VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
BRNO UNIVERSITY OF TECHNOLOGY

FAKULTA STAVEBNÍ
ÚSTAV BETONOVÝCH A ZDĚNÝCH KONSTRUKCÍ

FACULTY OF CIVIL ENGINEERING
INSTITUTE OF CONCRETE AND MASONRY STRUCTURES

STATIC SOLUTION OF REINFORCED CONCRETE CEILING CONSTRUCTION OF PEDESTRIAN SUBWAY

STATICKÉ ŘEŠENÍ ŽELEZOBETONOVÉ STROPNÍ KONSTRUKCE PODCHODU

BAKALÁŘSKÁ PRÁCE
BACHELOR'S THESIS

AUTOR PRÁCE
AUTHOR
PETR MAŠEK

VEDOUCÍ PRÁCE
SUPERVISOR
Ing. MARTIN ZLÁMAL, Ph.D.

BRNO 2016

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
FAKULTA STAVEBNÍ

Studijní program	B3607 Civil Engineering
Typ studijního programu	Bakalářský studijní program s výukou v anglickém jazyce a prezenční formou studia
Studijní obor	3608R001 Pozemní stavby
Pracoviště	Ústav betonových a zděných konstrukcí

ZADÁNÍ BAKALÁŘSKÉ PRÁCE

Student	Petr Mašek
Název	Statické řešení železobetonové stropní konstrukce podchodu
Vedoucí bakalářské práce	Ing. Martin Zlámal, Ph.D.
Datum zadání bakalářské práce	30. 11. 2015
Datum odevzdání bakalářské práce	27. 5. 2016

V Brně dne 30. 11. 2015

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prof. RNDr. Ing. Petr Štěpánek, CSc. Vedoucí ústavu	prof. Ing. Rostislav Drochytka, CSc., MBA Děkan Fakulty stavební VUT

Podklady a literatura

Platné normy:
- ČSN EN 1990: Zásady navrhování konstrukcí. 2004
- ČSN EN 1991-1 až 4: Zatížení stavebních konstrukcí. 2004-2007
- ČSN EN 1992-1-1: Navrhování betonových konstrukcí - Část 1-1: Obecná pravidla a pravidla pro pozemní stavby. 2006

Další potřebná literatura po dohodě s vedoucím diplomové práce.

Zásady pro vypracování

Bakalářská práce musí být vypracována v plném rozsahu dle požadavků zadání a dle platných norem. Vypracujte statické řešení zastropení podchodu, nadimenzujte vybrané prvky železobetonové konstrukce dle zadání vedoucího práce a proveďte jejich posouzení dle mezního stavu únosnosti. Dále vypracujte výkresy tvaru konstrukce a výztuže počítaných prvků.

Ostatní úpravy provádějte podle pokynů vedoucího bakalářské práce.

Požadované výstupy:
Textová část (obsahuje průvodní zprávu a ostatní náležitosti podle níže uvedených směrnic)
Přílohy textové části:
P1. Použité podklady
P2. Statický výpočet (v rozsahu určeném vedoucím bakalářské práce)
P3. Přílohy ke statickému výpočtu
P4. Výkresy - přehledné, podrobné a detaily (v rozsahu určeném vedoucím bakalářské práce).

Prohlášení o shodě listinné a elektronické formy VŠKP (1x).
Popisný soubor závěrečné práce (1x).
Bakalářské práce bude odevzdána v listinné a elektronické formě podle směrnic a 1x na CD.

