Structural design of residential buildings according to Eurocode

M Bešević1, M V Purcar1, L Kozarić1 and S Zivković1

1 Faculty of Civil Engineering Subotica, Subotica, Serbia

* miroslav.besevic@gmail.com

Abstract. In this paper, the dimensioning of the load-bearing structures A, B and C of building complex in the surroundings of Salzburg, Austria is given. The floors of object A are underground floor, ground floor and two floors, and for objects B and C it is underground floor, ground floor, first floor and the attic. These buildings have an underground shared garage. The foundation is 30 cm thick reinforced concrete slab, with capitals 200/200 cm, thickness dpp = 20 cm that are constructed in the middle part of the garage under the columns. Other underground parts of the buildings are the basements of each individual building. In addition to the common garage, the buildings have a common part of the ground floor, which connects the separate buildings. The construction of the garage at ground level is in the form of reinforced concrete slab with thickness dp = 35 cm with reinforcement-capitals under the columns with thickness dkpl. = 20 cm. The foundation and the ground floor slab are separated by an expansion joint in the axis 7. The waterproofing of the ground floor slab is achieved uniquely for the whole slab of the complex. Special attention is paid to the thermal calculation.

1. Introduction

The paper presents an example of design project of structure according to EC standards. The residential building consists of three independent units - building A, B and C, which are shown in figure 1 (situation with buildings). The complex of three buildings is located in the Strasbourg district of Austria, and consists of a common underground garage, basement rooms for each building and floors. The floors of object A are underground floor, ground floor and two floors, and for objects B and C it is underground floor, ground floor, first floor and the attic. Due to the extremely low temperatures at the place of construction of the complex of objects of approx. 3000.00 m², walls of greater thickness (30 cm) were applied with thermal insulation outer layers of thickness diz = 20 cm.

The windows and doors of the balconies are designed with a thermal break bridge to provide savings in heating during the winter. In addition to the thermal insulation of all A, B and C buildings, sound insulation was also taken into account between the apartments and the external noise. Vertical communication in the buildings is achieved by stairs and an elevator. The construction works on buildings are carried out in phases. Access to the complex is made possible from the access road.

Special attention was paid to the thermal disconnection of the floor and balcony slabs, using the certified element "Isokorb" [1], which allows the acceptance of influence on the balcony slab by applying the tightened reinforcement in the upper zone of the balcony slab, as well as receiving the pressure force on the lower part of the floor from high quality concrete reinforced with steel microfibers, which are performed on construction site as strips of width greater than 100 mm.
The layout of the ground floor and view of building A, B and C and cutaway view of the building C are shown in figures 2, 3, 4 and 5 [2].
2. Structure of the building

The main bearing structure is designed in the form of load-bearing reinforced concrete solid slabs, supported by Porotherm load-bearing walls from the ground floor to the roof slabs, vertical columns and elevator reinforced concrete wall panels. Reinforced concrete floor slabs are constructed in-situ and their thickness is: \( d = 22.30 \) cm and \( 35 \) cm. At ground level these slabs are supported by a system of longitudinal and transverse beams for buildings B and C, where beams are supported by basement walls and garage columns, while at building A they are supported on internal walls, columns and beams. The ground floor slab also has capitals in the part of the columns of the garage, measuring \( 200/200 \) cm, the thickness of the capitals \( d_{kp} = 30 \) cm. The foundations is in the form of reinforced concrete slab \( d = 30 \) cm thick with capitals below the columns \( d_{kp} = 20 \) cm. The foundation slab is divided into two parts - by expansion in axis 7. The connection of the parts of the foundation slab is achieved by specially built horizontal anchors in the middle of the thickness of the slab. Underneath the slab and walls of the building complex, a unique classic waterproofing is envisaged with the help of the waterproofing of the concrete foundation slab.

