_{c,min} = max \begin{cases} 20\ mm \\ 1{,}2 \cdot \emptyset_{assummed} = 1{,}2 \cdot 1{,}6 = 19{,}2\ mm \end{cases}$$

$S_{c,min} = 20\ mm$ (clear spacing of rebars)

AREA OF 1 REBAR ($\emptyset 25mm$)

$As_{1,25} = \frac{\pi \cdot 25^2}{4} = 490{,}87\ mm^2$

$\#$ bars $= \frac{As,req}{A_{s,1,25}} = \frac{1825}{401} = 4{,}61 \sim 5\ bars$

$S_a = \frac{b - 2c}{\#\ rebar - 1} = \frac{300 - 2 \cdot 40}{5 - 1} = 55\ mm$

$S_c = S_a - \emptyset = 55 - 25 = 30\ mm$

$S_a < S_{a,max} \rightarrow 55mm < 250\ mm$ √

$S_c > S_{c,min} \rightarrow 30mm > 20\ mm$ √

$A_{s,min}\ and\ A_{s,req} < A_{s,prov} < A_{s,max}$

$155{,}50\ mm^2\ and\ 1850\ mm^2 < 2454{,}35\ mm^2 < 4272\ mm^2$

Therefore, we will use the follow combination 5Ø25@55mm

5.6.3 Detailed verification

$A_{s,prov} = 490{,}87 \cdot 5 \text{ bars} = 2454{,}35 \text{ mm}^2$

$d_{prov} = h_b - c \; - \emptyset_{sw} - \frac{\emptyset prov}{2} = 400 - 40 - 10 - \frac{25}{2} = 337{,}5 \; mm^2$

$x = \frac{A_{s,prov} \cdot f_{yd}}{0{,}8 \cdot b \cdot f_{cd}} = \frac{2454{,}35 \cdot 434}{0{,}8 \cdot 400 \cdot 26{,}6} = 125{,}13 \; mm$

$\xi = \frac{x}{d_{prov}} = \frac{125{,}13}{337{,}5} = 0{,}370 \; < 0{,}45$

z= $d_{prov} - 0{,}4x = 337{,}5 - 0{,}4(125{,}13) = 287{,}44mm$

$M_{Rd} = A_{s,prov} \cdot f_{yd} \cdot z = 2454{,}35 \cdot 434 \cdot 287{,}44 = 306{,}17 \; kN \cdot m$

$M_{Rd} \; > \; M_{Ed}$

$306{,}17 \; > 246{,}11$ √

5.7 Flexural reinforcement (positive moment)

5.7.1 Data specification

$M_{Ed} = 246{,}11 \cdot 10^6 N$ *(design value of bending moment)*

$h_b = 400 \; mm \; (cross - section \; depth)$

$c = 25 \; mm \; (concrete \; cover)$

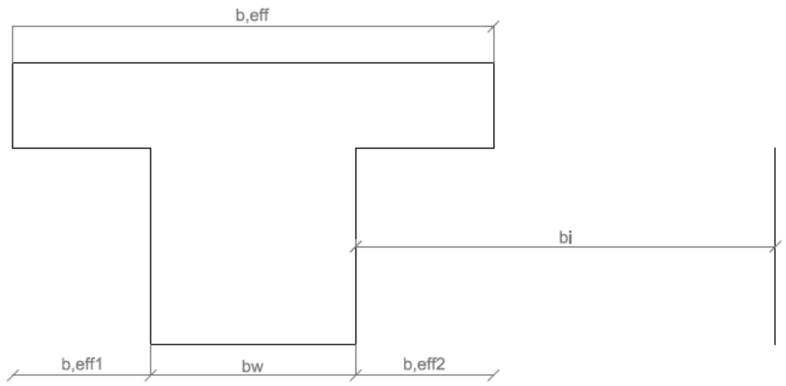
$\emptyset_{sw} = 10 \; mm \; (\; stirrups \; diameter)$

$f_{yk} = 500 \; MPa \; (characterisctic \; yield \; strength \; of \; reinforcement)$

