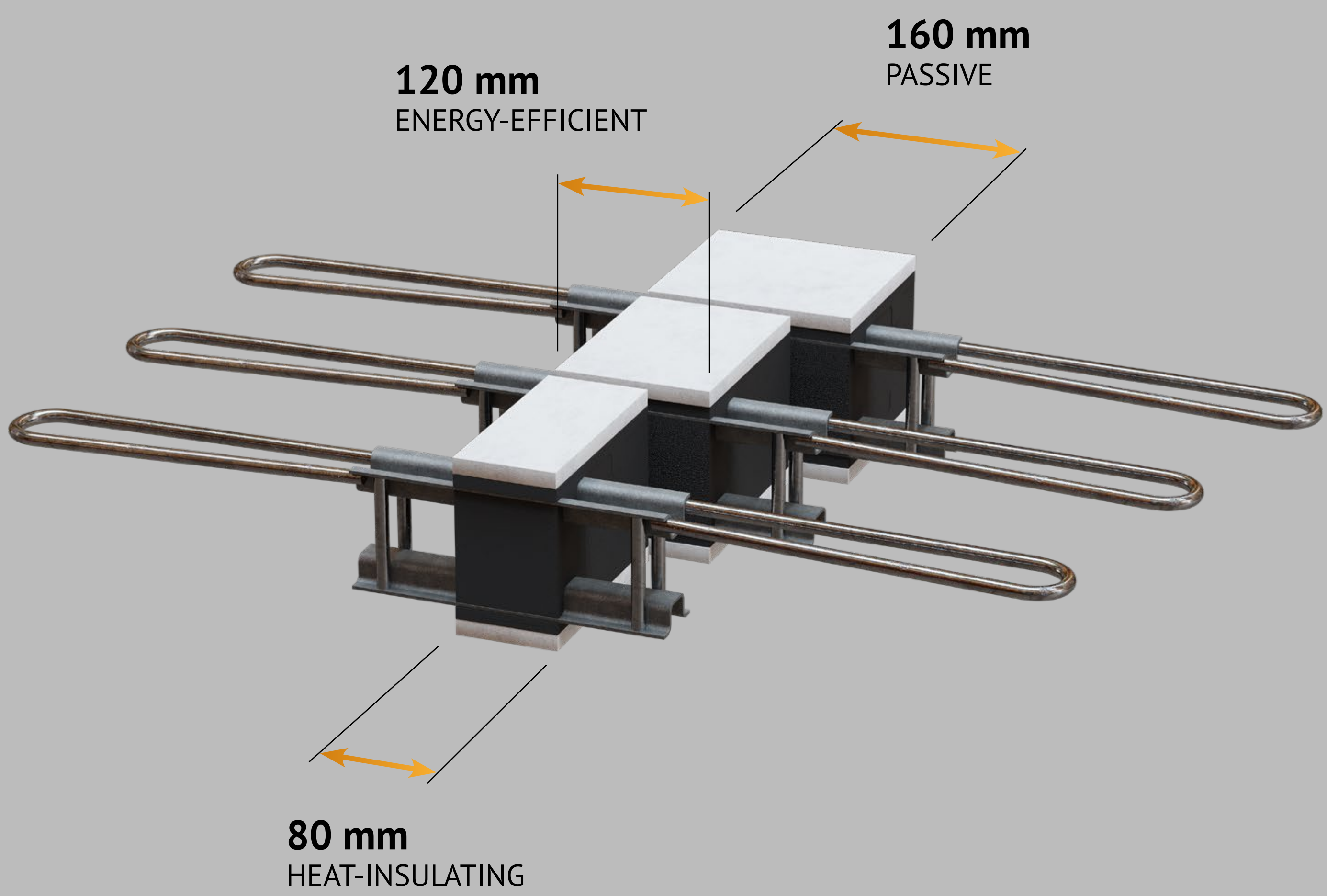
TIPOMEGA

PREMIUM BALCONY CONNECTORS



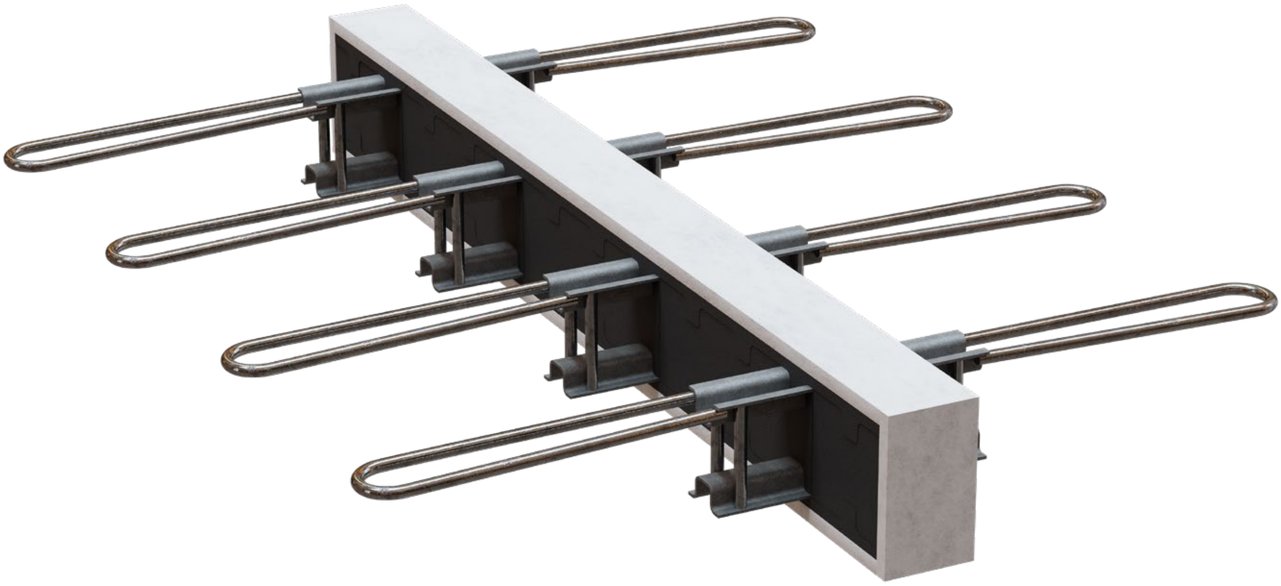
– DESIGN GUIDELINES –

CONNECTION BETWEEN REINFORCED CONCRETE AND REINFORCED CONCRETE

JANUARY 2022

tipomega.eu

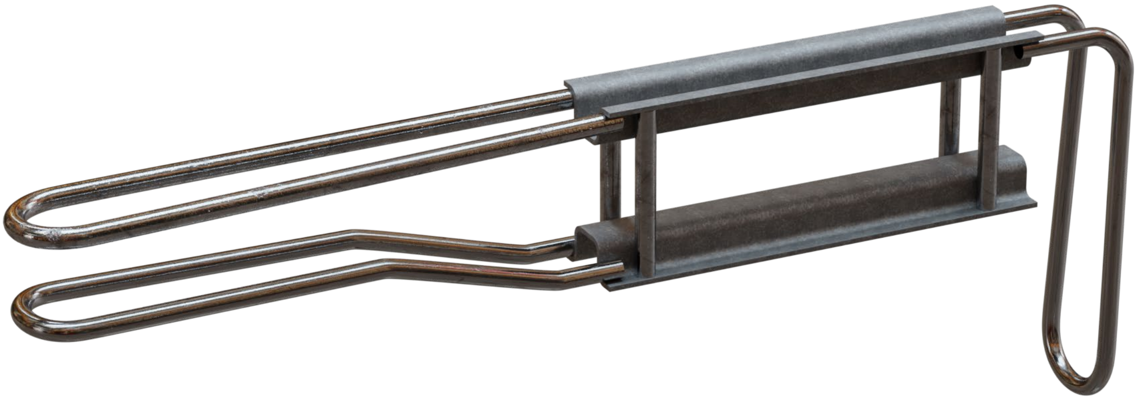
EXPLANATION OF PRODUCT MARKING



TIPOMEGA.08

Name of the system of balcony connectors

Insulation thickness of the system (in this case, 8cm)



OMEGA.12.18.U12.UD30

Name of load-bearing unit

Insulation thickness of the system
(in this case, 12cm)

Thickness of the balcony reinforced concrete slab
(in this case, 18cm)

Designation of anchoring rod on the balcony side

Rod shape welded to the top profile of the frame
(in this case, shape 1)

Rod shape welded to the bottom profile of the frame
(in this case, shape 2)

Designation of anchoring rod on the floor slab side

Rod shape welded to the top profile of the frame (in this case, shape 3)

Rod shape welded to the bottom profile of the frame
(in this case, 0 indicates no bar at this location)

1. INTENDED USE

TIPOMEGA® is a system intended for the connection of reinforced concrete components with improved thermal insulation parameters and fire-resistance rating. It is used to reduce the thermal conductivity between external reinforced concrete components (e.g. balcony and canopy slabs) and internal reinforced concrete components in buildings (e.g. floor slabs, beams and walls). Components of the TIPOMEGA® system are assembled between the internal and external building components (see fig. 1).