The following loads were analyzed in the structure calculation of the building:

- imposed load \( = 2.0 \) kN/m\(^2\),
- snow load \( = 3.93 \) kN/m\(^2\),
- partition walls \( = 1.20 \) kN/m\(^2\),
- floor layers \( = 2.50 \) kN/m\(^2\),
- wind load \( = 0.80 \) kN/m\(^2\),
- balconies \( = 4.00 \) kN/m\(^2\),
- seismic loading is irrelevant,
- the self-weight of the structure is taken into account by the program.
3. Structural analysis

The calculation of the structure included the calculation of the foundation slab of the garage and complete buildings A, B and C. Figure 6 shows a 3D model of a structure.

Dimensioning of structural bearing elements was carried out for the relevant influences according to load combinations, in all as shown in the static calculation. For simplicity of construction, the reinforcements in lower zone were Ø 12/15, in both directions and additional reinforcement is Ø 10/15 at an angle of 90° and in the upper zone Ø 7/10 and additional reinforcement above the columns Ø 20/12.5, and in middle of the slabs Ø 12/15. Reinforcements was shown in figure 7 and figure 8. The concrete class of all load-bearing structural elements of the structure, cast on site, is C25/30, and reinforcement B500.

![3D Model](image_url)

**Figure 6.** 3D model.

![Reinforcement Diagram](image_url)

**Figure 7.** Reinforcement of the slab – lower zone.
the Schöck BOLE system was used. The following text shows the calculation [3]:

\[ V_{Ed} = 930 \text{ kN} \]

Special attention was paid for checking punching shear of the slab. The certified computer program the Schöck BOLE system was used. The following text shows the calculation [3]:

**Force**

- Punching shear load: \( V_{Ed} = 930 \text{ kN} \)
- Dynamic part: \( V_{Ed,dy} = 0 \text{ kN} \)
- Load increasing factor: \( \beta = 1.15 \)

**Dimensions – Column**

- Width of the column: \( a = 250 \text{ mm} \)
- Thickness of the column: \( b = 200 \text{ mm} \)
- Thickness of the slab: \( h = 300 \text{ mm} \)
- Statical height: \( d = 270 \text{ mm} \)
- Concrete protection layer: \( c_o; c_u = 20; 20 \text{ mm} \)

**Material**

- Concrete: \( C35/45 (f_{ck}=35 \text{ N/mm}^2) \)
- Steel: \( B500 (f_{ak}=500 \text{ N/mm}^2) \)
- Reinforcement: \( \rho = 0.78% \)
- \( A_{as} = 20.9 \text{ cm}^2/m (\varnothing 20/150 \text{ mm}); A_{as} = 20.9 \text{ cm}^2/m (\varnothing 20/150 \text{ mm}) \)

**Punching shear calculation DS EN EC2:2015 + NA:2017 + ETA(\gamma=0.95)**

- Factor \( k \): \( k = \text{min} \{1+(d-200)/1000 \{\min 1.0; \max 1.6\} = 1.07 \)
- Influence of the slab width: \( \eta = 1+(d-200)/1000 \{\min 1.0; \max 1.6\} = 1.07 \)
- Factor \( C_{RD,c} \): \( C_{RD,c} = 0.18/\gamma_c = 0.12 \)
- Minimum load-bearing capacity of concrete: \( v_{min} = (0.0525/\gamma_c)^{\frac{k}{2}} f_{ck}^{\frac{3}{2}} = 525.5 \text{ kN/m}^2 \)
- Load-bearing capacity of concrete: \( V_{Rd,c} = \text{max} \{C_{RD,c} x (\rho x f_{ak})^{\frac{1}{2}}; v_{min}\} = 671.1 \text{ kN/m}^2 \)
- Edge of the column \( u_o \): \( u_o = 0.900 \text{ m} \)
- Perimeter of cross section: \( u_o = 0.900 \text{ m} \)
- Load-bearing capacity of concrete: \( V_{Rd,c,max,uo} = 0.4 v x f_{ed} = 4816.0 \text{ kN/m}^2 \)
- Load-bearing capacity of concrete: \( V_{Rd,c,max,uo} = V_{Rd,c,max,uo} d x u_o = 1170.3 \text{ kN} \)
Critical circular cross section $u_{crit}$