$f_{yd} = 434 \; MPa \; (design \; yield \; strength \; of \; reinforcement)$

$f_{cd} = 26{,}6 \; MPa \; (design \; compression \; strength \; of \; concrete)$

$f_{ctm} = 2{,}80 \; MPa \; (mean \; tensile \; strength \; of \; concrete)$



$b_W = 0{,}30$
$b_{l1} = 4{,}32$
$b_{l2} = 3{,}77$
$l_{b1} = 4{,}62$
$l_{b2} = 4{,}075$
$l_{01} = 0{,}7 \cdot l_{b1} = 3{,}23$
$l_{02} = 0{,}7 \cdot l_{b2} = 2{,}85$

$b_{eff} = b_w + \Sigma b_{effi}$

$b_{eff1} = 0{,}2 \cdot b_{i1} + 0{,}1 \cdot l_{01} \leq 0{,}2 \cdot l_{01}$

$b_{eff1} = 0{,}2 \cdot 4{,}32 + 0{,}1 \cdot 3.23 \leq 0{,}2 \cdot 3{,}23$

$b_{eff1} = 1{,}187 \leq 0{,}646$ *INCORRECT, SO WE WILL TAKE THE MINIMUM ONE*

$b_{eff1} = 0{,}646$

$b_{eff2} = 0{,}2 \cdot b_{i2} + 0{,}1 \cdot l_{02} \leq 0{,}2 \cdot l_{02}$

$b_{eff2} = 0{,}2 \cdot 3{,}77 + 0{,}1 \cdot 2{,}85 \leq 0{,}2 \cdot 2{,}85$

$b_{eff2} = 1{,}039 \leq 0{,}646$ *INCORRECT, SO WE WILL TAKE THE MINIMUM ONE*

$b_{eff2} = 0{,}646$

$b_{eff} = 0{,}30 + 0{,}646 + 0{,}646 = 1.592$

5.7.2 Preliminary design

$d = h_b - c - \emptyset_{sw} - \frac{\emptyset}{2} = 400 - 25 - 10 - \frac{18}{2} = 356$ mm (effective cross – section depth)

$\mu = \frac{M_{Ed,max}}{\text{beff} \cdot \text{d}^2 \cdot f_{cd}} = \frac{246{,}11 \cdot 10^6}{1592 \cdot 356^2 \cdot 26{,}6} = 0{,}0458$

Using the table, we determine ζ:

ζ = 0.977 √

$A_{s,req} = \frac{M_{Ed}}{\zeta \cdot \text{d} \cdot f_{yd}} = \frac{246{,}11}{0{,}977\ 0{,}356 \cdot 434 \cdot 10^3} = 0{,}00163\ m^2 = 1630\ mm^2$

$$A_{s,min} = max \begin{cases} 0{,}26 \cdot \frac{f_{ctm}}{f_{yk}} \cdot b \cdot d = 0{,}26 \cdot \frac{2{,}80}{500} \cdot 300 \cdot 356 = 155{,}50\ mm^2 \\ 0.0013 \cdot b \cdot d = 0{,}0013 \cdot 300 \cdot 356 = 138{,}84\ mm^2 \end{cases}$$

$A_{s,min} = 155{,}50\ mm^2$

$A_{s,max} = 0{,}04 \cdot b \cdot d = 0{,}04 \cdot 300 \cdot 356 = 4272\ mm^2$

$$S_{a,max} = min \begin{cases} 2 \cdot h_b = 2 \cdot 400 = 800\ mm \\ 250\ mm \end{cases}$$

$S_{a,max} = 250\ mm$ (axial spacing of rebars)

$$S_{c,min} = max \begin{cases} 20\ mm \\ 1{,}2 \cdot \emptyset_{assummed} = 1{,}2 \cdot 1{,}6 = 19{,}2\ mm \end{cases}$$

$S_{c,min} = 20\ mm$ (clear spacing of rebars)

AREA OF 1 REBAR ($\emptyset 25mm$)

