CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF CIVIL ENGINEERING
Department Of Building Structures

Master's Thesis

Structural Project Of Dwelling House

Supervisor: doc. Ing. František Kulhánek,CSc.

2018 Udham Singh

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DIPLOMA THESIS ASSIGNMENT FORM

I. PERSONAL AND STUDY DATA

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Assigning Department: K124

Study programme: Civil Engineering

Branch of study: Building Structures

II. DIPLOMA THESIS DATA

Diploma Thesis (DT) title: Structural Project of Dwelling House

Diploma Thesis title in English: Structural Project of Dwelling House

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

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: ___________________________

Acknowledgement:

I have taken efforts in this project. However, it would not have been possible without the kind support and assistance of many individuals. I would like to extend my sincere thanks to all of them.

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Abstract:

This master thesis work gives an insight into the typical construction practice adopted in Spain and Czech Republic for the construction of the dwelling houses. The thesis mainly revolves around the different bearing systems that can be chosen for the same type of building in Spain and in Czech Republic. The study is concentrated on selecting the most optimized bearing system that can be used in Czech Republic from the four possible ways depending on the building standards, convenient construction, safety and aesthetics.

The preliminary static calculations and staircase calculations have been done for all the four practical options. The Czech software *Teplo* is used to calculate the efficiency of the selected insulation for the external walls and the roof according to the Czech standards.

The drawings are made for all the four-structural bearing system. The architectural and structural drawings of ground floor plan, typical floor plan, roof plan, section of the building and details are prepared to the scale 1:50 for the most suited bearing system.

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

Abstrakt:

Diplomová práce poskytuje náhled do problematiky konstrukčního řešení obytného domu přizpůsobeného podmínkám v České republice a ve Španělsku. Práce se zabývá především různými nosnými systémy, které by mohly být použity pro stejný typ budovy v Čechách a ve Španělsku. Studie je zaměřena na nalezení nejoptimálnějšího nosného systému, který by mohl být použit v České republice z hlediska stavebních standardů, vhodné konstrukce, bezpečnosti a estetiky. Předběžné statické výpočty a výpočty schodiště byly provedeny pro všechny čtyři názorné možnosti. Pro výpočet efektivity navržené (dle českých standardů) tepelné izolace u obvodových konstrukcí a střechy byl použit program *Teplo.*

Výkresová dokumentace byla vyhotovena pro všechny čtyři nosné konstrukce. Pro nejvhodnější konstrukční systém byly rozkresleny architektonické a konstrukční výkresy přízemí, typického podlaží, střechy a řezu budovou v měřítku 1:50, detaily v měřítku 1:10.

klíčová slova: nosný konstrukční systém, tepelná izolace, české standardy, řez, půdorys, detail, optimalizovat, výkresy

Contents

1 Introduction:

Every human being has an inherent liking for a peaceful and safe living environment. From time immemorial men has been making efforts in improving their standard of living. The idea of this effort has been to provide an economic and efficient shelter. Nowadays the residential building construction is a major aspect to work for the social progress of the country. Everyday new techniques are being developed for the construction of houses economically, efficiently and fulfilling the design standards. With the emerging knowledge in scientific fields and the rise of new materials and technology, architecture engineering began to separate, and the architects began to concentrate on aesthetics and humanist aspects, often at the expense of technical aspects of the building.

Structural Engineers while designing a building must keep in mind the importance of culture and aesthetics but their main motive should be to design a building which is safe and provides the basic needs for living. The important parameters such as climate plays a huge role in the construction of a building, for example a building standard followed in south part of Spain cannot be followed in Prague, Czech Republic due to enormous difference in the climatic conditions.

The project will give an insight into the different bearing systems that can be adopted for the construction of a residential building of area (123.2 m^2) but at two separate locations with difference in climatic conditions and how the insulation plays an important part in the construction of a building. The design is supported with preliminary calculations of all the bearing systems, staircase design and insulation using Czech software *teplo*. The architectural and structural drawings are prepared for the most appropriate system.

1.1 Salient features:

Utility of building -	Residential building
Number of stories -	G+3
Number of apartments -	4
Type of apartment -	3+1

Type of construction - R.C.C framed construction
Types of wall - Brick Wall
Elevator - No
Insulation - Yes
Roof type - Flat roof
Ground floor - 2.6 m
Floor to floor height - 2.6 m
Depth of foundation - 1 m
Concrete grade - C30/37
Bearing capacity of soil - 5000 Psf

2 Load Bearing System:

The safety of the building depends on its load bearing system. Therefore, the load bearing system of a building should be strong to take all the dead load and live loads coming on the structure. The load bearing system in a residential building can mainly be of two types - load bearing wall system or Beam-column system. In this project the beam - column system is used for the design of the building. The four-different possibility of load bearing systems are explained below.

2.1 Load Bearing System–1:

This load bearing system is a typical system designed to be constructed in Spain. The columns are placed at maximum distance of 4.2 meters in one direction and at 3.8 m in the other direction and originally the size of the column was 200*400 mm. The preliminary calculation of the structure was done keeping the same position of the beams and columns and the sizes calculated for columns and beams were 200*200 mm and 200*300 mm respectively. The slab was calculated to be 175 mm. The stairs were supported by the beam column frame but due to the shape of the stairs it did not look to be best conceivable way available. This system had a decent size of the structural members, but it had considerable number of columns with respect to the size of the building. So, there was a possibility of reducing the number of columns by increasing the distance between them. The bearing structure plan and section can be seen in the annex c. As you will be able to see there are beams running below the slab in almost all the bedrooms and in the dinning and living area of the building which did not seemed a good option from the aesthetic point of view. Also, possibility of covering those beams was not possible as the floor to floor distance which is 2.6 m would decrease and it would appear to be very short distance between the clear floors. This drawback developed a necessity of thinking out a better option and this led to another system.

2.2 Load Bearing System-2:

This system led to the removal of the columns. The columns which were placed at 4.2 m were now place at 7m. Number of columns were certainly reduced. The preliminary calculation is done for this system which gave the sizes of the beams and columns as 250*550 mm and 250*450 mm respectively. The slab size increased numerously to 250 mm. This slab size was without providing and acoustic insulation and without considering other layers such as concrete layer and tiles layer. The generous size of the slab layers with came to 350 mm with all the other layers which was quiet a lot. This system even reduced the floor to floor distance to 2.1 m which was smaller than clear distance left in bearing system-1. There was a beam which was passing all the way through the living room and one of the bedrooms which did not looked pleasant. The staircase was supported by the beam column system as in the bearing system-1. The increase in the thickness of slab also meant that it is not an efficient system economically and there can be still a better option.

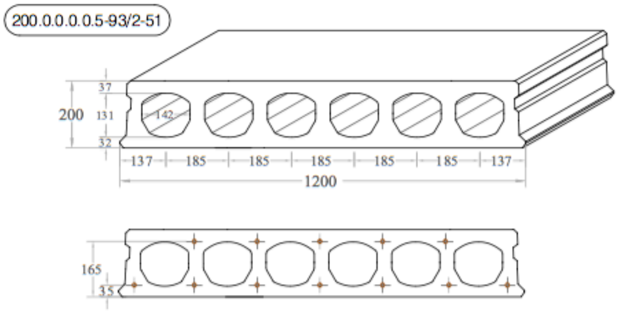
2.3 Load Bearing System-3:

In this system the columns are placed at an equal distance of 5.1 m and the staircase is supported by the reinforced concrete wall. The preliminary calculations for this system recommended size of beam and column as 250*500 mm and 250*300 mm respectively. The slab thickness was 200 mm. This system supported the staircase very well by the concrete wall. This system was better than the two in terms of overall stability of the system. The thickness of the beam was a little high and there was still beam running through the living area. There was a cantilever beam as result of the placement of the columns and the geometry of the structure which was not the best option to have. Though this system was the best one from the three, but it was still aesthetically not the best option and the cantilever beam was a problem. So, there was possibility of improving on these aspects with finding another structural system.

2.4 Load Bearing System-4:

In this system the staircase was supported by the reinforced cement concrete walls around the staircase area. The prestressed concrete panel of thickness 200 mm was used instead of monolithic slab. The idea of choosing the panel was that it would be economical as the estimated loads on the building was taken well by the panel of small thickness and it would save lot of construction time which would be economical for the project. **The properties of the panel can be seen from the table below:**

Table 1: Properties of panel



PRODUCTION DIMENSIONS

width - 1200mm
height - **200**mm

Date Issued:
March 2008

SELF WEIGHT

Own weight per linear metre 297.17 kgs/ l.m

Thickness of Panel - mm	Area mm^2	Centroid mm	Moments of Inertia mm^4	Radii of Gyration mm
200	137922	X - 600 Y - 100	I - 6.71×10^8 J - 1.63×10^{10}	X - 69.74 Y - 343.56

PRECAST PRESTRESSED CONCRETE PANELS - SAFE LOAD TABLES

SPAN	SAFE LOAD	MAX. SAFE SHEAR
2.00m (6.56ft)		
2.50m (8.20ft)		
3.00m (9.84ft)	2799.49kg/m^2 (573.34lbs/ft^2)	5.04Ton. per Panel
3.50m (11.48ft)	2364.30kg/m^2 (484.21lbs/ft^2)	4.97Ton. per Panel
4.00m (13.12ft)	2037.90kg/m^2 (417.36lbs/ft^2)	4.89Ton. per Panel
4.50m (14.76ft)	1784.04kg/m^2 (365.37lbs/ft^2)	4.82Ton. per Panel
5.00m (16.40ft)	1580.95kg/m^2 (323.78lbs/ft^2)	4.74Ton. per Panel
5.50m (18.05ft)	1414.78kg/m^2 (289.75lbs/ft^2)	4.67Ton. per Panel
6.00m (19.69ft)	1211.64kg/m^2 (248.14lbs/ft^2)	4.59Ton. per Panel
6.50m (21.33ft)	995.88kg/m^2 (203.96lbs/ft^2)	4.52Ton. per Panel
7.00m (22.97ft)	824.69kg/m^2 (168.90lbs/ft^2)	4.45Ton. per Panel
7.50m (24.61ft)	686.58kg/m^2 (140.61lbs/ft^2)	4.37Ton. per Panel
8.00m (26.25ft)	573.55kg/m^2 (117.46lbs/ft^2)	4.30Ton. per Panel
8.50m (27.89ft)	479.87kg/m^2 (98.28lbs/ft^2)	4.22Ton. per Panel
9.00m (29.53ft)	401.36kg/m^2 (82.20lbs/ft^2)	4.15Ton. per Panel
9.50m (31.17ft)	334.92kg/m^2 (68.59lbs/ft^2)	4.08Ton. per Panel
10.00m (32.81ft)	278.20kg/m^2 (56.98lbs/ft^2)	4.00Ton. per Panel
10.50m (34.45ft)	229.38kg/m^2 (46.98lbs/ft^2)	3.93Ton. per Panel

The Preliminary calculations are done taking panel as a slab for the building and the size of the beam and column are 250*300 mm and 250*250 mm respectively. The size of the column and beam were the most efficient one from all the system above. The panels act like a one-way slab supported on two beams. The selection of panels eliminated the beams running across the building and hence it was better from aesthetics point of view. If you refer to annex c in the plan of bearing system 4 you can see that due to the geometry of the building, the two panels must be supported by the wall on one side. The best suited bearing system is the bearing system 4 and the drawings are prepared for this system.

3 Structure:

3.1 Roof composition:

The roof is the top most part of the building which protects the building from rain, snow, heat, wind, sunlight etc. The roofs can be of different shapes depending on the location of the building and the usage of the building. The roof must be designed keeping in mind that its durability should be good as it is difficult to repair the roof especially the outer part which is exposed to outer climatic condition. The roof used in the project is flat and supported by the beam column system. As the building is designed for Czech Republic it must be well insulated to protect it against cold climate. The thickness of slab used in the roof is panel of 200 mm thickness. The insulation material used in the roof insulation is rock wool dachrock max of thickness 280 mm. The full detailed materials and calculations can be seen in Annex-B. The roof is provided with two pipes of 10 mm diameter for draining the water from the roof. The placement of the pipes is done according to the best possible place depending on the geometry of the roof. The roof is provided with a wall of thickness 150 mm on the edges for safety as it is walkable roof and insulation purpose. The roof slab above the staircase is 100 mm monolithic concrete slab as can be seen from the structural section and it has the same insulation as in roof. The roof of the staircase is provided with a small wall on the three edges for the insulation purpose and one edge is left fee for the water to drop in the pipe below.

3.2 Wall composition:

3.2.1 External walls:

The external wall used is a part of insulation of the building and is calculated with the insulation to check if it follows the Czech standards using software *teplo* and according to the standards the insulation is effective. The calculations done can be seen in the Annex B where there is all the result from the software. The thickness of the external wall is 240 mm. The different layers used for the insulation and their thickness can be seen from the Annex-B. The material used for the external wall is lime sand bricks.

3.2.2 Partition walls:

The partition walls are vertical structural element used to divide the area inside the building to appropriate rooms. Partition walls can be additionally used for various purpose such as load bearing, acoustic insulation etc. For this project partition walls are non-load bearing walls. The materials used for the partition wall is bricks. The partition walls are 150 mm thick.

3.2.3 Reinforced concrete wall:

The reinforced concrete wall is designed as a compression member which can be used to transfer load from the slab when beam is not provided. In this project it is used to support the staircase in bearing system 3 and 4. The thickness of reinforced wall is 240 mm.

3.3 Beams and columns:

A column is a compression member which is used mainly to support axial compressive loads and has a height at least three times more than its lateral dimension. A reinforced concrete column is said to be subjected to axial load when line of the resultant load supported by the column is coincident with the line of centre of gravity of the column in the longitudinal direction. Depending upon the architectural requirements and loads to be supported columns can be of different shapes i.e. square, rectangle and circular etc. The shape of the columns used in each system are of square or rectangular shape and it can be seen in the Annex-C from drawings or from Annex – A from calculations. The material used for columns is typical R.C.C.

Table 2: Column dimensions

Bearing System	Column dimensions (mm)
1	200*200
2	250*450
3	250*300
4	250*250

A beam is a horizontal structural member which transfer load from the slab to the columns. The beam is designed for bending when the load is applied laterally to the axis of the beam. The shape and size of the beams used are different for different bearing system. The dimensions of the beams can be seen from Annex – A from calculation of beams. The material used for the beam is the typical reinforced cement concrete.

Table 3: Beam dimensions

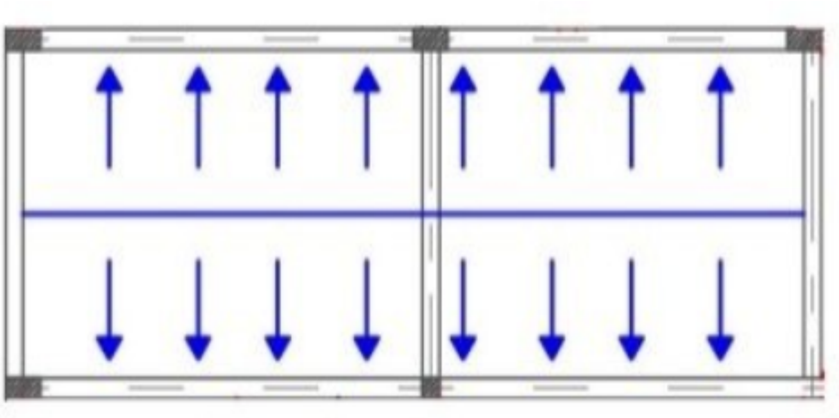
Bearing System	Beam dimensions (mm)
1	200*300
2	250*550
3	250*500
4	250*300

3.4 Slab:

Slab is a plate element forming floor and roof of the building carrying distributed loads primarily by flexure. The slabs can be of two types:

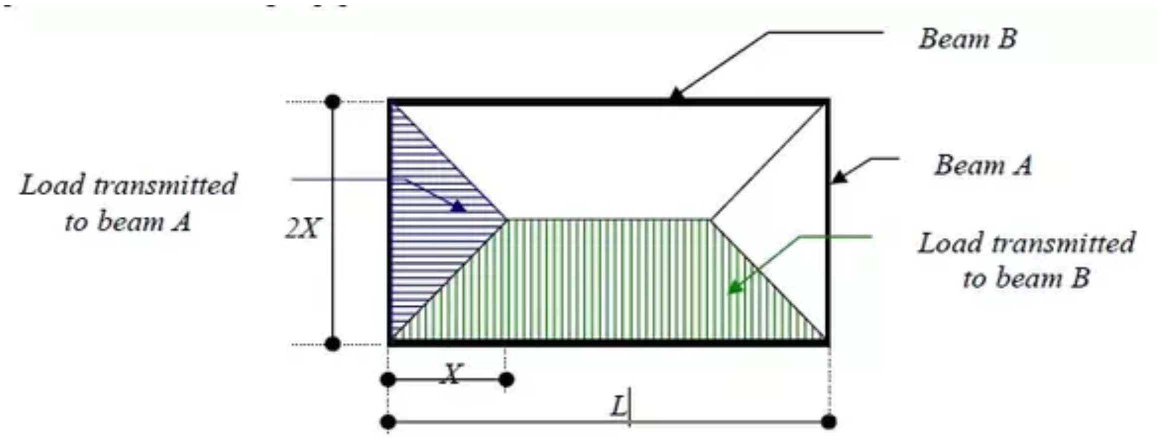
One-way slab: One-way slab are those in which the length is more than twice the breadth. One-way slab bend in one direction and transfer their load to two opposite beams. It can be simply supported beam or continuous beam.