Critical distance

Range of circular cross section

Transverse force

Load-bearing capacity of concrete

Maximum load-bearing capacity

$\min \{ V_{Rd,c, crit}; V_{Rd,c, max, uo} \}$

**Punching shear reinforcement required!**

Chosen: $8 \times $Schock BOLE U 20/260-3/A570-CV20

Proof of load-bearing capacity of steel

External circular cross section

Length of reinforced area

Range of circular cross section

Load increasing factor

Transverse force

Load-bearing capacity of concrete

Load-bearing capacity of concrete

$\min \{ V_{Rd,c, crit}; V_{Rd,c, max, uo} \}$

**Punching shear reinforcement sufficient!**

---

4. Thermal bridges in buildings

At low outdoor temperatures, such as is the case for the location of the above buildings, in the area of insufficient insulated connections the surface temperature in the interior of the building decreases more than in other areas. Thermal bridges are created in these places, with two types being distinguished:

- material-induced thermal bridges that occur when building elements of significantly different thermal conductivity are found next to one another;
- geometric thermal bridges, which arise when the surface that gives the heat is much larger than the one that receives the heat.

Particularly critical areas are balconies-terraces, because they are conditioned by the material and geometry conditioned thermal bridges. Condensation is created in the area of the thermal bridge, which leads to permanent damage to the ceilings and walls of the apartments. The consequence of thermal bridges is higher energy consumption, which in turn has the effect of increasing the heating costs of the building but also increasing the environmental impact. This structural design uses the certified...
innovative element Schöck Isokorb. Schöck refers to solutions to problems in the field of structural physics, statics and structures. Also, this innovative element is used in the areas of thermal insulation and sound protection in new buildings. The following figures 10 and 11 show the effects of heat with and without a thermal bridge.

![Figure 10](image1.png) **Figure 10.** Without thermal bridge interruption.  
![Figure 11](image2.png) **Figure 11.** With thermal bridge interruption.

The Isokorb, Novomur and Tronsol Schöck product groups represent outstanding solutions, the latest technology. Figures 12, 13 and 14 show the static influences in the balcony-terrace by applying this system to one terrace of object A and also, there is the case of slab-slabs, balcony length l = 7.00 m and cantilever a = 1.94 m.

![Figure 12](image3.png) **Figure 12.** Loading of the balcony.  
![Figure 13](image4.png) **Figure 13.** Reinforcement in the slab.

![Figure 14](image5.png) **Figure 14.** Balcony with thermal bridge interruption.

The bending moment of the cantilever (balcony) is accepted by the coupling of internal forces, tension and pressure.

In the upper zone, the tensile force receives the reinforcement and the pressure force is transmitted directly through the lower part of the innovative element of the Shock Bole. The balcony slab is made of high grade steel fiber. Figure 15 gives a detail of the construction of the balcony with the application of the innovative solution.
The installation of Schöck Isokorb in the balcony connection area interrupts the thermal conductivity of the reinforced concrete slab. The thermal bridge was constructively broken and the energy flow at the critical location was minimized.

5. Conclusion
This paper analyses in detail the static analysis and optimized dimensioning of reinforced concrete structural elements. According to the EC code, the punching shear strength of the slab was also analysed and one of the methods of punching protection was adopted. Section 4 deals with thermal bridges and methods of reducing the influence heat transfer from the structural elements of the balcony-terraces with the interior reinforced-concrete slabs of the floors of the buildings.

Acknowledgement
The present work has been supported by The Ministry of Education and Science of the Republic of Serbia (Project No. ON174027).

References
[1] Sertifikat Bauteile GmbH, Austrija in Schöck Bauteile GmbHBaden-Baden Nemacka Isokorb XT bzw. T Typen H
[2] Besevic M and Gajic M Structural design of buildings A, B and C at Salzburg Austria
[3] Eurocode 2 Design of concrete structures - Part 1-1: General rules and rules for buildings European Committee for Standardization (CEN) Brussels Belgium