Struktura bakalářské/diplomové práce

VŠKP vypracujte a rozčleňte podle dále uvedené struktury:

1. Textová část VŠKP zpracovaná podle Směrnice rektora "Úprava, odevzdávání, zveřejňování a uchovávání vysokoškolských kvalifikačních prací" a Směrnice děkana "Úprava, odevzdávání, zveřejňování a uchovávání vysokoškolských kvalifikačních prací na FAST VUT" (povinná součást VŠKP).
2. Přílohy textové části VŠKP zpracované podle Směrnice rektora "Úprava, odevzdávání, zveřejňování a uchovávání vysokoškolských kvalifikačních prací" a Směrnice děkana "Úprava, odevzdávání, zveřejňování a uchovávání vysokoškolských kvalifikačních prací na FAST VUT" (nepovinná součást VŠKP v případě, že přílohy nejsou součástí textové části VŠKP, ale textovou část doplňují).

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Ing. Martin Zlámal, Ph.D.
Vedoucí bakalářské práce

Abstract

This bachelor`s thesis deals with design of a reinforced concrete structure of a pedestrian subway, which is connecting two newly built administrative buildings in a new business area of the city. The subway structure is taking over a four lane urban road and inside it enables a free passage for pedestrians between both administrative buildings. The frame structure fixed to the foundation strips was chosen as the best solution. The structure was assessed according to valid European norms. General and detailed drawing documentation is also part of the thesis.

Keywords

Reinforced concrete, pedestrian subway, structural analysis, drawing documentation, frame structure, foundation strips

Abstrakt

Tato bakalářská práce se zabývá návrhem železobetonového podchodu pro chodce, který spojuje dvě nově stavěné administrativní budovy v nové obchodní části města. Konstrukce podchodu převádí čtyřproudovou komunikaci a uvnitř umožňuje volný pohyb chodců mezi oběma budovami. Rámová konstrukce vetknutá do základových pásů byla zvolena jako nejlepší řešení. Konstrukce byla posouzená podle platných evropských norem. Přehledná a podrobná výkresová dokumentace je také součástí práce.

Klíčová slova

Železobeton, podchod pro chodce, statický výpočet, výkresová dokumentace, rámová konstrukce, základové pásy

Bibliographic quotations

Petr Mašek *Static solution of reinforced concrete ceiling construction of pedestrian subway*. Brno, 2016. 24 p., 147 p. ann. Bachelor's thesis. Brno university of technology, Faculty of civil engineering, Institute of concrete and masonry structures. Supervisor Ing. Martin Zlámal, Ph.D.

Bibliografická citace VŠKP

Petr Mašek *Statické řešení železobetonové stropní konstrukce podchodu.* Brno, 2016. 24 s., 147 s. příl. Bakalářská práce. Vysoké učení technické v Brně, Fakulta stavební, Ústav betonových a zděných konstrukcí. Vedoucí práce Ing. Martin Zlámal, Ph.D.

Statement:

I am stating, that bachelor’s thesis handed in electronic form is identical with one handed in printed version.

In Brno day 25.5.2016

Prohlášení:

Prohlašuji, že elektronická forma odevzdané bakalářské práce je shodná s odevzdanou listinnou formou.

V Brně dne 25.5.2016

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podpis autora / signature of the author

Petr Mašek

Acknowledgement

In this way I would like to express thanks to my supervisor, Ing. Martin Zlámal, Ph.D. for the professional assistance with a structure assesment. Next I would like to express thanks to doc. Ing. Ladislav Klusáček, CSc. for his professional assistance with load combinations.

Poděkování

Touto cestou bych chtěl poděkovat mému vedoucímu, panu Ing. Martinu Zlámalovi, Ph.D., za odbornou pomoc při posuzování konstrukce. Déle bych chtěl poděkovat panu doc. Ing. Ladislavu Klusáčkovi, CSc. za odbornou pomoc se zatěžovacími kombinacemi.

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INTRODUCTION

This bachelor`s thesis deals with design of a reinforced concrete structure of a pedestrian subway, which is connecting two newly built administrative buildings in new business area of the city. The subway structure is taking over a four lane urban road with wide sidewalks on both sides of the road. Inside it enables a free passage for pedestrians between both administrative buildings.