Figure 1: Distribution of load in one-way slab



Two-way slab: Two-way slabs are supported on all the four sides and the ratio of the length to breadth is less than 2. The load is carried in both the directions. Therefore, main reinforcement is provided in both directions of two-way slab.

Figure 2: Distribution of load in two-way slab



The slabs used in the bearing system 1,2 and 3 are typical monolithic concrete slab which acts like a two-way slab. The slab used in the bearing system 4 is a prestressed panel of thickness 200 mm which acts as a one-way slab.

Table 4: Thickness of Slab

Bearing System	Slab Thickness (mm)
1	175
2	250
3	200
4	200

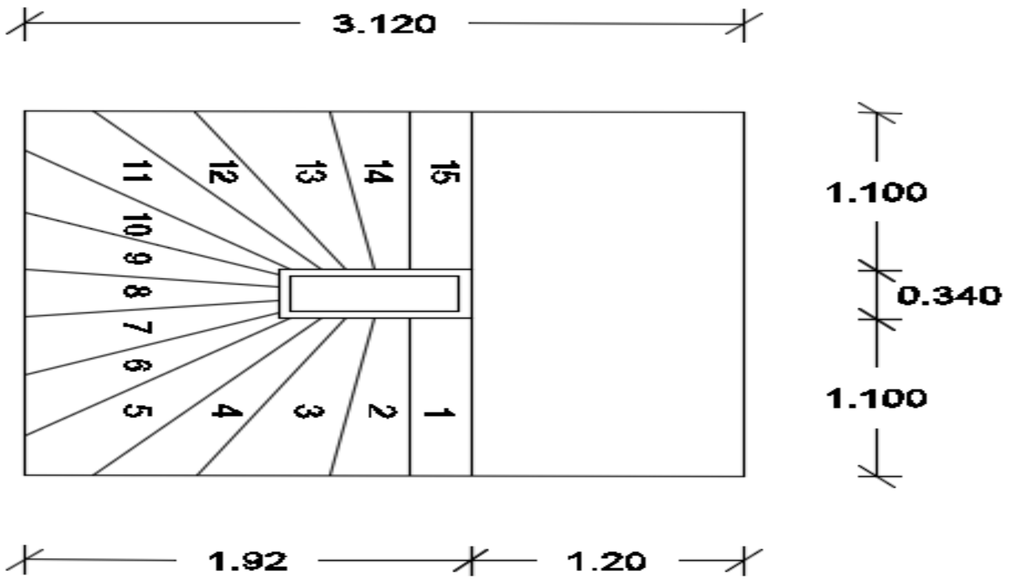
3.5 Stairs:

The staircase is designed to bridge a large vertical gap between floors by dividing it into smaller vertical equal steps. The stairs can be of different shapes such as straight, circular etc. The purpose of the staircase is to provide access to all the members living in the building. The shape and structural arrangement of the staircase depends on the two-main factor:

- Availability of space.
- Type of construction of structure around the staircase i.e. reinforced concrete wall, brick wall etc.

The staircase design can be referred from Annex A. Due to the availability of small space for the stairs the design of the stairs is circular.

Figure 3: Staircase design



3.6 Flooring:

Flooring is a general term used for the permanent covering of the floor. Floor covering is a smooth surface used for walking over the loose material under. There are many type of materials that can be used as floor material i.e. Carpet, laminate, tiles and Vinyl. The choice of material for floor depends on several factors such as cost, endurance, acoustic insulation, comfort and cleaning effort.

Ceramic tiles: This is a tile manufactured from the hard-wearing ceramic material. These tiles are used for covering roof, floor, wall, showers etc. Ceramic tiles are glazed for the interior use and are unglazed while used in the exterior parts of the building. Floor tiles are typically set into mortar consisting of sand, cement and often a latex additive for extra adhesion. The spaces between the tiles are filled with floor grout or mortar can also be used.

The ceramic tiles are used for the flooring in the project building. The composition of the floor in the sequence is slab, acoustic layer, concrete layer and tiles.

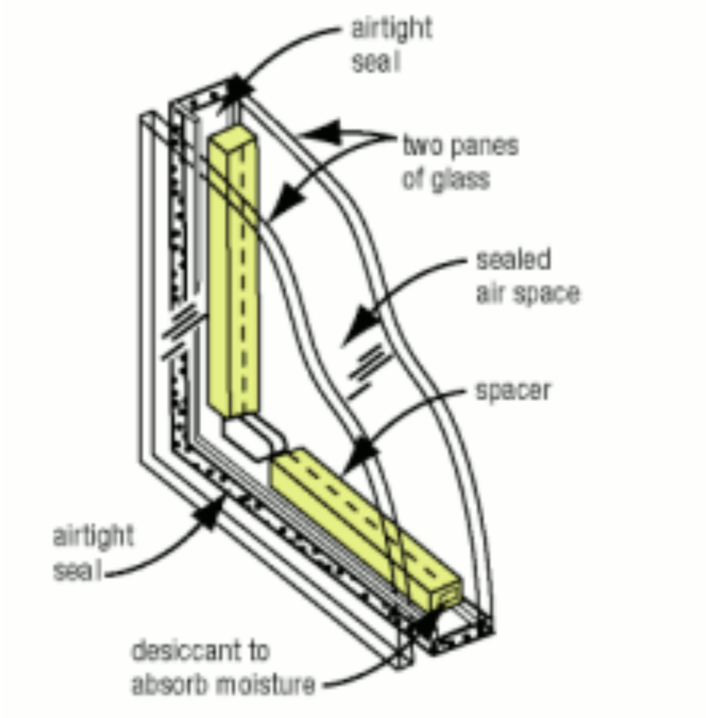
3.7 Windows and Doors:

A window is an opening in a wall that allows the passage of light and air. The windows used in the building are wooden frame with double glazing. The double glazing is also known as insulating glass which consist of two glass window panes separated by a vacuum or gas filled space to reduce heat transfer across a part of the building. The thickness of the glass used is 5 mm each.

A door is used to allow access inside the building or to different rooms within the building. Doors typically consist of one or two solid panel with or without windows. Doors are significant in preventing the spread of fire and it acts as a barrier to noise. In our case a typical wooden single panel door is used and one glass slider door. There is one slider door which is used in one of the bedroom to go to the garden which is 1.5 m in breadth. The garage door is 2.9 m in breadth.

Figure 4: Double glazed window

Figure 5: Double glazed window with details of material



3.8 Footings:

Foundations are structural elements that transfer loads from the building or individual column to the earth. If these loads are to be properly transmitted, foundations must be designed to prevent excessive settlement or rotation, to minimize differential settlement and to provide adequate safety against sliding and overturning. The size of the foundation depends on permissible bearing capacity of soil. The total load per unit area under the footing must be less than the permissible bearing capacity of soil to the excessive settlements.

The factors which play an important role in calculating the size of the footing are as under:

- Bearing capacity of soil.
- Type of structure.
- Type of loads.
- Permissible differential settlements.
- Economy.

The working footing size used is 1.9 m under the columns and the footing of width 0.6 m is provided under the external wall which is supporting the panel.

4 Results and Discussion:

The fact that factors such as location of the building and climatic conditions plays a huge role in the designing of the building can be seen from the above work. The building which can be constructed in south part of Spain where there is hot climatic conditions, different standards and culture is not suited for construction in Czech Republic. The different type of bearing systems that could have been possible for this building has been worked out keeping in mind the stability of the building, aesthetics, safety and typical standards.

In the end the best suited bearing system for the final construction of the building in Czech Republic is the bearing system 4. The building with bearing system 4 has even column system, good support for staircase in the form of reinforced concrete wall, typical slab thickness and beam dimensions. The panels are prefabricated, and the construction time reduces making the construction economical and time saving.

List of tables:

List of figures:

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Appendix A:

Preliminary calculation for system 1:

Length = 4.41 m

Concrete class = C30/37

Steel strength= 400 MPa

Slab design:

Using the formula,

$$d_s \geq \frac{l}{k_{c1} * k_{c2} * k_{c3} * \lambda_{d,tab}}$$

Where,

d_s = Effective depth of cross-section

l = Maximum span length

K_{c1} = Coefficient of cross-section (Rectangular cross-section – 1;T-shape cross-section-0.80)

K_{c2} = Coefficient of span (for $l \leq 7m$; kc2=1.0, other cases $K_{c2}=7/l$)

K_{c3} = Coefficient of stress in tensile reinforcement (assumed K_{c3}= 1.1-1.3)

$\lambda_{d,tab}$ = Design span to depth ratio obtained from attached table (In our case, for reinforcement ratio ρ=0.5% and C30/37, $\lambda_{d,tab}$=26.0)

Therefore,

$$d_s \geq \frac{4410}{1 * 1 * 1.2 * 26.0}$$

$d_s \geq$ 141.35

Now, using the formula for slab thickness

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

Where,

h_s = Slab thickness (cross-section depth)

c = concrete cover

Ø = Assumed bar diameter (for slab 8, 10, 12 bar)

Therefore,

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

$$h_s = 141.35 + 20 + \frac{8}{2}$$

$$h_s = 165.35\ mm$$

Take, slab thickness h_s = 175 mm

Reinforced concrete beam design:

To calculate the depth and width of beam use formula,

$$h_b = \left(\frac{1}{12} \div \frac{1}{8}\right) * l_b$$

$$W_b = \left(\frac{1}{3} \div \frac{1}{2}\right) * h_b$$

Where,

l_b = Beam span

h_b = cross-section depth

w_b = cross-section width

Therefore,

$$h_b = \left(\frac{1}{12} \div \frac{1}{8}\right) * 4410$$

$$h_b = (367.5 - 551.25)$$

$$h_b = 400\ mm$$

$$W_b = \left(\frac{1}{3} \div \frac{1}{2}\right) * 400$$

$$w_b = (133.3 - 200)$$

$$w_b = 150\ mm$$

Calculation of dead load and live load on the slab:

Dead load = (0.020*24) + (0.040*24) + (0.040*30) + (0.175*25)

Dead load = 7.02 KN/m^2

Dead load = 7.02*1.35 KN/m^2

Dead load = 9.47 KN/m^2

Assume,

Live load = 1.5 KN/m^2

Live load = 1.5*1.5 KN/m^2

Live load = 2.25 KN/m^2

Live load = 1.2 KN/m^2

Live load = 1.2*1.5 KN/m^2

Live load = 1.8 KN/m^2

Total Live load = 4.05 KN/m^2

Total load = Live load + Dead load

Total load = (9.47+4.05) KN/m^2

Total load = 13.52 KN/m^2

Now load distribution on the beams is shown in the figure below:

C = 1.068 m

D = 2.274 m

l = 4.410 m

The load taken by the beam of length 7 m = (13.52*1.850*2) KN/m

g = 50.024 KN/m

Using formula,

$$M_{Ed,max} = \frac{1}{12} * \frac{g}{l} [l^3 - c^2(2l - c)]$$

$$M_{Ed,max} = \frac{1}{12} * \frac{50.024}{4.410} [4.41^3 - 1.068^2(2 * 4.41 - 1.068)]$$

$$M_{Ed,max} = 72.71 \ KNm$$

Check for bending moment:

Using the formula,

$$\mu = \frac{M_{Ed,max}}{w_b * {d_b}^2 * f_{cd}}$$

Using μ in the table determine ξ (ξ should be between 0.15-0.40)

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

Where,

Ø = Assumed flexural reinforcement diameter (16, 18, 20,22,25,28 mm)

$\emptyset_{sw}$ = Assumed stirrups diameter (8 or 10 mm)

f_{cd} = design value of compressive concrete strength.

Now,

$$d_b = 400 - 30 - 10 + \frac{20}{2}$$

$$d_b = 350\, mm$$

$$\mu = \frac{72.71 * 10^6}{200 * 300^2 * 20}$$

$$\mu = 0.202$$

From the table we get ξ = 0.284

Hence, Safe

Check for shear force:

$$V_{Ed,max} \leq V_{Rd,max}$$

$$V_{Rd,max} = \upsilon * f_{cd} * w_b * \zeta * d_b * \frac{\cot\theta}{1 + \cot\theta^2}$$

Where,

$V_{Rd,max}$= The design value of the maximum shear force which can be sustained by the member, limited by crushing of the compression struts

$\upsilon = 0.6 * \left(1 - \frac{f_{ck}}{250}\right)$

ζ = General coefficient, use the table

$\cot\theta$ = Cotangent of the angle between the concrete compression strut and the beam axis perpendicular to the shear force, use 1.2 - 1.5

f_{ck} = Characteristic value of compressive concrete strength (depends on concrete strength class)

Therefore,

$$\upsilon = 0.6 * \left(1 - \frac{30}{250}\right)$$

$$\upsilon = 0.528$$

$$V_{Rd,max} = 0.528 * 20 * 0.2 * 0.886 * 0.2 * \frac{1.3}{1 + 1.3}$$

$V_{Rd,max}$ = 317.296 KN

$\sum M_A$ = 0

R_B*4.41 = (26.7*3.702) + (26.7*0.712) + (113.76*2.207)

R_B = 83.66 KN

$V_{Ed,max}$ = 83.66 KN

$V_{Ed,max} \leq V_{Rd,max}$, Hence Safe

Take, Beam dimension = 200*300 mm

Column Design:

Self weight of beam of 4.410 m = (0.200*0.300*2.205*25)*4*1.35

= 17.861 KN

Self weight of beam of 3.70 m = (0.200*0.300*3.70*25)*4*1.35

= 29.97 KN

Self weight of column = (0.200*0.200*2.6*25)*4*1.35

= 14.04 KN

Reaction from beam of 4.410 m:

$\sum M_A$ = 0

R_B*4.41 = (26.7*3.702) + (26.7*0.712) + (113.76*2.207)

R_B = 83.66 KN

Reaction from beam of 3.70 m:

$\sum M_A$ = 0

R_B*3.70 = 92.54*1.85

R_B = 46.27 KN

Load = [(83.66*4) + (2*46.27*4)]

Load = 704.8 KN

P = 766.671 KN

Using the formula,

$P \leq 0.8 * A_c * f_{cd} + A_s * \sigma_s$

$766.671 * 10^3 \leq 0.8 * A_c * 20 + 0.2 * A_c * 400$

$A_c \geq 31944.625 \text{ mm}^2$

Take column cross-section = 200*200 mm

Preliminary calculation for system 2:

Length = 7.0 m

Concrete class = C30/37

Steel strength= 400 MPa

Slab design:

Using the formula,

$$d_s \geq \frac{7000}{1*1*1.2*26.0}$$

$$d_s \geq 222.76$$

Now, using the formula for slab thickness

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

$$h_s = 222.76 + 20 + \frac{8}{2}$$

$$h_s = 246.76\, mm$$

Take, slab thickness h_s = 250 mm

Reinforced concrete beam design:

To calculate the depth and width of beam use formula,

$$h_b = \left(\frac{1}{12} \div \frac{1}{8}\right) * 7000$$

$$h_b = (583.33 - 875)$$

$$h_b = 600\, mm$$

$$W_b = \left(\frac{1}{3} \div \frac{1}{2}\right) * 600$$

$$w_b = (200 - 300)$$

$$w_b = 250\, mm$$

Calculation of dead load and live load on the slab:

Dead load = (0.020*24) + (0.040*24) + (0.040*30) + (0.250*25)

Dead load = 8.89 KN/m^2

Dead load = 8.89*1.35 KN/m^2

Dead load = 12.002 KN/m^2

Assume,

Live load = 1.5 KN/m^2

Live load = 1.5*1.5 KN/m^2

Live load = 2.25 KN/m^2

Live load = 1.2 KN/m^2

Live load = 1.2*1.5 KN/m^2

Live load = 1.8 KN/m^2

Total Live load = 4.05 KN/m^2

Total load = Live load + Dead load

Total load = (12.002+4.05) KN/m^2

Total load = 16.1 KN/m^2

Now load distribution on the beams is shown in the figure below:

C = 1.804 m

D = 3.392 m

l = 7.0 m

The load taken by the beam of length 7 m = (16.1*3.125*2) KN/m

g = 100.3 KN/m

Using formula,

$$M_{Ed,max} = \frac{1}{12} * \frac{g}{l}[l^3 - c^2(2l - c)]$$

$$M_{Ed,max} = \frac{1}{12} * \frac{100.3}{7.0}[7.0^3 - 1.804^2(2 * 7.0 - 1.804)]$$

$$M_{Ed,max} = 362.2 \ KNm$$

Check for bending moment:

Using the formula,

$$d_b = 600 - 30 - 10 + \frac{20}{2}$$

$$d_b = 550 \ mm$$

$$\mu = \frac{M_{Ed,max}}{w_b * {d_b}^2 * f_{cd}}$$

$$\mu = \frac{362.2 * 10^6}{250 * 550^2 * 20}$$

$\mu = 0.24$

From the table we get $\xi = 0.349$

Hence, Safe

Check for shear force:

$V_{Ed,max} \leq V_{Rd,max}$

$$V_{Rd,max} = \upsilon * f_{cd} * w_b * \zeta * d_b * \frac{\cot\theta}{1 + \cot\theta^2}$$

$\upsilon = 0.6 * \left(1 - \frac{30}{250}\right)$

$\upsilon = 0.528$

$$V_{Rd,max} = 0.528 * 20 * 0.250 * 0.861 * 0.550 * \frac{1.3}{1 + 1.3}$$

$V_{Rd,max}$ = 706.6 KN

$\sum M_A = 0$

R_B*7.0 = (90.5*1.203) + (340.22*3.503) + (90.5*5.803)

R_B = 260.8KN

$V_{Ed,max}$ = 260.8 KN

$V_{Ed,max} \leq V_{Rd,max}$, Hence Safe

Take, Beam dimension = 250*550 mm

Column Design:

Self weight of beam of 7.0 m = (0.250*0.550*3.5*25)*4*1.35

= 64.97 KN

Self weight of beam of 6.25 m = (0.250*0.550*6.25*25)*4*1.35

= 116.02 KN

Self weight of column = (0.350*0.350*2.6*25)*4*1.35

= 42.998 KN

Reaction from beam of 7.0 m:

$\sum M_A = 0$

R_B*7.0 = (90.5*1.203) + (340.22*3.503) + (90.5*5.803)

R_B = 260.8KN

Reaction from beam of 6.25 m:

$\sum M_A$ = 0

R_B*6.25 = (313.44*3.125)

R_B = 156.72 KN

Load = [(260.8*4) + (2*156.72*4)]

Load = 2296.96 KN

P = 2520.8 KN

Using the formula,

$$P \leq 0.8 * A_c * f_{cd} + A_s * \sigma_s$$

$$2520.8 * 10^3 \leq 0.8 * A_c * 20 + 0.2 * A_c * 400$$

$A_c \geq$ 105,033.33 mm^2

Take column cross-section = 250*450 mm

Preliminary calculation for system 3:

Length = 7.0 m

Concrete class = C30/37

Steel strength= 400 MPa

Slab design:

Using the formula,

$$d_s \geq \frac{7000}{1 * 1 * 1.2 * 26.0}$$

$d_s \geq$ 222.76

Now, using the formula for slab thickness

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

$$h_s = 222.76 + 20 + \frac{8}{2}$$

$$h_s = 246.76\, mm$$

Take, slab thickness h_s = 200 mm

Reinforced concrete beam design:

To calculate the depth and width of beam use formula,

$$h_b = \left(\frac{1}{12} \div \frac{1}{8}\right) * 7000$$

$$h_b = (583.33 - 875)$$

$$h_b = 600\ mm$$

$$W_b = \left(\frac{1}{3} \div \frac{1}{2}\right) * 600$$

$$w_b = (200 - 300)$$

$$w_b = 250\ mm$$

Calculation of dead load and live load on the slab:

Dead load = (0.020*24) + (0.040*24) + (0.040*30) + (0.200*25)

Dead load = 7.64 KN/m^2

Dead load = 7.64*1.35 KN/m^2

Dead load = 10.314 KN/m^2

Assume,

Live load = 1.5 KN/m^2

Live load = 1.5*1.5 KN/m^2

Live load = 2.25 KN/m^2

Live load = 1.2 KN/m^2

Live load = 1.2*1.5 KN/m^2

Live load = 1.8 KN/m^2

Total Live load = 4.05 KN/m^2

Total load = Live load + Dead load

Total load = (10.314+4.05) KN/m^2

Total load = 14.364 KN/m^2

Now load distribution on the beams is shown in the figure below:

C = 1.501 m

D = 3.998 m

l = 7.0 m

The load taken by the beam of length 7 m = (14.364*2.60*2) KN/m

g = 74.69 KN/m

Using formula,

$$M_{Ed,max} = \frac{1}{12} * \frac{g}{l}[l^3 - c^2(2l - c)]$$

$$M_{Ed,max} = \frac{1}{12} * \frac{74.69}{7.0}[7.0^3 - 1.501^2(2 * 7.0 - 1.501)]$$

$$M_{Ed,max} = 279.95 \ KNm$$

Check for bending moment:

Using the formula,

$$d_b = 600 - 30 - 10 + \frac{20}{2}$$

$$d_b = 550 \, mm$$

$$\mu = \frac{M_{Ed,max}}{w_b * {d_b}^2 * f_{cd}}$$

$$\mu = \frac{279.95 * 10^6}{250 * 550^2 * 20}$$

$$\mu = 0.19$$

From the table we get ξ = 0.266

$$\mu = \frac{M_{Ed,max}}{w_b * {d_b}^2 * f_{cd}}$$

$$\mu = \frac{279.95 * 10^6}{250 * 500^2 * 20}$$

$$\mu = 0.22$$

From the table we get ξ = 0.315

Hence, Safe

Check for shear force:

$$V_{Ed,max} \leq V_{Rd,max}$$

$$V_{Rd,max} = \ \upsilon * f_{cd} * w_b * \zeta * d_b * \frac{\cot\theta}{1 + \cot\theta^2}$$

$$\upsilon = 0.6 * \left(1 - \frac{30}{250}\right)$$

$$\upsilon = 0.528$$

$V_{Rd,max} = 0.528 * 20 * 0.250 * 0.874 * 0.500 * \frac{1.3}{1 + 1.3}$

$V_{Rd,max}$ = 652.1 KN

$\sum M_A$ = 0

R_B*7.0 = (56.06*1.001) + (298.6*3.5) + (56.06*5.99)

R_B = 205.36 KN

$V_{Ed,max}$ = 205.36 KN

$V_{Ed,max} \leq V_{Rd,max}$, Hence Safe

Take, Beam dimension = 250*500 mm

Column Design:

Self weight of beam of 7.0 m = (0.250*0.500*3.5*25)*4*1.35

= 59.06 KN

Self weight of beam of 5.20 m = (0.250*0.500*5.20*25)*4*1.35

= 87.75 KN

Self weight of column = (0.300*0.300*2.6*25)*4*1.35

= 31.59 KN

Reaction from beam of 7.0 m:

$\sum M_A$ = 0

R_B*7.0 = (56.06*1.001) + (298.6*3.5) + (56.06*5.99)

R_B = 205.36 KN

Reaction from beam of 5.2 m:

$\sum M_A$ = 0

R_B*5.20 = (194.194*5.20)

R_B = 97.1 KN

Load = [(205.36*4) + (2*97.1*4)]

Load = 1598.24 KN

P = 1776.64 KN

Using the formula,

$P \leq 0.8 * A_c * f_{cd} + A_s * \sigma_s$

$1776.64 * 10^3 \leq 0.8 * A_c * 20 + 0.2 * A_c * 400$

$A_c \geq 74{,}027$ mm^2

Take column cross-section = 250*300 mm

Preliminary calculation for system 4:

l = 7.0 m

Dead load = (0.0200*24) + (0.040*24) + (0.040*30)

Dead load = 2.64 KN/m^2

Dead load = 2.64*1.35 KN/m^2

Dead load = 3.564 KN/m^2

Assume,

Live load = 1.5 KN/m^2

Live load = 1.5*1.5 KN/m^2

Live load = 2.25 KN/m^2

Live load = 1.2 KN/m^2

Live load = 1.2*1.5 KN/m^2

Live load = 1.8 KN/m^2

Total Live load = 4.05 KN/m^2

Total load = Live load + Dead load

Total load = (3.564+4.05) KN/m^2

Total load = 7.614 KN/m^2

Total load = 776.412 Kg/m^2

Depending on the load choose the panel from the table:

Panel thickness = 200 mm

Dead load of the panel = 297.17 Kg/m^2

Total Live load = $\frac{297.17}{1.20} Kg/m^2$

Dead load of the panel = 247.642 Kg/m^2

Dead load of the panel = 2.43 KN/m^2

Dead load of the panel = 2.43*1.35 KN/m^2

Dead load of the panel = 3.2805 KN/m^2

Total load = (7.614+4.05) KN/m^2

Total load = 10.895 KN/m^2

The panel acts like a one-way slab

Load, W = 10.895*3.50

Load, W = 38.13 KN/m

M = $\frac{W*l^2}{12} = \frac{38.13*5.20^2}{12}$ = 85.92 KNm

$$h_b = \left(\frac{1}{12} \div \frac{1}{8}\right) * 7000$$

$$h_b = (583.33 - 875)$$

$$h_b = 600\, mm$$

$$W_b = \left(\frac{1}{3} \div \frac{1}{2}\right) * 600$$

$$w_b = (200 - 300)$$

$$w_b = 250\, mm$$

$$d_b = 600 - 30 - 10 + \frac{20}{2}$$

$$d_b = 550\, mm$$

$$\mu = \frac{M_{Ed,max}}{w_b * {d_b}^2 * f_{cd}}$$

$$\mu = \frac{85.92 * 10^6}{250 * 550^2 * 20}$$

$$\mu = 0.06$$

From the table we get ξ = 0.077

Change the dimension

$$\mu = \frac{85.92 * 10^6}{250 * 300^2 * 20}$$

$$\mu = 0.20$$

From the table we get ξ = 0.282

Shear check:

$V_{Ed,max.} = \frac{Wl}{2} = \frac{38.13*5.20}{2}$ = 99.14 KN

$\upsilon = 0.6 * \left(1 - \frac{30}{250}\right)$

$\upsilon = 0.528$

$$V_{Rd,max} = 0.528 * 20 * 0.250 * 0.887 * 0.300 * \frac{1.3}{1 + 1.3}$$

$V_{Rd,max}$ = 397.07 KN

$V_{Ed,max} \leq V_{Rd,max}$, Hence Safe

Beam dimension = 250*300 mm

Column design:

Self weight of beam of = (0.250*0.300*5.2*25)*4*1.35

= 52.65 KN

Self weight of column = (0.350*0.350*2.6*25)*4*1.35

= 42.998 KN

Load = 10.895*4*17.92

Load = 780.95

P = 876.598 KN

Using the formula,

$P \leq 0.8 * A_c * f_{cd} + A_s * \sigma_s$

$876.598 * 10^3 \leq 0.8 * A_c * 20 + 0.2 * A_c * 400$

$A_c \geq 36{,}524.92$ mm^2

Take column cross-section = 250*250 mm

Staircase calculation:

l = 2.90 m

Let's assume, Riser = 18.5 cm

No. of riser = $\frac{2.90}{0.185}$ = 16.11 ≈ 16 steps

Riser height = $\frac{2.90}{16}$ = 0.18125 m = 18.125 cm

Now, using the formula

Tread + (2*18.125) = 63

Tread = 63-(2*18.125)

Tread = 26.75 cm

∴ R = 18.125 cm

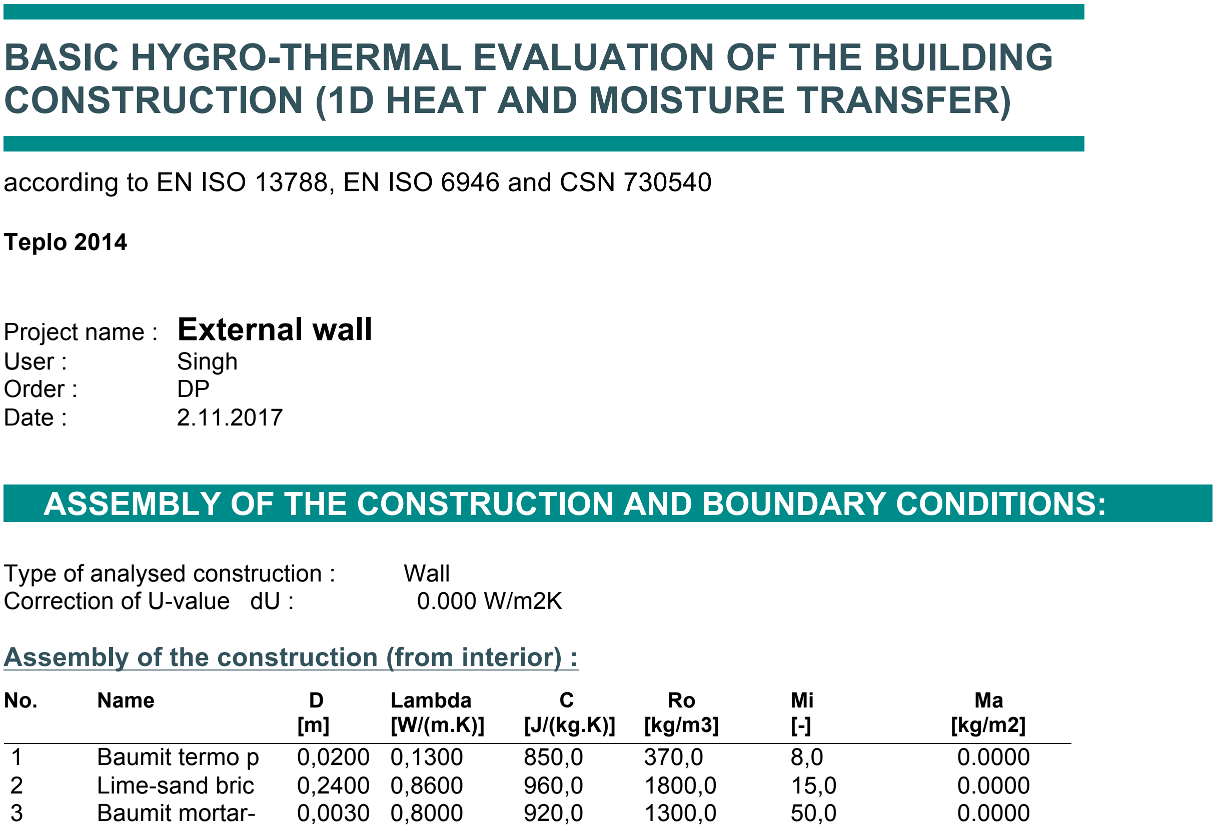
T = 26.75 cm

Appendix B:

Insulation calculations:

Insulation calculation for External wall:

The insulation of the external wall is checked for safety using the Czech software *Teplo* and the results are as follows:



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 :	**External wall**
User :	Singh
Order :	DP
Date :	2.11.2017

ASSEMBLY OF THE CONSTRUCTION AND BOUNDARY CONDITIONS:

Type of analysed construction : 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	Baumit termo p	0,0200	0,1300	850,0	370,0	8,0	0.0000
2	Lime-sand bric	0,2400	0,8600	960,0	1800,0	15,0	0.0000
3	Baumit mortar-	0,0030	0,8000	920,0	1300,0	50,0	0.0000

4	Rockwool Speed	0,1600	0,0450	840,0	100,0	3,0	0.0000
5	Baumit mortar-	0,0030	0,8000	920,0	1300,0	18,0	0.0000
6	Baumit ušlecht	0,0020	0,8000	920,0	1700,0	12,0	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	Baumit termo plaster (ThermoPutz)	---
2	Lime-sand bricks 3 DF	---
3	Baumit mortar-glue (Baumit KlebeSpachtel)	---
4	Rockwool Speedrock	---
5	Baumit mortar-glue (HaftMörtel)	---
6	Baumit ušlechtilá omítka speciál/extra (EdelPutz)	---

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 : 0.04 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	-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 : 3.998 m2K/W
Thermal transmittance of construction U : **0.240 W/m2K**

U-value of built-in construction U,kc : 0.26 / 0.29 / 0.34 / 0.44 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 :	2.4E+0010 m/s
Decrement factor of construction Ny* :	465.8
Time shift of temperature oscillation Psi* :	12.6 h

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

Internal surface temperature for design conditions Tsi,p :	19.02 C
Temperature factor in design conditions f,Rsi,p :	**0.942**

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	0.586	8.0	0.444	19.6	0.942	46.9
2	12.0	0.589	8.7	0.436	19.7	0.942	48.8
3	13.0	0.558	9.7	0.371	20.0	0.942	51.5
4	14.4	0.502	11.0	0.246	20.2	0.942	55.3
5	16.3	0.430	12.8	0.014	20.5	0.942	61.3
6	17.7	0.346	14.2	------	20.7	0.942	66.2
7	18.4	0.245	14.8	------	20.8	0.942	68.8
8	18.1	0.280	14.6	------	20.8	0.942	67.9
9	16.5	0.419	13.1	------	20.6	0.942	62.2
10	14.6	0.492	11.1	0.224	20.3	0.942	55.8
11	13.0	0.558	9.6	0.372	19.9	0.942	51.4
12	12.2	0.591	8.8	0.436	19.7	0.942	49.3

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

Vapour 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**	**5-6**	**e**
theta[C]:	19.9	18.7	16.4	16.4	-12.6	-12.7	-12.7
p [Pa]:	1367	1324	357	316	187	173	166
p,sat [Pa]:	2328	2153	1865	1862	205	204	204

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.

Vapour diffusion flow rate Gd : 5.375E-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 vapour diffusion was performed with the assumption of 1D vapour 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.

The full detailed conclusion is described in full extent in Czech language:

VYHODNOCENÍ VÝSLEDKŮ PODLE KRITÉRIÍ ČSN 730540-2 (2011)

Název konstrukce: External 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	Baumit termo plaster (ThermoPu	0,020	0,130	8,0
2	Lime-sand bricks 3 DF	0,240	0,860	15,0
3	Baumit mortar-glue (Baumit Kle	0,003	0,800	50,0
4	Rockwool Speedrock	0,160	0,045	3,0
5	Baumit mortar-glue (HaftMörtel	0,003	0,800	18,0
6	Baumit ušlechtilá omítka speci	0,002	0,800	12,0

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 = 0,942

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 = 0,240 W/m2K
U < U,N ... POŽADAVEK JE SPLNĚN.

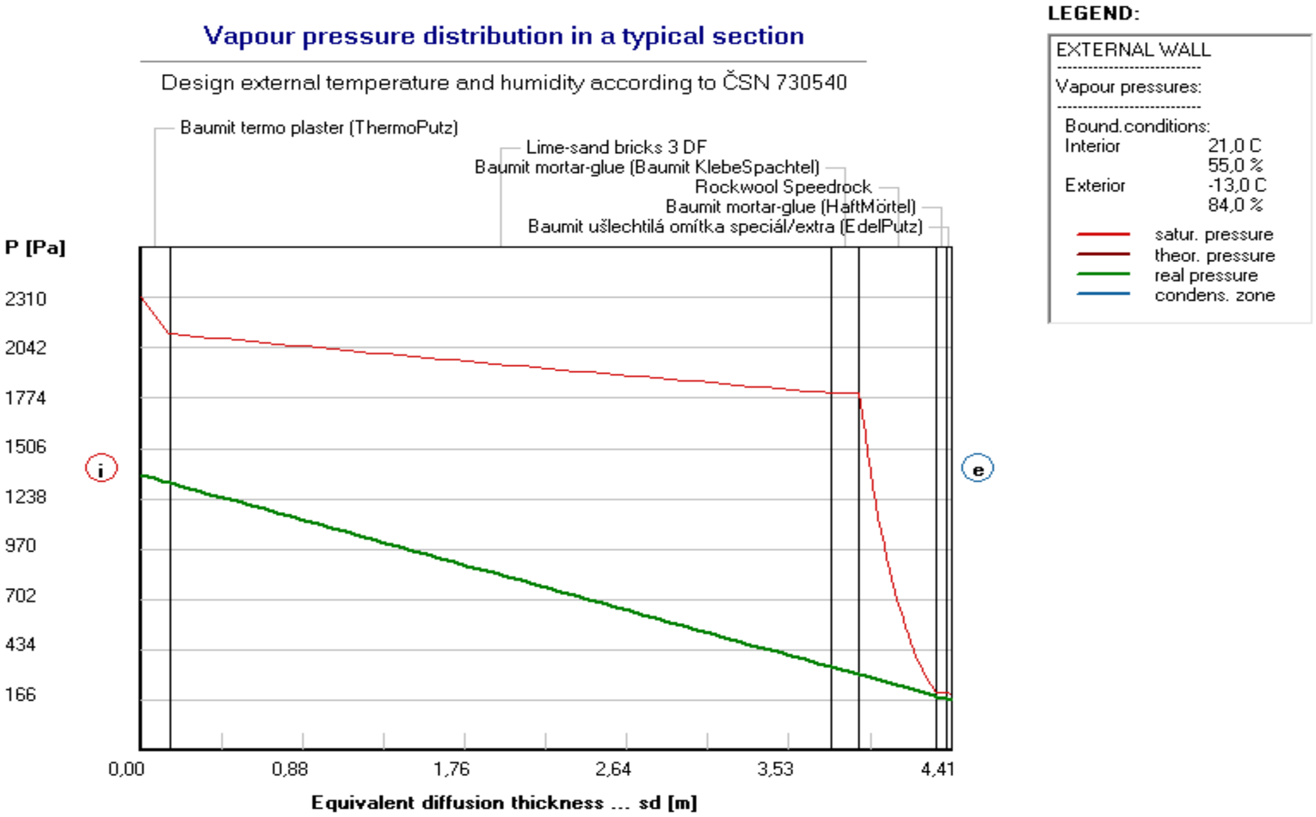
Vypočtený součinitel prostupu tepla musí zahrnovat vliv systematických tepelných mostů (např. krokví v zateplené šikmé střeše).

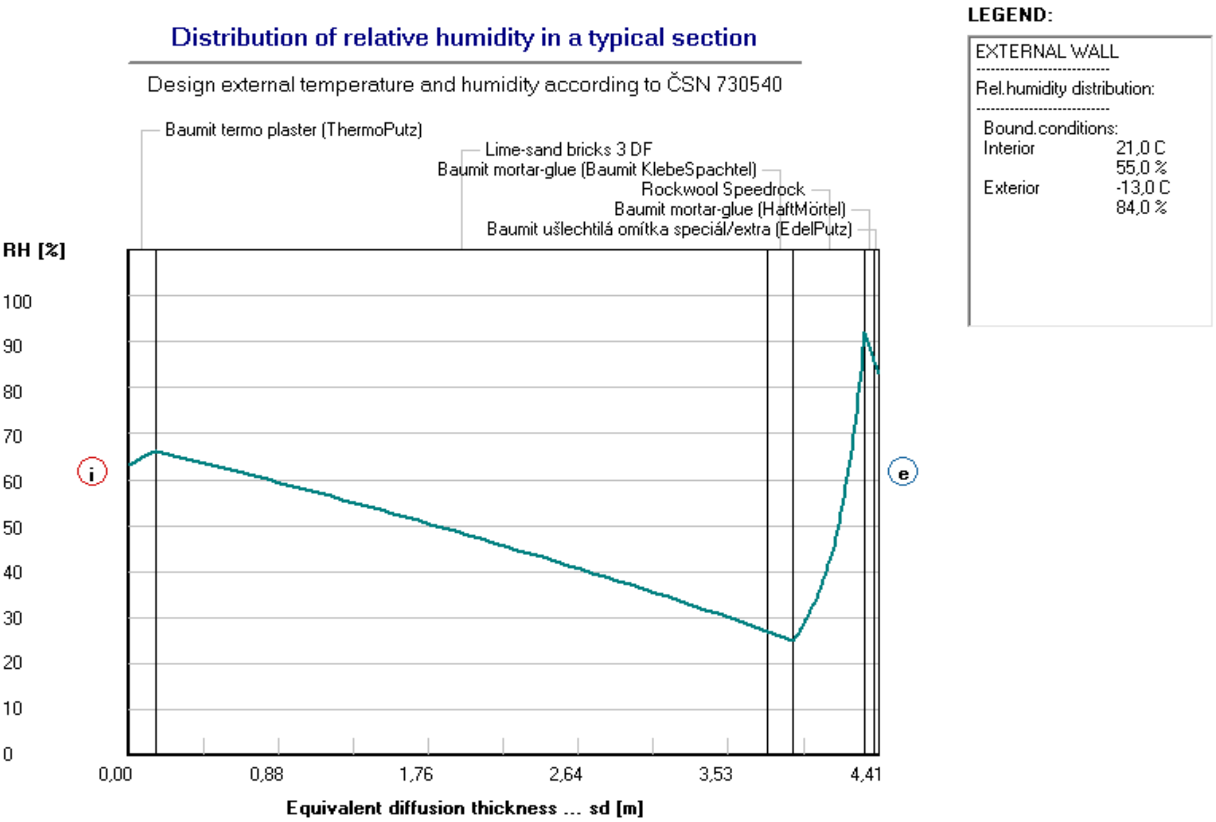
III. Požadavky na šíření vlhkosti konstrukcí (čl. 6.1 a 6.2 v ČSN 730540-2)

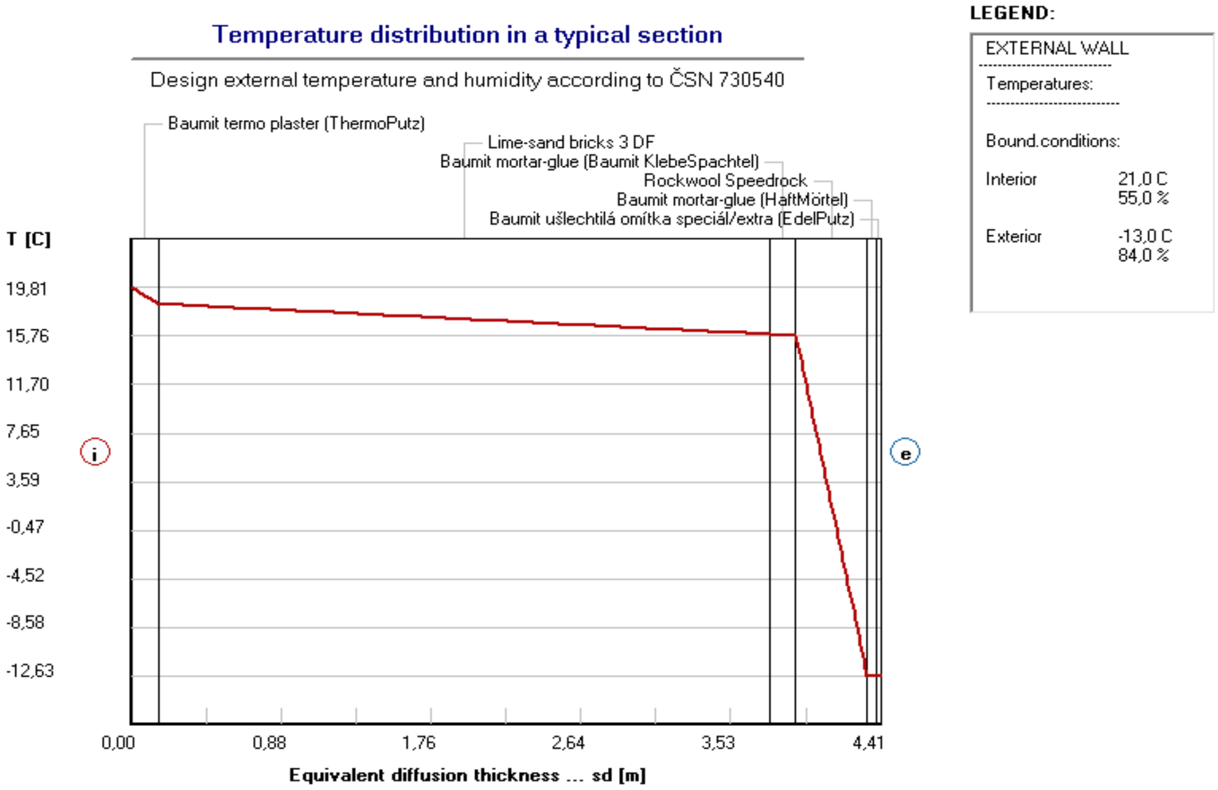
Požadavky:
1. Kondenzace vodní páry nesmí ohrozit funkci konstrukce.
2. Roční množství kondenzátu musí být nižší než roční kapacita odparu.
3. Roční množství kondenzátu Mc,a musí být nižší než 0,1 kg/m2.rok, nebo 3-6% plošné hmotnosti materiálu (nižší z hodnot).

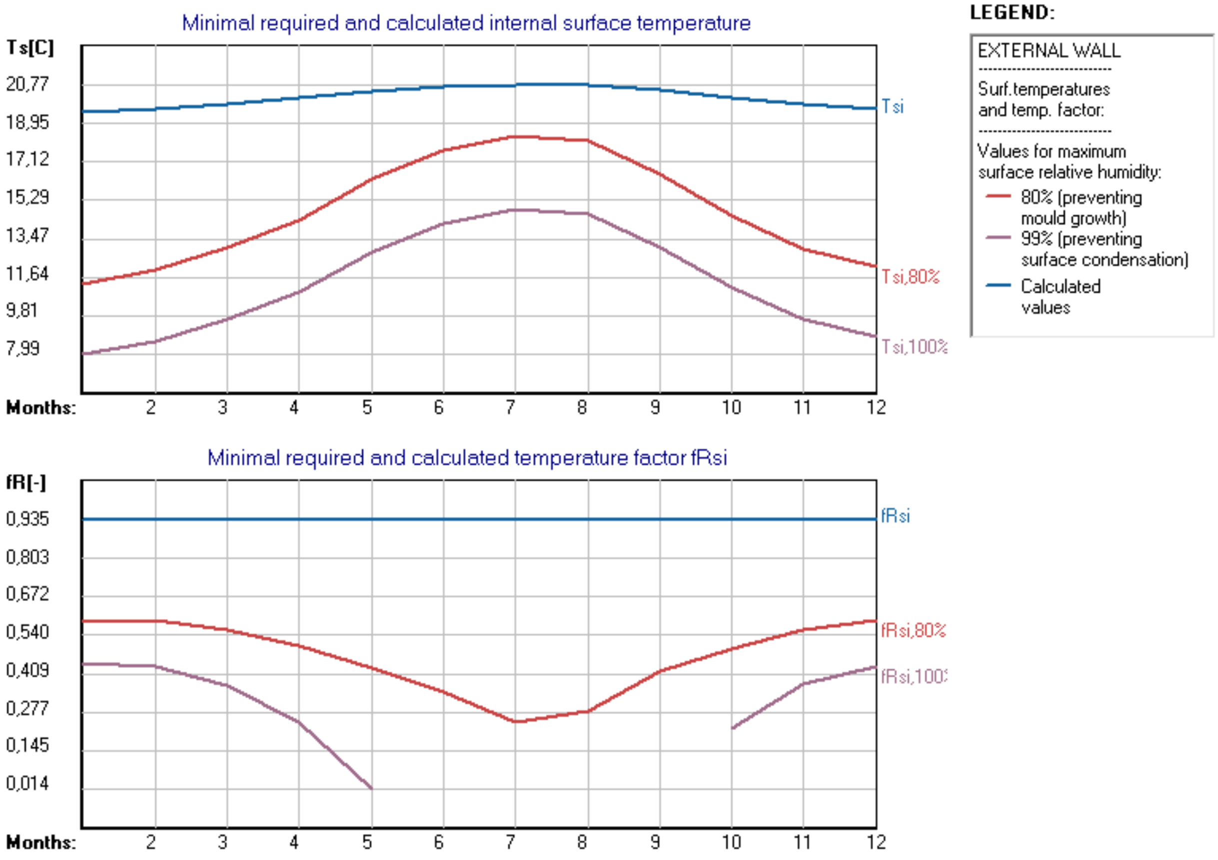
Vypočtené hodnoty: V konstrukci nedochází při venkovní návrhové teplotě ke kondenzaci.
V konstrukci nedochází během modelového roku ke kondenzaci.