$As_{1,25} = \frac{\pi \cdot 25^2}{4} = 490{,}87\ mm^2$

$\#\ \text{bars} = \frac{As,req}{As_{,1,25}} = \frac{1630}{490{,}87} = 3{,}32 \sim 4\ bars$

$S_a = \frac{b - 2c}{\#\ rebar - 1} = \frac{300 - 2 \cdot 40}{4 - 1} = 73\ mm$

$S_c = S_a - \emptyset = 73 - 25 = 48\ mm$

$S_a < S_{a,max} \rightarrow 55\text{mm} < 250\ mm$ √

$S_c > S_{c,min} \rightarrow 48\text{mm} > 20\ mm$ √

$A_{s,min}\ and\ A_{s,req} < A_{s,prov} < A_{s,max}$

$155{,}50\ mm^2\ and\ 1630\ mm^2 < 1963{,}48\ mm^2 < 4272\ mm^2$

Therefore, we will use the follow combination $4\emptyset 25@73mm$

5.7.2 Detailed verification

$A_{s,prov} = 490{,}87 \cdot 4 \text{ bars} = 1963{,}48 \text{ mm}^2$

$d_{prov} = h_b - c - \emptyset_{sw} - \frac{\emptyset prov}{2} = 400 - 40 - 10 - \frac{25}{2} = 337{,}5\ mm^2$

$$x = \frac{A_{s,prov} \cdot f_{yd}}{0{,}8 \cdot beff \cdot f_{cd}} = \frac{1963{,}48 \cdot 434}{0{,}8 \cdot 1592 \cdot 26{,}6} = 25{,}15mm$$

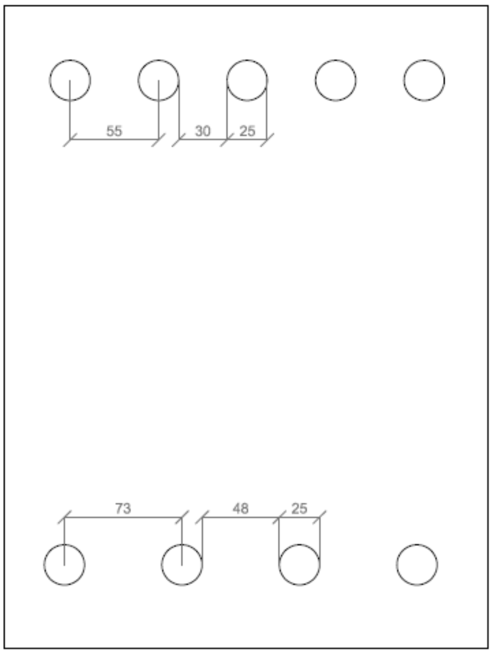
$\xi = \frac{x}{d_{prov}} = \frac{25{,}15}{337{,}5} = 0{,}074 < 0{,}45$