A frame structure fixed to foundation strips was chosen as the best solution. For this solution were done two models. The first was a beam model done by a method of effective breadth, where all loads were recalculated on the breadth 1.000 m. On this model were checked the proposed dimensions, possible loads and an overview of the structure behavior was obtained. The second was a more precise spatial slab model, which was essential for consequential structural design. For this solution was done a structural analysis on ultimate limit state (ULS) and serviceability limit state (SLS) according to valid norms ČSN EN. Next general and detailed project documentation has been done, which gives information about the location of the structure, geometry of load-bearing structure, foundations and reinforcement in it.

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TECHNICAL REPORT

BAKALÁŘSKÁ PRÁCE
BACHELOR'S THESIS

AUTOR PRÁCE PETR MAŠEK
AUTHOR

VEDOUCÍ PRÁCE Ing. MARTIN ZLÁMAL, Ph.D.
SUPERVISOR

BRNO 2016

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1 IDENTIFICATION DATA

Construction:	New business area
Object of the construction:	213 – Pedestrian subway connecting two administrative buildings under the urban road no. 635
Cadastral municipality:	Olomouc
Region:	Olomouc
Investor:	GEMO DEVELOPMENT, spol. s.r.o. Dlouhá 562/22, Lazce 779 00 Olomouc
Administrator:	GEMO DEVELOPMENT, spol. s.r.o. Dlouhá 562/22, Lazce 779 00 Olomouc

2 GENERAL INFORMATION

Material:	Reinforced concrete
Type of transport:	Road
Type of obstacle:	Pedestrian subway
Duration:	Permanent
Change of location:	Not movable
Type of structure:	Frame
Clear span:	12.000 m
Effective span:	12.600 m
Length of the LB structure:	13.720 m
Length of the structure:	19.440 m
Height:	≈ 3.850 m
Clear height:	2.850 m
Width of the LB structure:	23.000 m
Width of the structure:	23.000 m
Crossing angle:	100g

3 EXPLANATION OF THE STRUCTURE

3.1 CHANGES ACCORDING TO ASSIGNMENT

An assignment was given just on the ceiling construction of the pedestrian subway, because was intended to solve the ceiling slab as a simple supported, but later on has shown, that more efficient solution is to solve it as a frame. From this reason are also designed frame walls. In consequence was agreed, that also foundations are going to be designed to complete the project of the pedestrian subway.

3.2 ROAD CHARACTERISTICS

Pedestrian subway is located in the new a business area in Olomouc. It is an urban road, with the width 23.000 m and with design speed 50 km/h. Road is in a constant longitudinal slope 1.0 %. Transversal slope is 2.5 % on both sides of the road the same and it is going from the point with the maximal thickness of the ceiling slab in the place of road axis to the place, where is the minimal thickness of the ceiling slab. Under sidewalks the transversal slope of the ceiling slab structure is 2.0 % and the slope is going from the face of the ceiling slab to the place with the minimal thickness of the ceiling slab.

Altitude 209.500 m above sea level is at the point, where vertical alignment of the road and the axis of the pedestrian subway meet.

Width configuration of the road:

- Left cornice with public sidewalk	3.000 m
- Roadside	0.500 m
- Guiding strip	0.250 m
- Traffic lane	3.000 m
- Traffic lane	3.000 m
- Guiding strip	0.250 m
- Roadside	0.500 m
- Middle strip	2.000 m
- Roadside	0.500 m
- Guiding strip	0.250 m
- Traffic lane	3.000 m

-	Traffic lane	3.000 m
-	Guiding strip	0.250 m
-	Roadside	0.500 m
-	Right cornice with public sidewalk	3.000 m
	Overall	**23.000 m**

3.3 GEOTECHNICAL AND HYDROGEOLOGICAL CONDITIONS

One geological penetration probe (J-332) was performed to a depth of 8 m below ground level.