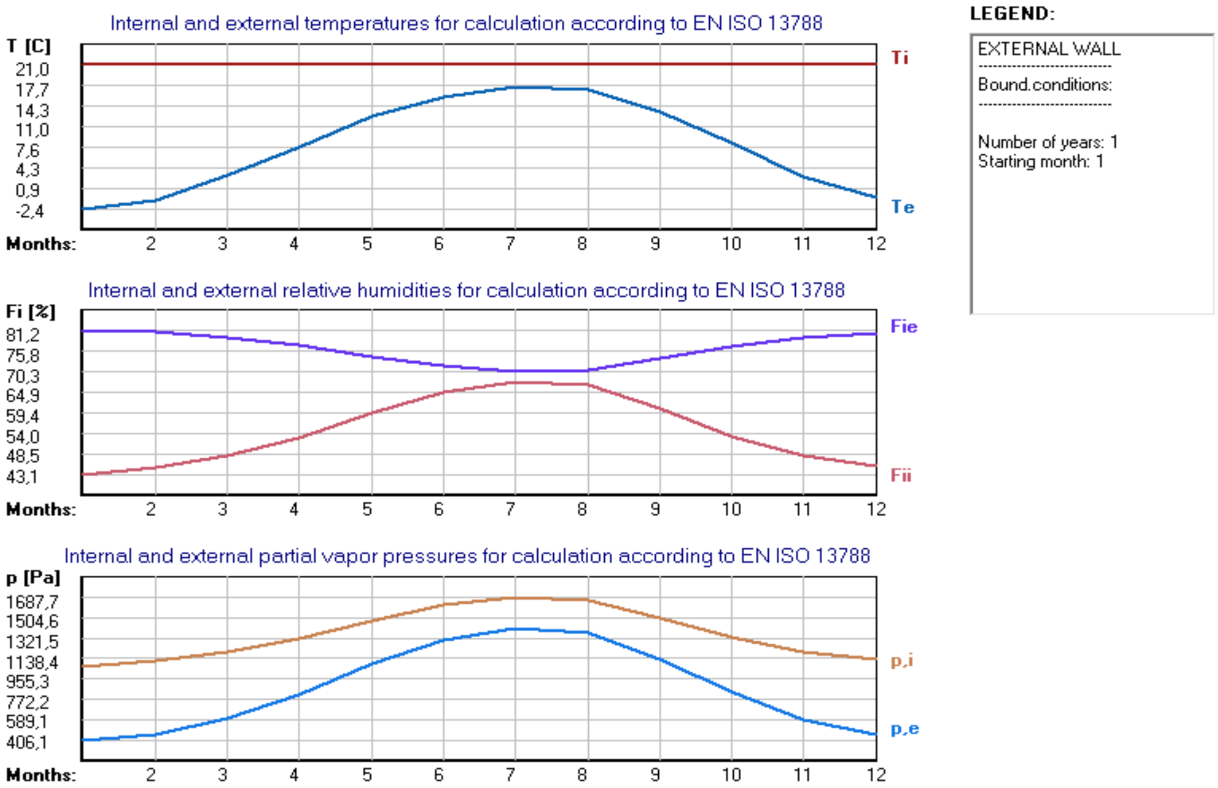
POŽADAVKY JSOU SPLNĚNY.


Vapour pressure distribution in a typical section
Design external temperature and humidity according to ČSN 730540
Baumit termo plaster (ThermoPutz)
Lime-sand bricks 3 DF
Baumit mortar-glue (Baumit KlebeSpachtel)
Rockwool Speedrock
Baumit mortar-glue (HaftMörtel)
Baumit ušlechtilá omítka speciál/extra (EdelPutz)
P [Pa]
2310
2042
1774
1506
1238
970
702
434
166
i
e
0,00
0,88
1,76
2,64
3,53
4,41
Equivalent diffusion thickness ... sd [m]
LEGEND:
EXTERNAL WALL
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
Baumit termo plaster (ThermoPutz)
Lime-sand bricks 3 DF
Baumit mortar-glue (Baumit KlebeSpachtel)
Rockwool Speedrock
Baumit mortar-glue (HaftMörtel)
Baumit ušlechtilá omítka speciál/extra (EdelPutz)
RH [%]
100
90
80
70
60
50
40
30
20
10
0
i
e
0,00
0,88
1,76
2,64
3,53
4,41
Equivalent diffusion thickness ... sd [m]
LEGEND:
EXTERNAL WALL
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
Baumit termo plaster (ThermoPutz)
Lime-sand bricks 3 DF
Baumit mortar-glue (Baumit KlebeSpachtel)
Rockwool Speedrock
Baumit mortar-glue (HaftMörtel)
Baumit ušlechtilá omítka speciál/extra (EdelPutz)
T [C]
19,81
15,76
11,70
7,65
3,59
-0,47
-4,52
-8,58
-12,63
i
e
0,00
0,88
1,76
2,64
3,53
4,41
Equivalent diffusion thickness ... sd [m]
LEGEND:
EXTERNAL 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]
20,77
18,95
17,12
15,29
13,47
11,64
9,81
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[-]
0,935
0,803
0,672
0,540
0,409
0,277
0,145
0,014
fRsi
fRsi,80%
fRsi,100
Months:
2
3
4
5
6
7
8
9
10
11
12
LEGEND:
EXTERNAL WALL
Surf.temperatures
and temp. factor:
Values for maximum
surface relative humidity:
80% (preventing
mould growth)
99% (preventing
surface condensation)
Calculated
values



EXTERNAL WALL

Bound.conditions:

Number of years: 1
Starting month: 1

Insulation Calculation for roof:

The insulation of the external wall is checked for safety using the Czech software *Teplo* and the results are as follows:

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 : Singh
Order : DP
Date : 2.11.2017

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	Baumit termo p	0,0200	0,1300	850,0	370,0	8,0	0.0000
2	Reinforced con	0,2000	1,5800	1020,0	2400,0	29,0	0.0000
3	Sarnavap 1000	0,0002	0,3500	1470,0	1800,0	900000,0	0.0000
4	Rockwool Dachr	0,2800	0,0450	840,0	100,0	3,0	0.0000
5	Sarnafil S15	0,0015	0,1500	960,0	1200,0	15000,0	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	Baumit termo plaster (ThermoPutz)	---
2	Reinforced concrete 2	---
3	Sarnavap 1000	---
4	Rockwool Dachrock Max	---
5	Sarnafil S15	---

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 :

RESULTS OF CALCULATION :

Thermal resistance and thermal transmittance according to EN ISO 6946 :

Thermal resistance of construction R :	6.513 m2K/W
Thermal transmittance of construction U :	**0.150 W/m2K**

U-value of built-in construction U,kc : 0.17 / 0.20 / 0.25 / 0.35 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:

Vapour diffusion resistance of construction ZpT :	1.2E+0012 m/s
Decrement factor of construction Ny* :	1178.3
Time shift of temperature oscillation Psi* :	14.2 h

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

Internal surface temperature for design conditions Tsi,p :	19.75 C
Temperature factor in design conditions f,Rsi,p :	**0.963**

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	20.1	0.963	45.7
2	12.0	0.623	8.7	0.483	20.1	0.963	47.6
3	13.0	0.602	9.7	0.434	20.3	0.963	50.5
4	14.4	0.567	11.0	0.345	20.4	0.963	54.6
5	16.3	0.541	12.8	0.205	20.6	0.963	60.9
6	17.7	0.530	14.2	0.038	20.7	0.963	66.1
7	18.4	0.520	14.8	------	20.8	0.963	68.7
8	18.1	0.520	14.6	------	20.8	0.963	67.8
9	16.5	0.539	13.1	0.182	20.6	0.963	61.8
10	14.6	0.561	11.1	0.330	20.5	0.963	55.1
11	13.0	0.602	9.6	0.435	20.3	0.963	50.4
12	12.2	0.625	8.8	0.484	20.1	0.963	48.1

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

Vapour 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]:	20.5	19.7	19.1	19.1	-12.7	-12.8
p [Pa]:	1367	1366	1336	290	285	166
p,sat [Pa]:	2409	2294	2204	2203	203	202

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.

Interstitial condensation occurs in the design conditions.

Cond.zone no.	**Cond.zone boundary left [m]**	**right**	**Vapor condensation rate [kg/m2s]**
1	0.5002	0.5002	8.143E-0010

Annual moisture balance:

Amount of condensated water vapor Mc,a:	**0.0016 kg/(m2.rok)**
Amount of evaporable water vapor Mev,a:	**0.0821 kg/(m2.rok)**

Condensation occurs if external temperature is lower than 0.0 C.

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 vapour diffusion was performed with the assumption of 1D vapour 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.

The full detailed conclusion is described in full extent in Czech language:

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	Baumit termo plaster (ThermoPu	0,020	0,130	8,0
2	Reinforced concrete 2	0,200	1,580	29,0
3	Sarnavap 1000	0,0002	0,350	900000,0
4	Rockwool Dachrock Max	0,280	0,045	2,95
5	Sarnafil S15	0,0015	0,150	15000,0

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 =	0,963

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 =	0,150 W/m2K

U < U,N ... POŽADAVEK JE SPLNĚN.

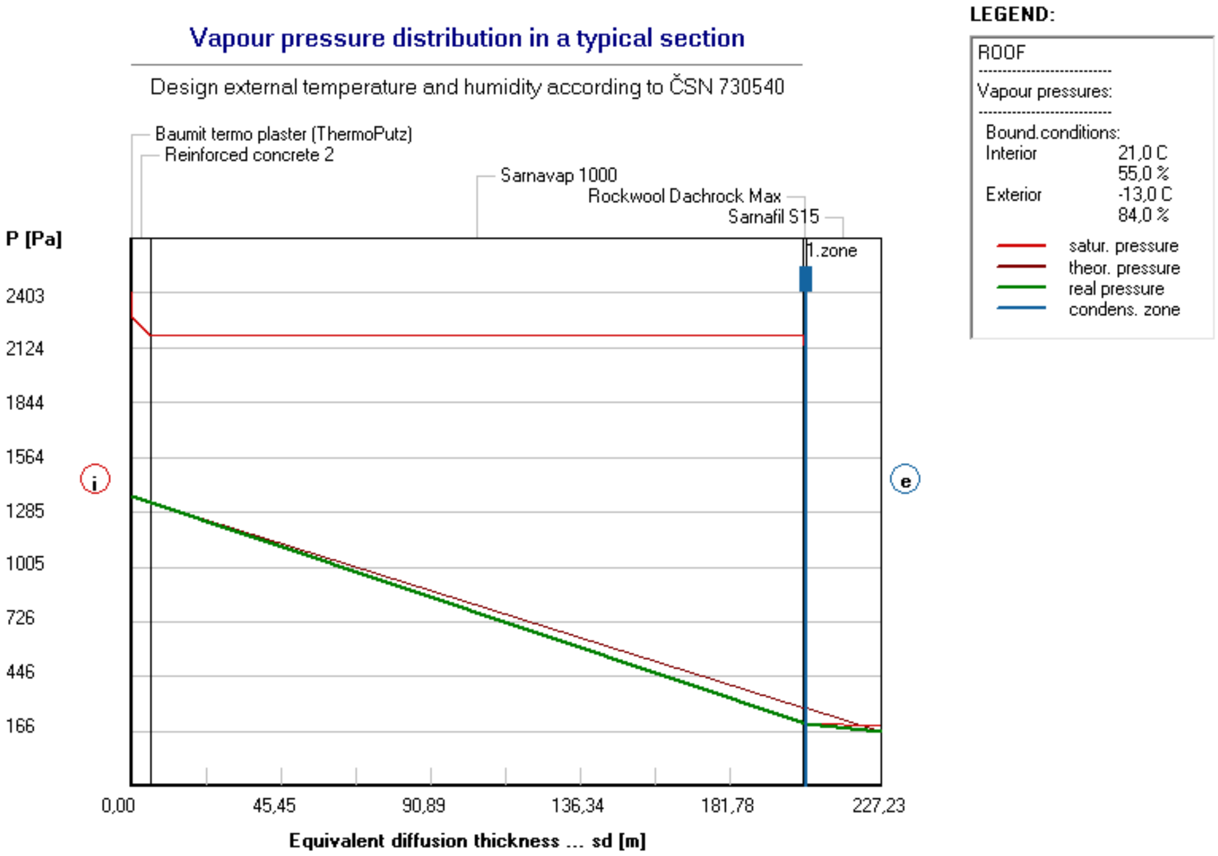
Vypočtený součinitel prostupu tepla musí zahrnovat vliv systematických tepelných mostů (např. krokví v zateplené šikmé střeše).

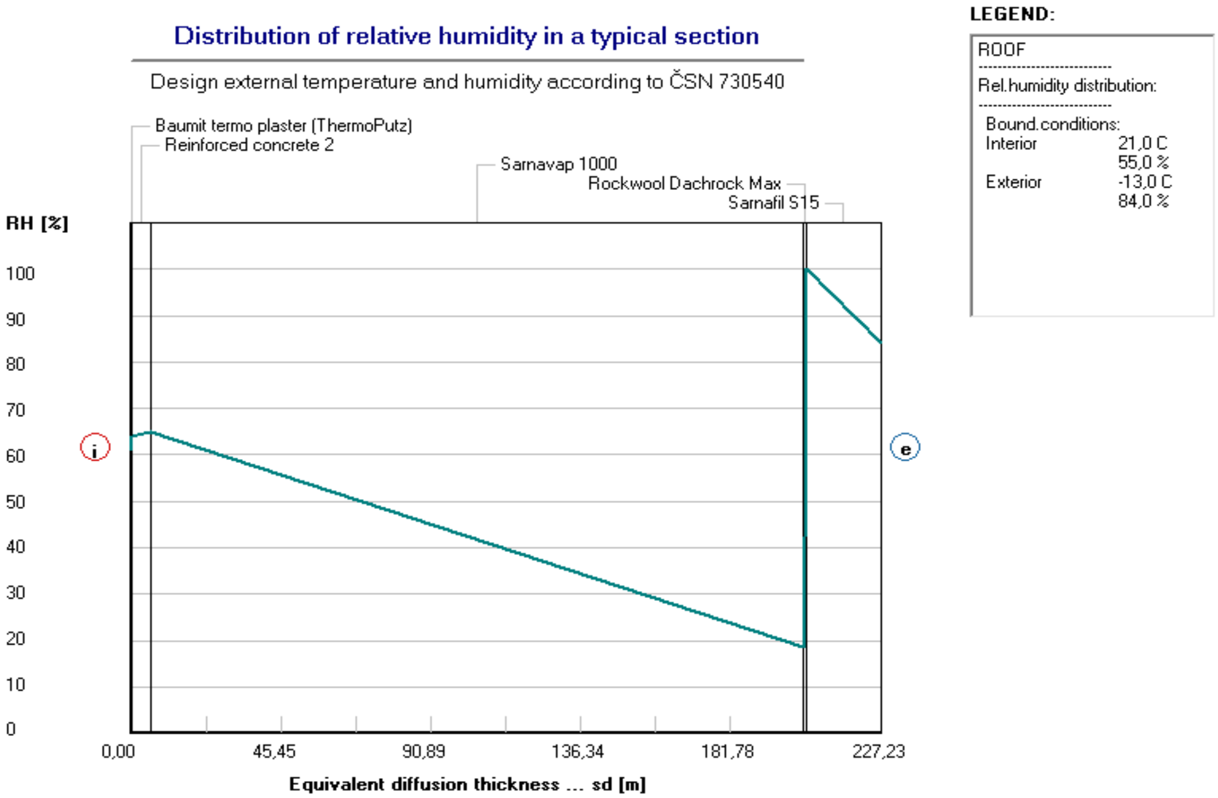
III. Požadavky na šíření vlhkosti konstrukcí (čl. 6.1 a 6.2 v ČSN 730540-2)