z= $d_{prov} - 0{,}4x = 337{,}5 - 0{,}4(25{,}15) = 327{,}44mm$

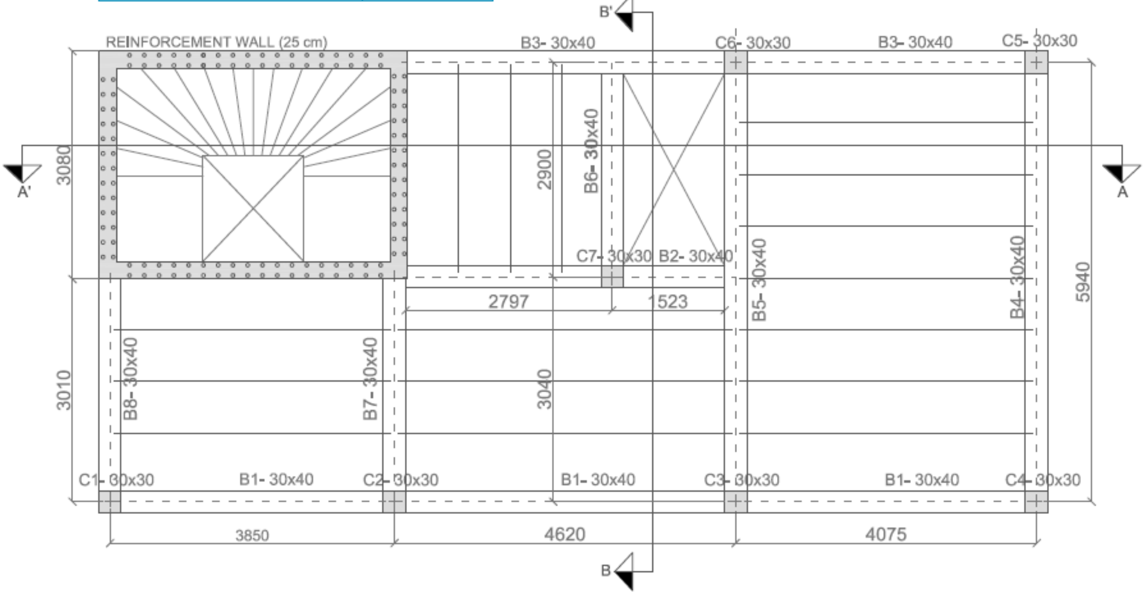
$M_{Rd} = A_{s,prov} \cdot f_{yd} \cdot z = 1963{,}48 \cdot 434 \cdot 327{,}44 = 279{,}02\ kN \cdot m$