Geotechnical profile:

-	0.0 – 0.2	Humus soil with roots	(MLO)
-	0.2 – 1.8	Gravelly clay	(F2 CG)
-	1.8 – 4.9	Gravel with admixture of fine soil	(G3 GF)
-	4.9 – 6.4	Siltstone	(R6)
-	6.4 – 8.0	Siltstone	(R5)

The level of groundwater was found at a depth of 7.200 m below ground level.

Based on the information above, the load-bearing capacity of the foundation joint was assessed on R_{dt} = 520 kPa.

4 TECHNICAL SOLUTION

4.1 MATERIALS

Blinding concrete	C16/20 XC2
Foundation strips	C25/30 XC2
Load-bearing structure	C30/37 XF2
Cornices (sidewalks)	C30/37 XF4
Approach slabs	C25/30 XF1

Reinforcement steel B500B

4.2 DESCRIPTION OF SUBWAY CONSTRUCTION

4.2.1 GROUND WORKS

In all places of intended excavations will be removed topsoil to a depth of 0.300 m. Then the actual excavation will start. Excavated material will be taken on a dump. Construction pit will have a slope inclination 1:1. The bottom of the excavation pit will be in comparison with floor plan dimensions of the foundations expanded by 0.700 m, because of the more comfortable work on the foundation strips. Construction pit must be properly drained. Blinding concrete slab is made of concrete C16/20, thickness 0.100 m and with overlaps 0.100 m according to the floor plan foundation dimensions. The backfill behind the frame walls is made of compacted gravel G1 GW. Materials must be frost-free. Compaction is done properly according to standard sheets.

4.2.2 FOUNDATIONS

Structure is founded on the reinforced concrete foundation strips (concrete C25/30) width 3.200 m, height 0.800 m and length 23.000 m. Foundation strips are done in the same horizontal.

4.2.3 LOAD-BEARING STRUCTURE

Load-bearing structure is a reinforced concrete frame (concrete C30/37) with a span 12.600 m and width 23.000 m. Thickness of the walls is 0.600 m. Thickness of the ceiling slab is variable. Minimal thickness 0.400 m is in distance 3.250 m from the side edge of the construction, at the place where transversal slopes are changing. Maximal thickness 0.606 m is in the middle of the structure, at the place of road axis. The frame has on both sides haunch with the axis length 2.300 m (2.000 m from the inner face of the wall) and the height difference between the midline of the slab and the midline of the haunch is 0.150 m. This solution is chosen because of better structural properties. Length of the middle part between haunches is 8.000 m. Thickness of the walls is 0.600 and each wall has a different height. In transversal direction the upper surface of the load bearing structure follows slope arrangement of carriageway 2.50 % and sidewalks 2 % going in opposite direction. The bottom surface in transversal direction is horizontal. Both surfaces in longitudinal direction follow longitudinal slope of carriageway 1 %. Bottom surface has just on sides different slopes caused by haunches.

On the outer side of the walls are small cantilevers (length 0.260 m, width 7.500 m) supporting the approach slabs, which are connected to cantilevers through notched joints. Cantilevers follow the upper surface of the load-bearing structure, but they are placed 0.295 m below it. Design lifetime of construction is 100 years.

4.2.4 APPROACH SLAB

The exact approach slab design is not a part of the bachelor's thesis. Design was done according to the standard sheets. Approach slabs are in the slope 10.00 % and to the load-bearing structure are connected by notched joints. Length is 3.000 m, width is 7.400 m, height is 0.250 m. Approach slabs are laying on the 0.100 m thick layer of blinding concrete, with overlaps 0.100 m. Between load-bearing structure and approach slab will be placed extruded polystyrene of th. 0.020 m.

4.2.5 CARRIAGEWAY

Carriageway above the pedestrian subway is designed with two layers and overall thickness 0.090 m.