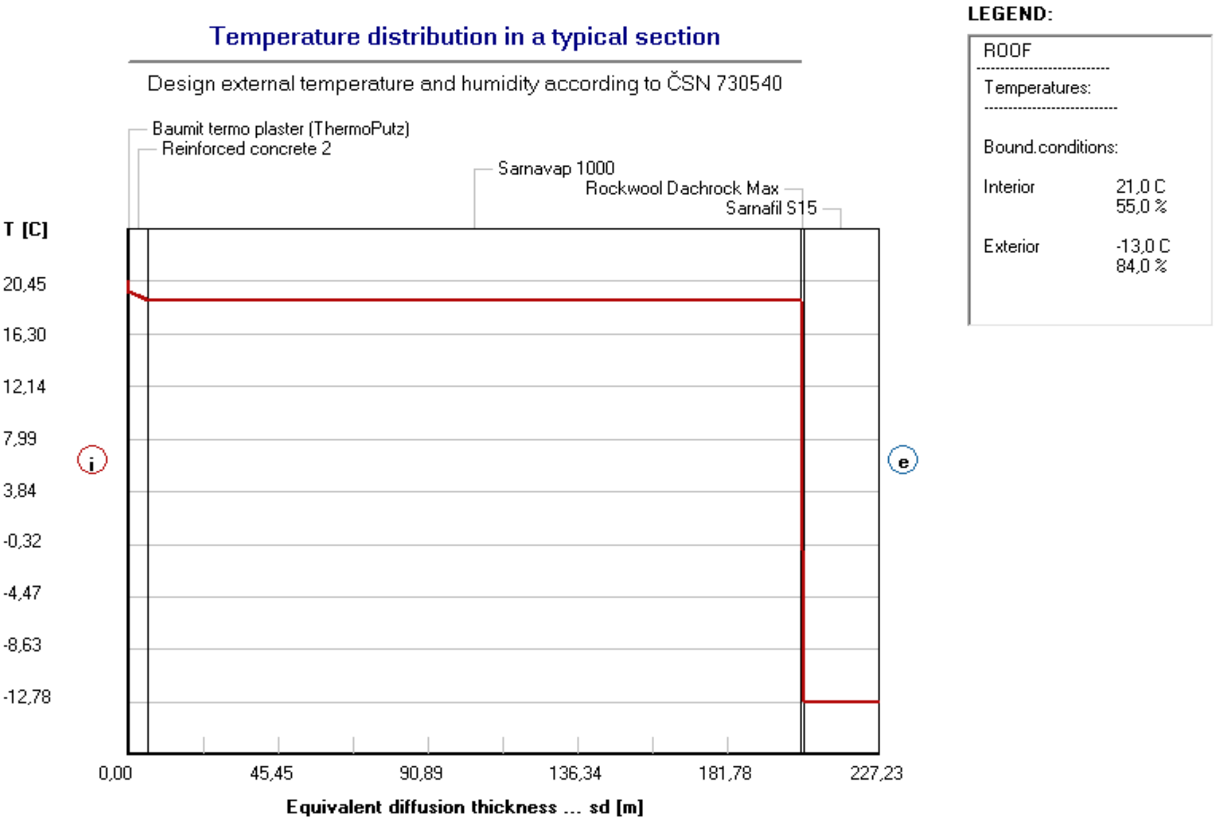
Požadavky:
1. Kondenzace vodní páry nesmí ohrozit funkci konstrukce.
2. Roční množství kondenzátu musí být nižší než roční kapacita odparu.
3. Roční množství kondenzátu Mc,a musí být nižší než 0,1 kg/m2.rok, nebo 3-6% plošné hmotnosti materiálu (nižší z hodnot).

Vypočtené hodnoty: V konstrukci dochází při venkovní návrhové teplotě ke kondenzaci.
V konstrukci nedochází během modelového roku ke kondenzaci.

Vyhodnocení 1. požadavku musí provést projektant.
OSTATNÍ POŽADAVKY JSOU SPLNĚNY.


Vapour pressure distribution in a typical section
Design external temperature and humidity according to ČSN 730540
Baumit termo plaster (ThermoPutz)
Reinforced concrete 2
Sarnavap 1000
Rockwool Dachrock Max
Sarnafil S15
P [Pa]
2403
2124
1844
1564
1285
1005
726
446
166
1.zone
i
e
0,00
45,45
90,89
136,34
181,78
227,23
Equivalent diffusion thickness ... sd [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
Baumit termo plaster (ThermoPutz)
Reinforced concrete 2
Sarnavap 1000
Rockwool Dachrock Max
Sarnafil S15
RH [%]
100
90
80
70
60
50
40
30
20
10
0
i
e
0,00
45,45
90,89
136,34
181,78
227,23
Equivalent diffusion thickness ... sd [m]
LEGEND:
ROOF
Rel.humidity distribution:
Bound.conditions:
Interior 21,0 C
55,0 %
Exterior -13,0 C
84,0 %



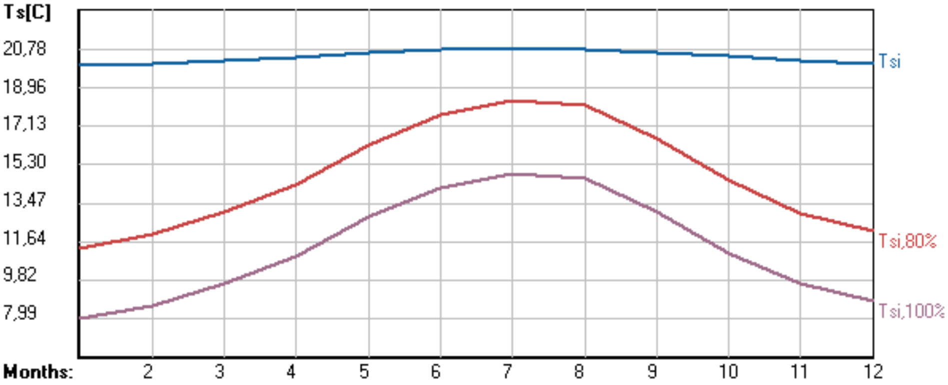
LEGEND:

ROOF

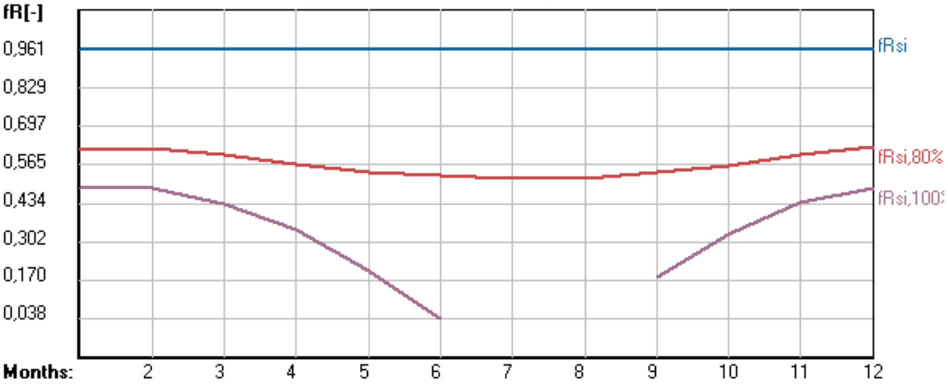
Temperatures:

Bound.conditions:

Interior	21,0 C 55,0 %
Exterior	-13,0 C 84,0 %



Minimal required and calculated internal surface temperature



Minimal required and calculated temperature factor fRsi

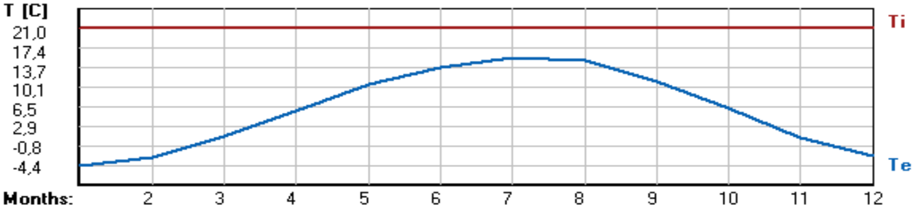
LEGEND:

ROOF

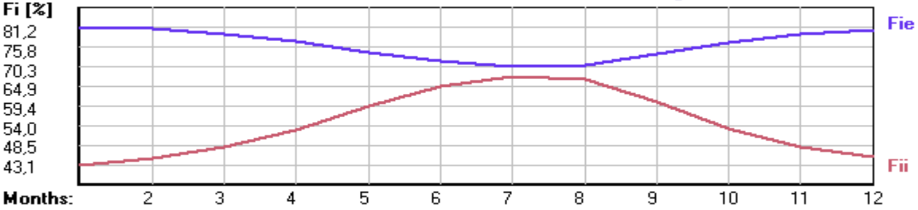
Surf.temperatures
and temp. factor:

Values for maximum
surface relative humidity:

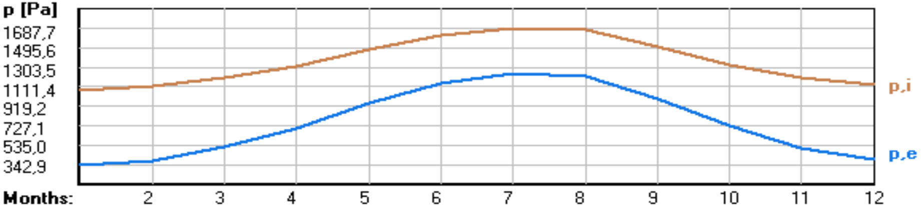
- 80% (preventing mould growth)
- 99% (preventing surface condensation)
- Calculated values



Internal and external temperatures for calculation according to EN ISO 13788



Internal and external relative humidities for calculation according to EN ISO 13788



Internal and external partial vapor pressures for calculation according to EN ISO 13788

LEGEND:

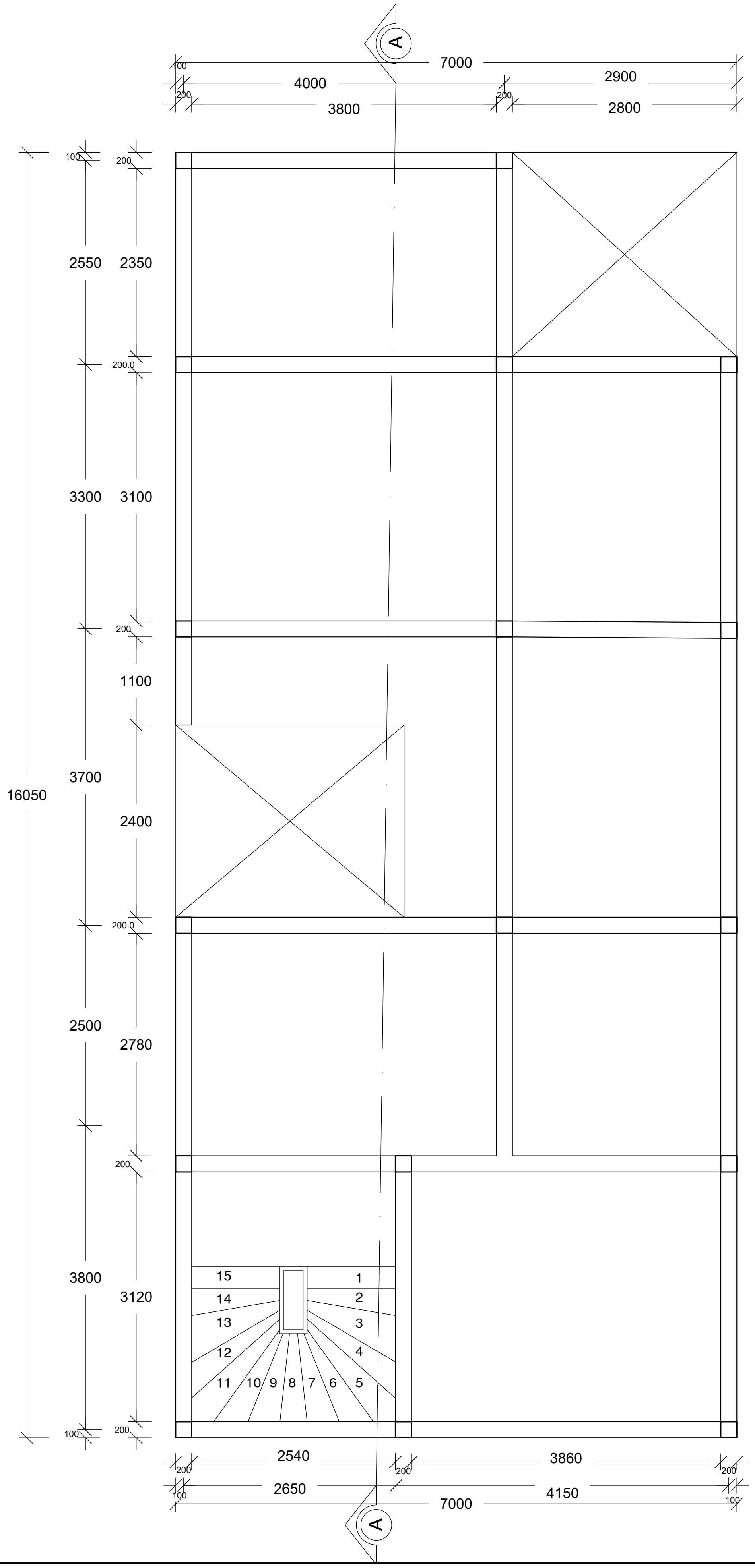
ROOF

Bound.conditions:

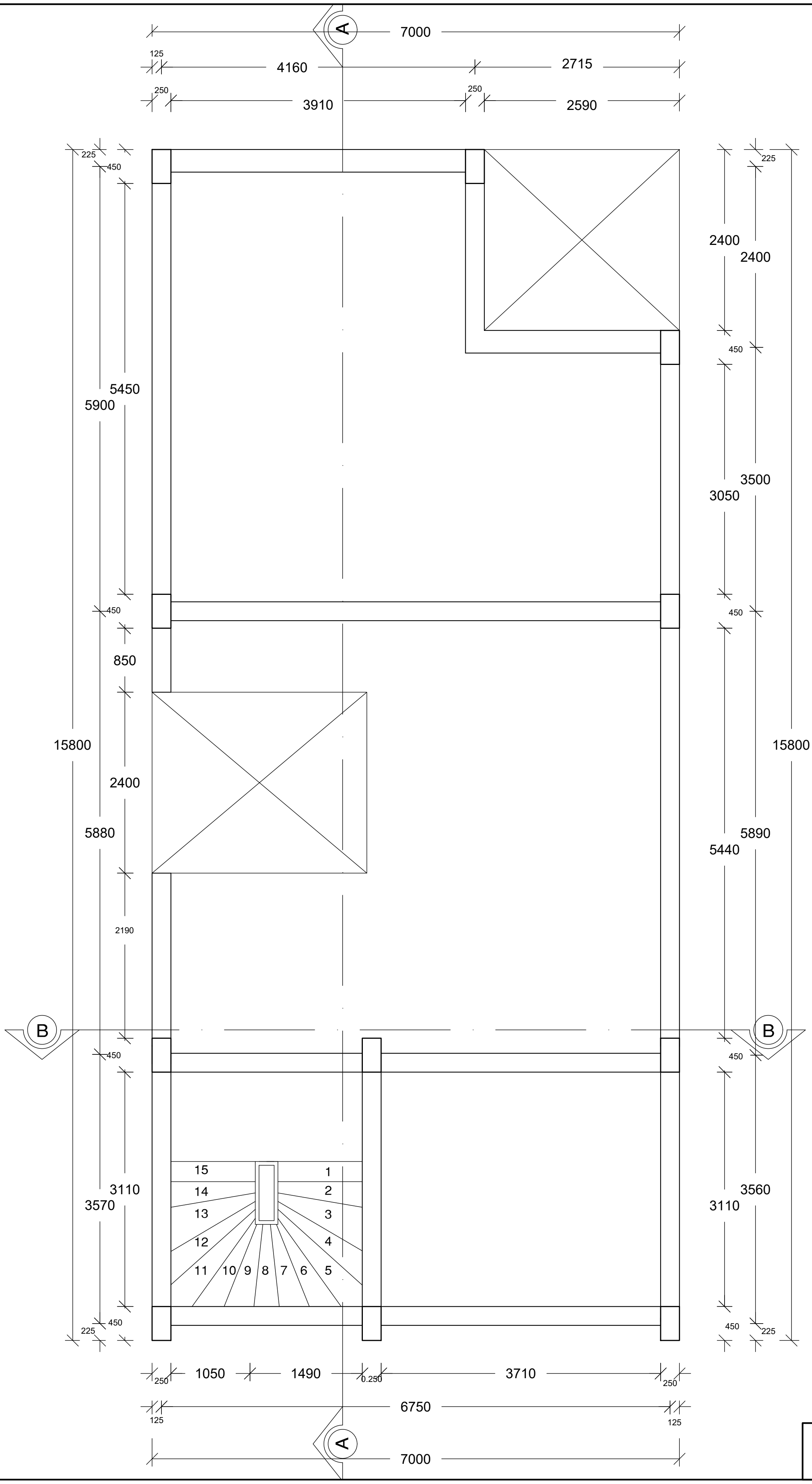
Number of years: 1
Starting month: 1

Appendix C:

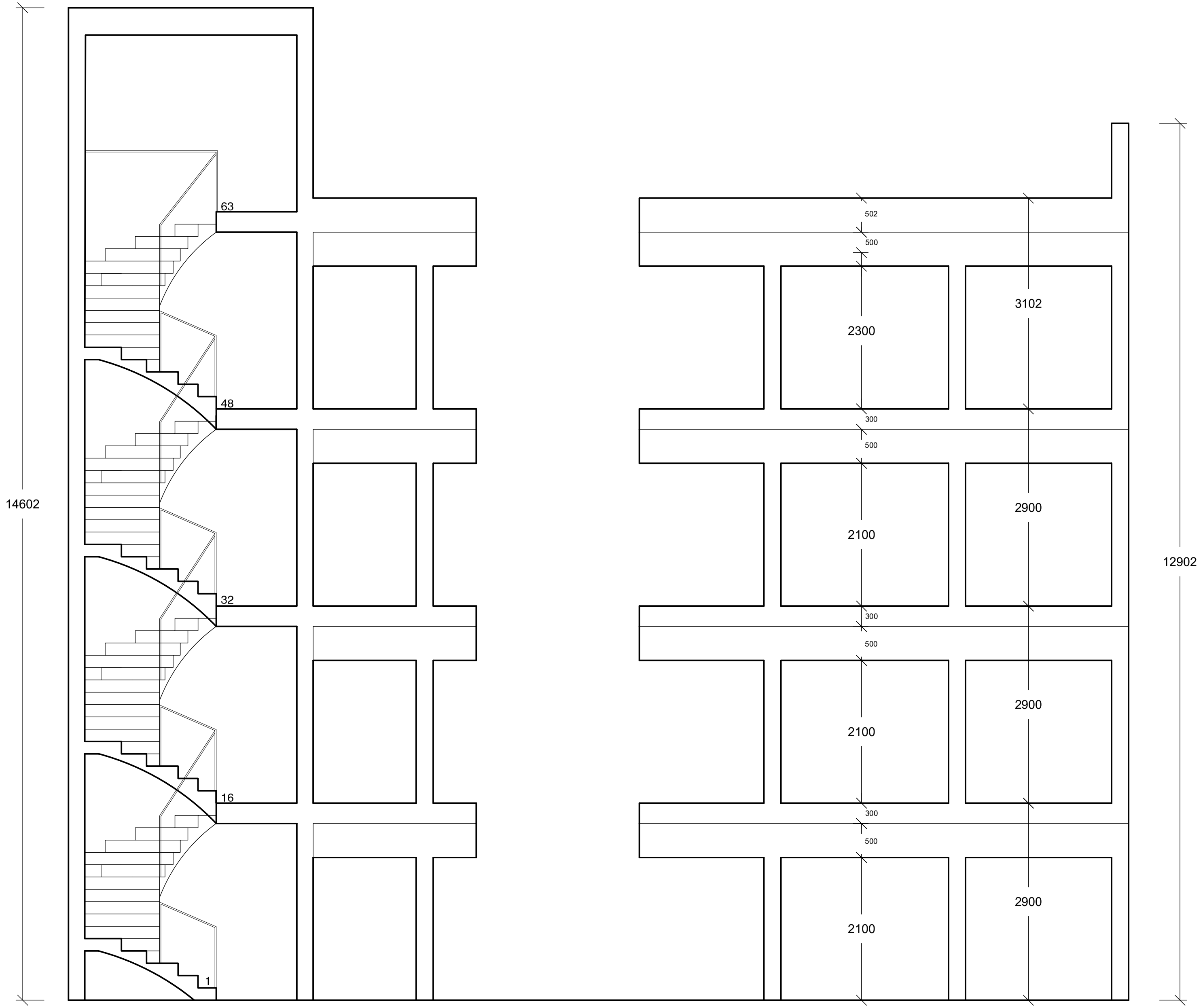
The structural scheme for all the four systems are presented on the following pages:



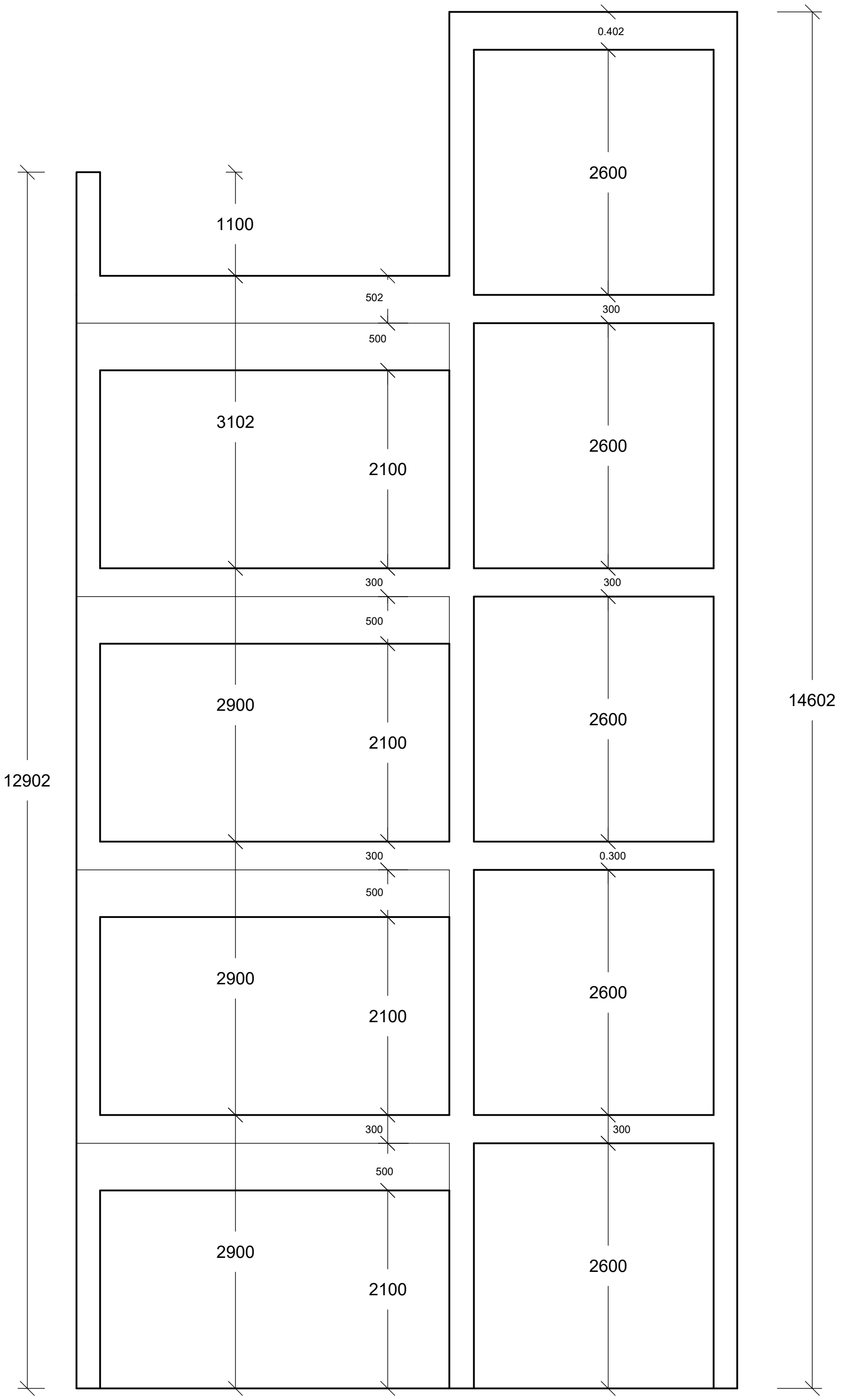
Bearing
Structure-1-Plan



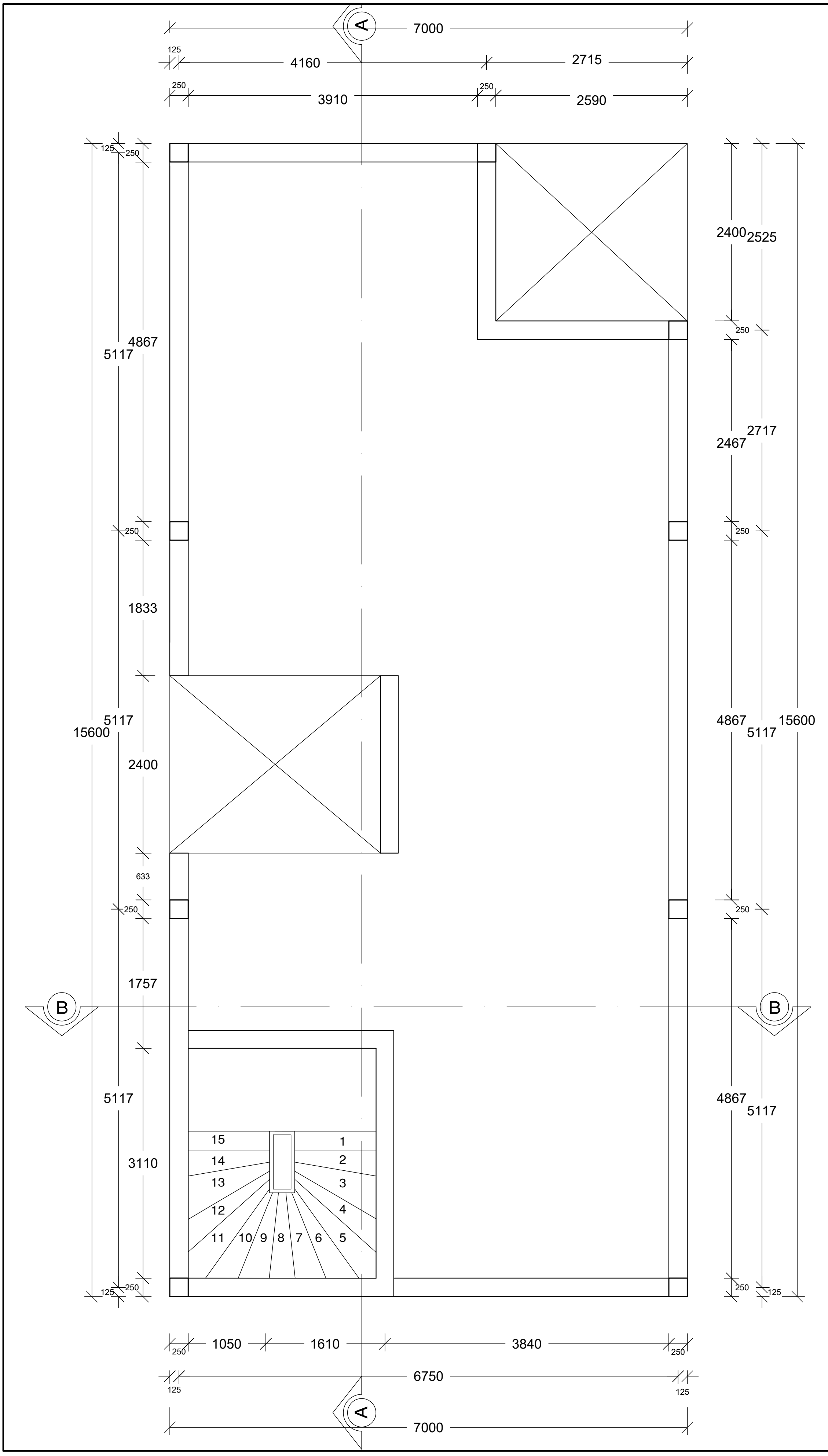
Bearing
Structure-2-Plan



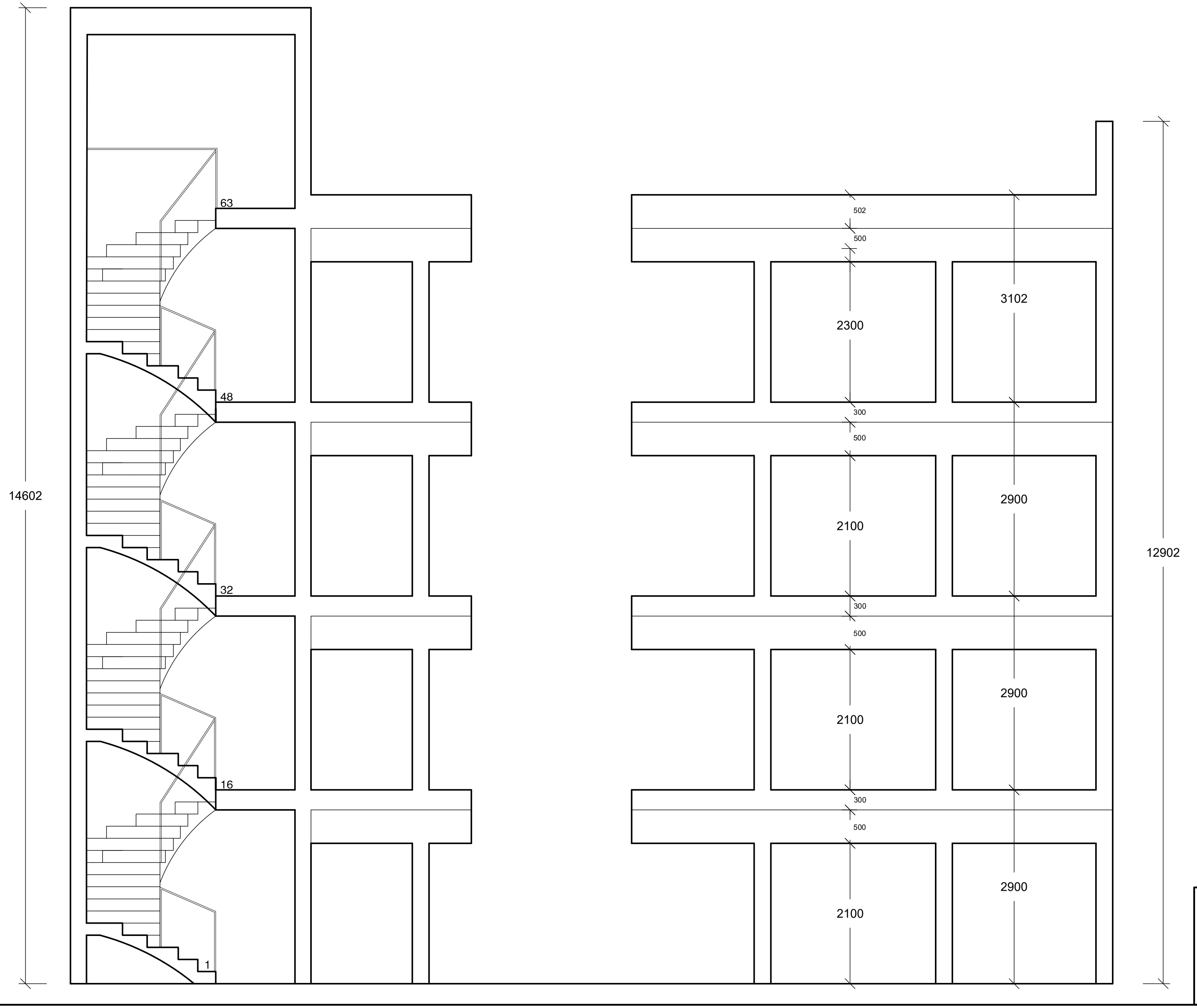
Bearing Structure-2-Section A-A



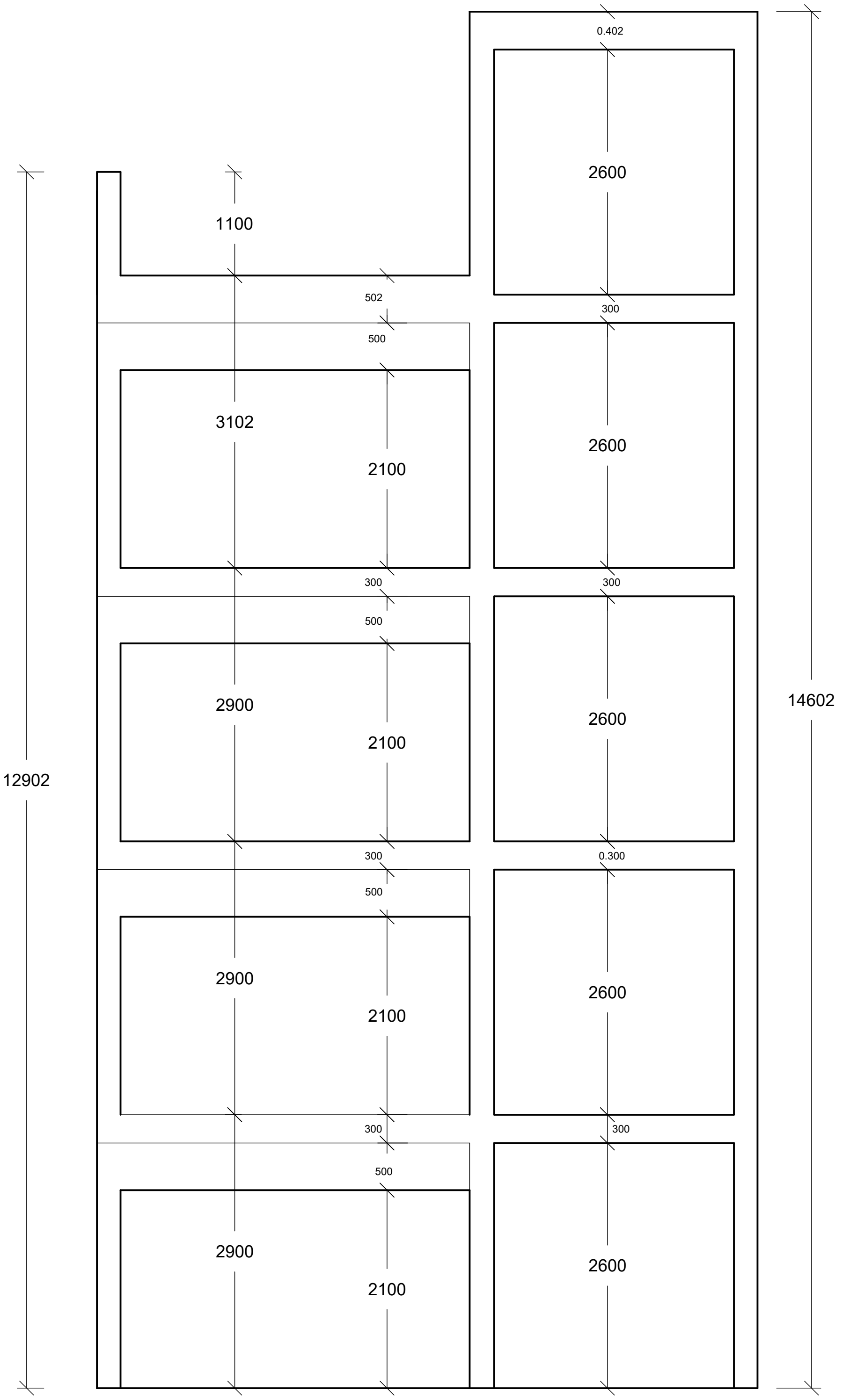
Bearing
Structure-2-Section
B-B



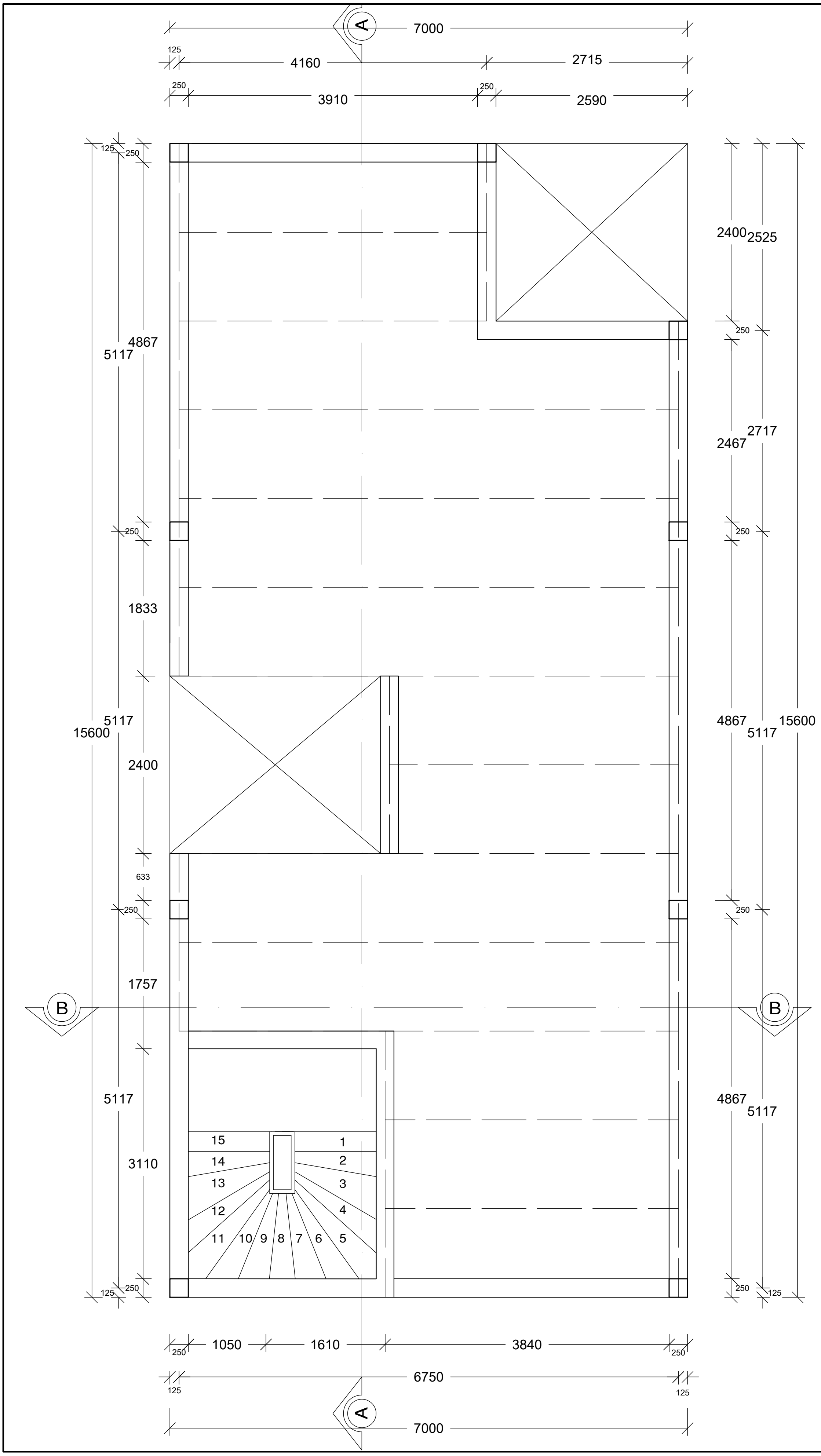
Bearing
Structure-3-Plan



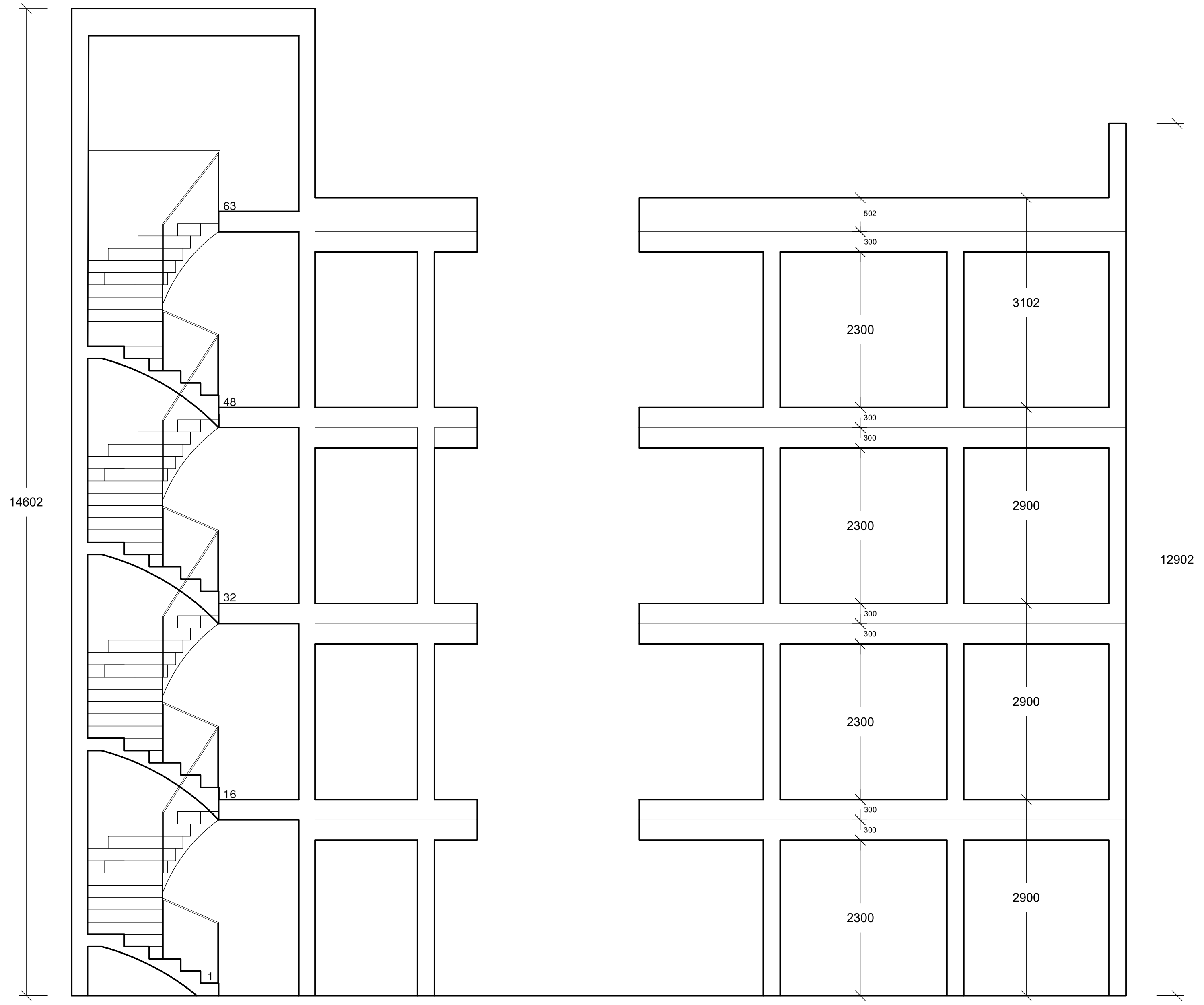
Bearing
Structure-3-Section
A-A



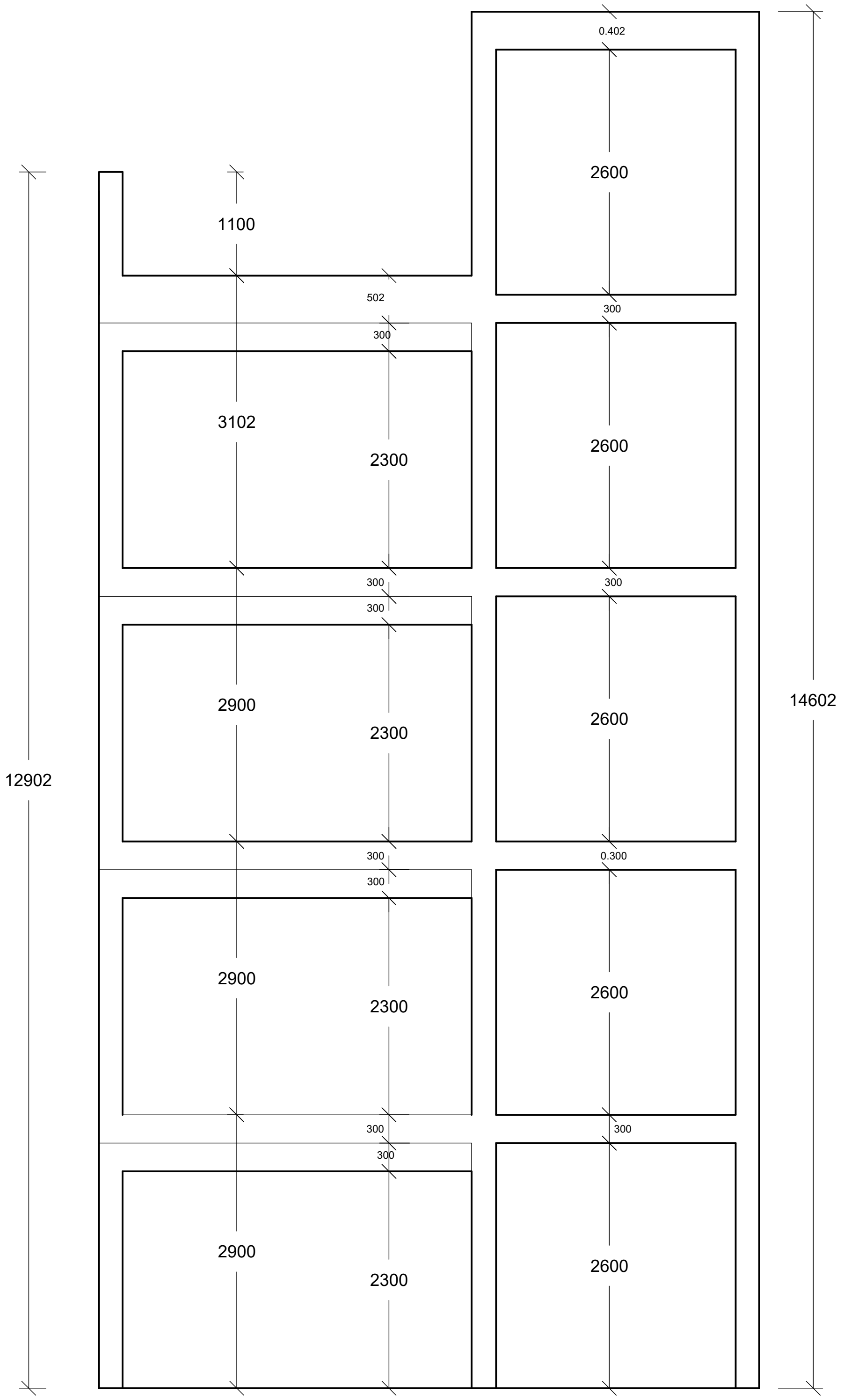
Bearing
Structure-3-Section
B-B



Bearing
Structure-4-Plan



Bearing Structure-4-Section A-A



Bearing
Structure-4-Section
B-B