$M_{Rd} > M_{Ed}$

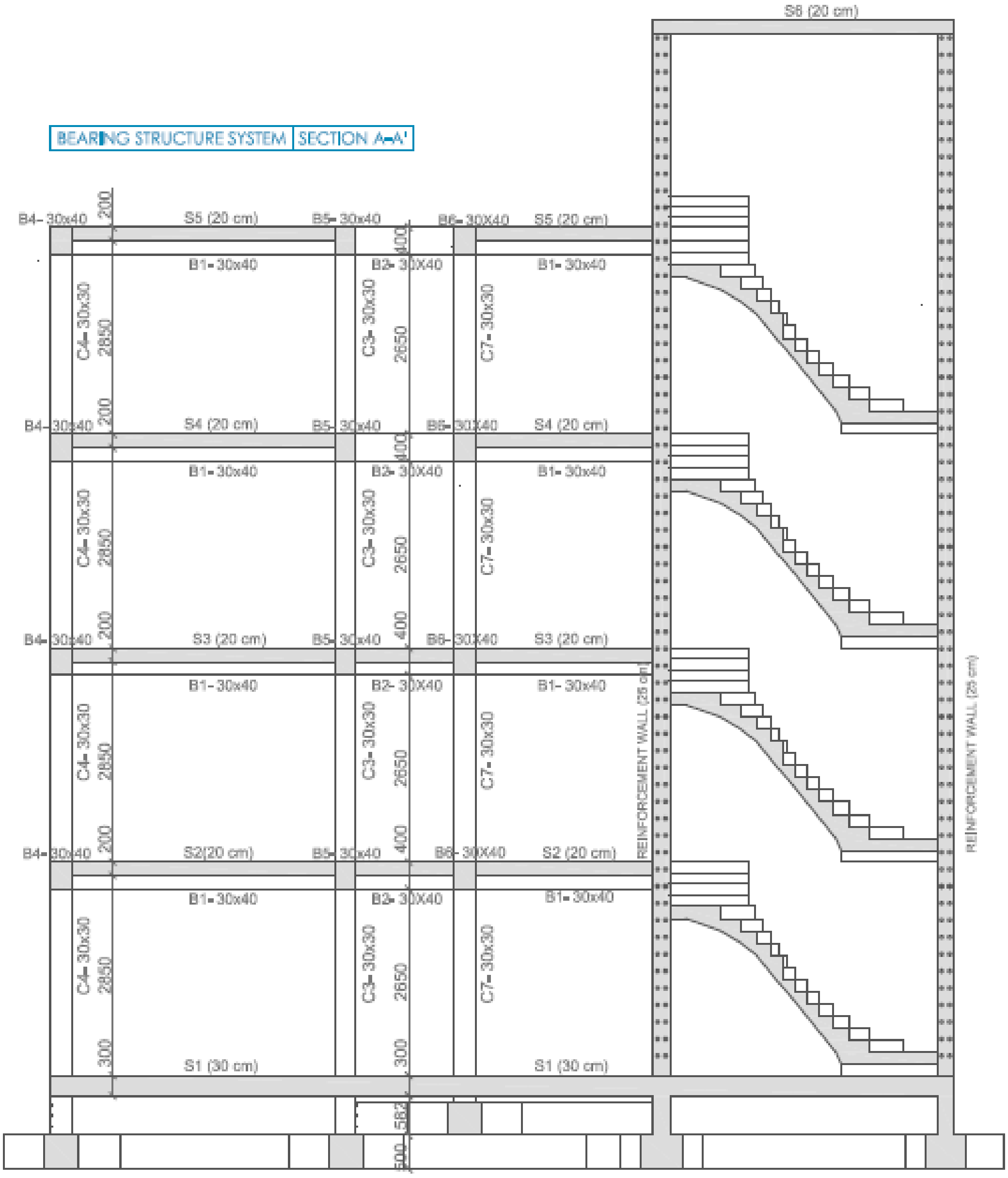
$279{,}02 > 246{,}11$ √



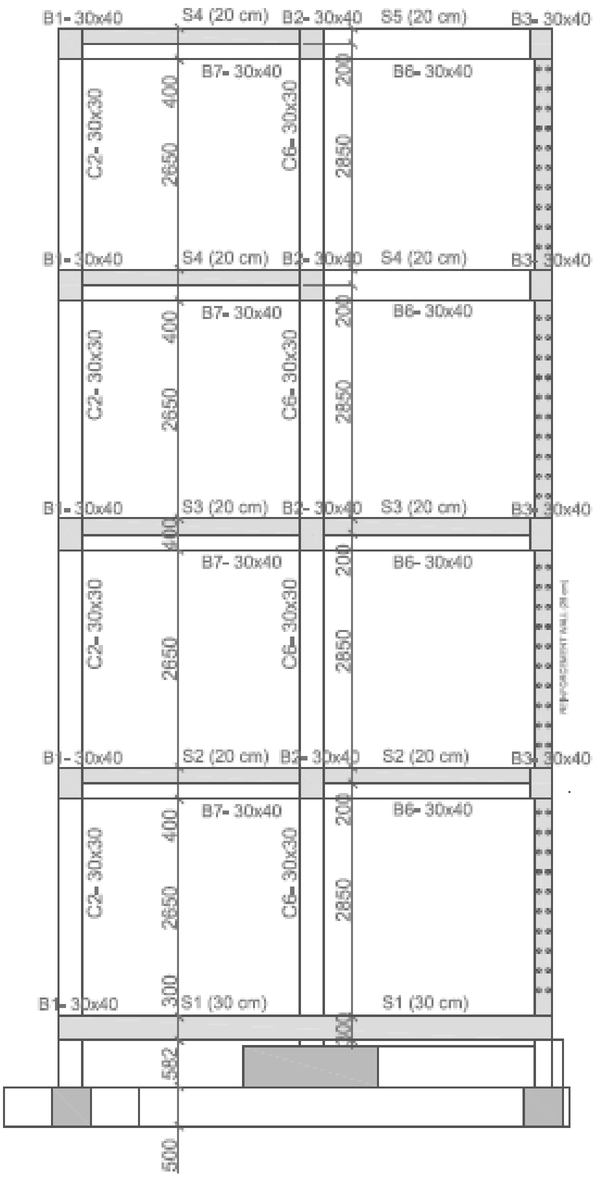
BEARING STRUCTURE SYSTEM | TYPE FLOOR



BEARING STRUCTURE SYSTEM | SECTION A-A'



BEARING STRUCTURE SYSTEM | SECTION B-B'



6. FINAL COMMENTS

CONCLUSION

Column was added at the end, after make all the calculation, to solve the connection between beam-column in the open space. Therefore, the predesign of elements are more than acceptable with this addition.

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