Carriageway composition:

- Wearing course - SMA 11 PMB	th. 0.040 m
- Connecting spraying	
- Base course - ACO 11 PMB	th. 0.045 m
- Connecting spraying	
- Isolation - AIP	th. 0.005 m
Overall	th. 0.090 m

4.2.6 CORNICES (SIDEWALKS)

On both sides of the road are designed wide monolithic reinforced concrete cornices, because of public sidewalks. The width 3.000 m is the same for both. Also the slope 2.00 % in direction to carriageway is the same for both. Height of the cornices is 0.150 m above the carriageway. Cornices are connected to load-bearing structure by anchors placed in the axial distance 2.000 m. Under the cornices is the isolation AIP placed in two layers.

4.2.7 MIDDLE STRIP

Middle strip is placed in the middle of the road and it is dividing the lanes going in opposite direction. The width is 2.000 m. Middle strip consists of road prefabricated concrete curbs 0.100 x 0.250 m placed into a plain concrete bed and of soil between, where the grass is going to brown.

4.2.8 FLOOR INSIDE THE PEDESTRIAN SUBWAY

Up to the top surface of the foundation strips is compacted gravel, fr. 0 – 32 mm. Compaction is done according to standard sheets. Then is placed 0.100 m thick layer of blinding concrete, on it is casted 0.270 m thick reinforced concrete floor slab, made of concrete C25/30 and on it is placed flooring itself. Floor is in the same horizontal level.

Flooring composition:

- Isolation - AIP	th. 0.005 m
- Concrete screed	th. 0.050 m
- Cement mortar	th. 0.015 m
- Ceramic tiles	th. 0.010 m
Overall	th. 0.080 m

Between floor and load-bearing construction is placed dilatation joint of thickness 0.020 m, which is made of extruded polystyrene (th. 0.020 m), sealed by sealing rubber (diameter 0.030 m) and topped by permanently flexible grout (th. 0.020 m and height also 0.020 m).

4.2.9 INTERIOR OF PEDESTRIAN SUBWAY

On the interior side of the walls and ceiling is 0.015 m layer of a plaster. Lighting is provided by five fluorescent lams symmetrically disposed in the right top corner. Ventilation is ensured by natural way. It is not going to be heated, but some heat is going to come from connected heated halls in the administrative buildings. Expected temperature is 15°C.

4.2.10 PROTECTION OF LAND UP SURFACES

Surfaces, which are going to be land up need to be protected against action of water. From this reason it is going to be protected by one penetration coat, one layer of AIP isolation (th. 0.005 m) and one layer of geotextile.

4.3 CONNECTION OF ADMINISTRATIVE BUILDING AND PEDESTRIAN SUBWAY

Between administrative building and pedestrian subway are done a dilatation joints 0.040 m thick. It is made of extruded polystyrene (th. 0.040 m), sealed by sealing rubber (diameter 0.050 m) and topped by permanently flexible grout (th. 0.040 m and height 0.020 m).

4.4 DEWATERING

Dewatering of the rainwater from the road surface is realized by the surface transversal and longitudinal inclination. Water is going to run beyond the subway structure, where is placed a canalization inlet.

Dewatering of water infiltrated through the carriageway is going to be done by a drainage rib located above external side of foundation strips. Drainage rib is filled by permeable material and fitted by drainage pipe ϕ 0.200 m. Drainage pipe is placed on 0.300 m wide layer of plain concrete C16/20 in a slope 2.0 % inclined to the administrative building “A”. Outlet of the drainage is going to be connected to a canalization of administrative building “A”. Water from the top surface of the ceiling slab is going to be drained by the transversal and longitudinal slope. Whole structure is protected against unfavorable acting of infiltrated water by isolation AIP thickness 0.005 m.

5 STRUCTURAL ANALYSIS

Structural analysis was done in the software SCIA Engineer. In this software were done two main models. The first one was a beam model done by a method of effective breadth. It means, that all loads were recalculated to the 1.000 m breath. A function of this model was to show the behavior of the structure under different types of load and to show the least favorable variable load assembly. The second model is a spatial slab model, there was applied the least favorable variable load assembly, with permanent loads and load from temperature. This model is more precise and more realistically describes the structure behavior. From this reason assessment of the structure and reinforcement design was done according to the slab model. From the beam model were obtained slightly bigger results, imperfections are caused by inaccuracy of load distribution among the breadth of the structure. Construction was assessed on ultimate and serviceability limit states according to valid norms ČSN EN.

6 CONSTRUCTION OF THE PEDESTRIAN SUBWAY

6.1 TECHNOLOGY AND CONSTRUCTION PROCESS

- Preparation of the construction site and removal of topsoil
- Digging of construction pit
- Dewatering of construction pit
- Formwork, tying of reinforcement, concrete casting of foundation strips
- Formwork, tying of reinforcement, concrete casting of the frame walls up to the construction joint
- Floor structure
- Formwork, tying of reinforcement, concrete casting of the rest of walls and the frame ceiling slab
- Isolation
- Backfill and compaction
- Casting of cornices and placement of curbs with soil
- Carriageway
- Internal works – plastering, placement of lams

Structure is divided into three work parts in the transversal direction, the parts on sides have width 9.000 m, the middle part has width 5.000 m. First are going to be build parts on sides and after a technological break will be constructed the middle part of the appropriate work step. This solution is used because of concrete shrinkage. For a proper solution should be carried out an assessment of concrete shrinkage, but it is not a part of this bachelor's thesis. It is necessary to fulfill the technological breaks needed for hardening of concrete.

6.2 RELATIONSHIP WITH THE TERRITORY

Before starting of construction works is necessary to layout all engineering networks. During the construction itself may happen that fuel leaks from machinery. In that case must be immediately tried to prevent intoxication of surroundings.

CONCLUSION

The aim of the bachelor's thesis was to design the ceiling construction of the pedestrian subway connecting two administrative buildings. As the best solution has shown to make a frame structure, from that reason was designed the whole frame, not only ceiling structure and also foundations were added. For this solution were done two models in the software SCIA Engineer. The first was a beam model done by a method of effective breadth, where all loads were recalculated on the breadth 1.000 m. The second was a more precise spatial slab model, which was essential for consequential structural design. Structural analysis was done on ultimate limit state (ULS) and serviceability limit state (SLS) according to valid norms ČSN EN. Calculations were done by hand or in the software Microsoft Excell. In the next step was done general and detailed project documentation. All project documentation was drawn in the software AutoCAD 2016.

LIST OF REFERENCES

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LIST OF USED ABBREVIATIONS AND SYMBOLS

A	cross-section area
A_c	cross-section area of concrete
A_s	cross-section area of steel reinforcement
$A_{s,min}$	minimal cross-sectional area of reinforcement
$A_{s,max}$	maximal cross-sectional area of reinforcement
A_{sw}	cross-section area of shear reinforcement
b_{eff}	effective breadth
c	concrete cover
e	eccentricity
E_s	design value of Young's modulus of steel
E_{cd}	design value of Young's modulus of concrete
F	force (point load)
h	cross-section height
q	continuous load
L	length
M_{Ek}	characteristic value of bending moment
M_{Ed}	design value of bending moment
N_{Ed}	design value of normal force
V_{Ed}	design value of shear force
f_{ck}	characteristic compressive cylinder strength of concrete
f_{cd}	design compressive cylinder strength of concrete
f_{yk}	characteristic yield strength of steel reinforcement
f_{yd}	design yield strength of steel reinforcement
γ_c	partial factor of concrete
γ_s	partial factor of steel reinforcement
ε_{cu3}	limiting strain of concrete in compression
ε_s	reinforcement strain
f_{ctm}	mean value strength of concrete in concentric tension
a	distance
th.	thickness
w	width of lane
σ_s	stress in steel reinforcement

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