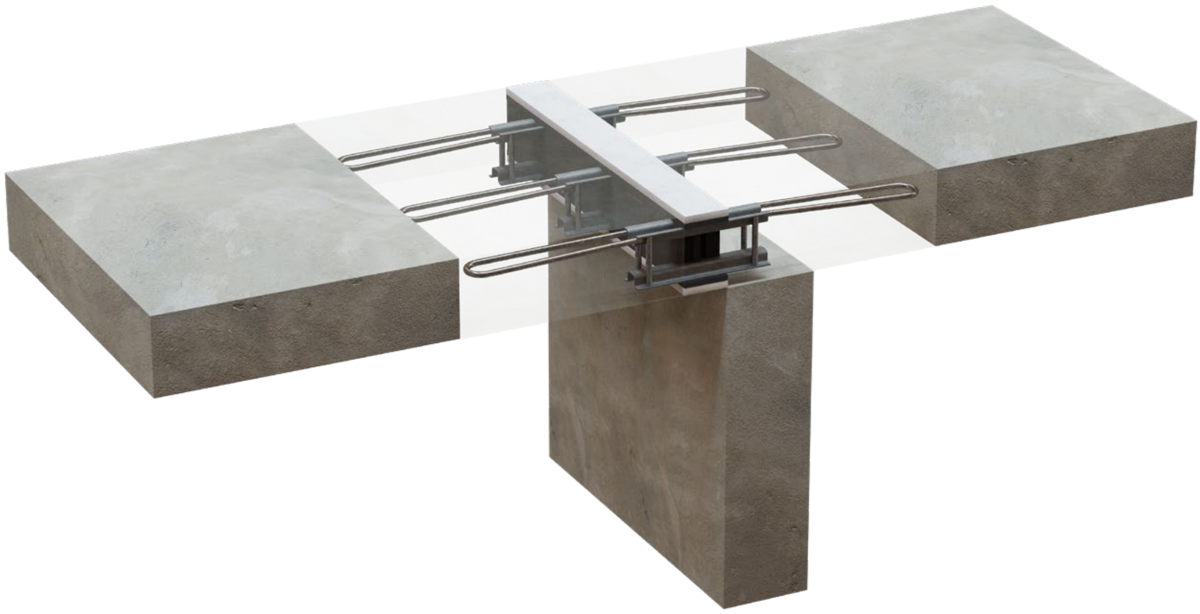


Fig. 1. TIPOMEGA® system in linear connector

2. DESIGN

Five heights of the TIPOMEGA® system are available: 16 cm, 18 cm, 20 cm, 22 cm and 24 cm; and three thicknesses for each of these heights: 8 cm, 12 cm and 16 cm.

TIPOMEGA®, always used in the set, consists of thermally insulating TIP profiles and OMEGA load-bearing modules. Thermally insulating TIP components can be made of expanded polystyrene (EPS), extruded polystyrene (XPS) or polyisocyanurate (PIR), which are protected against fire up to REI 120 from the top, bottom and side faces of the linear connector.

TIP dimensions depend on the height of the external reinforced concrete component and on the thickness of insulation used in the system. TIP insulation modules, on which the OMEGA load-bearing modules are set, are manufactured according to the individual design of the connection between the internal and external reinforced concrete elements.

The OMEGA modules, passing through the TIP insulation profiles, are used as load-bearing components in the TIPOMEGA® system. They are available in the systems composed of steel, stainless cold-formed profiles and reinforcing bars, interacting with the reinforced concrete components of the wall and floor slab structure, while from the other side - with balcony slab made of reinforced concrete. Dimensions and shape of the OMEGA load-bearing units depend on the geometrical dimensions and shapes of the reinforced concrete components being joined and the thickness of the insulation used in the system.

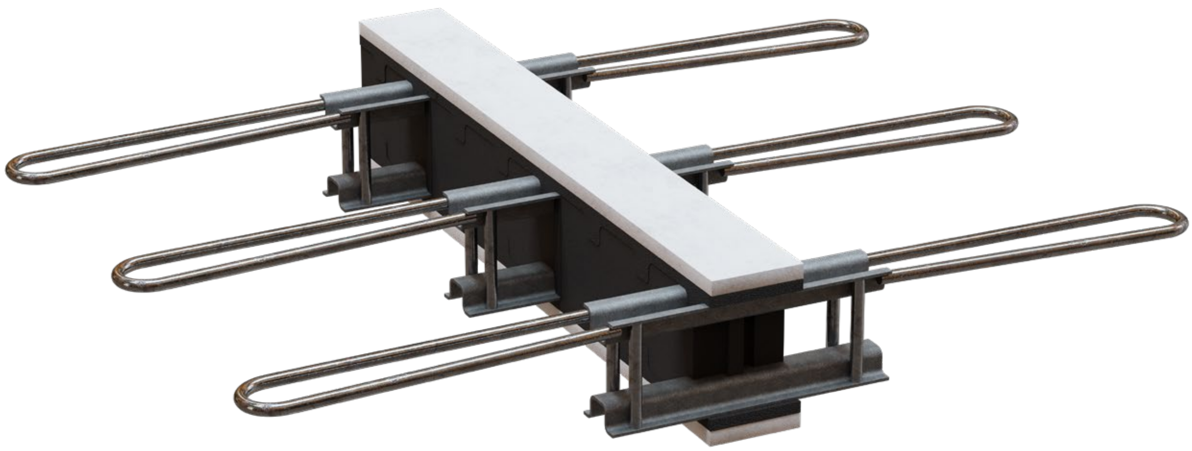


Fig. 2. OMEGA load-bearing units set in the TIP insulation profiles

ARCHITECT DESIGNER CONTRACTOR

3. VARIANTS OF USE

3.1. Anchoring in the floor slab using the OMEGA.XX.YY.U10.U10 frame

The balcony and the floor are at the same (top) level.

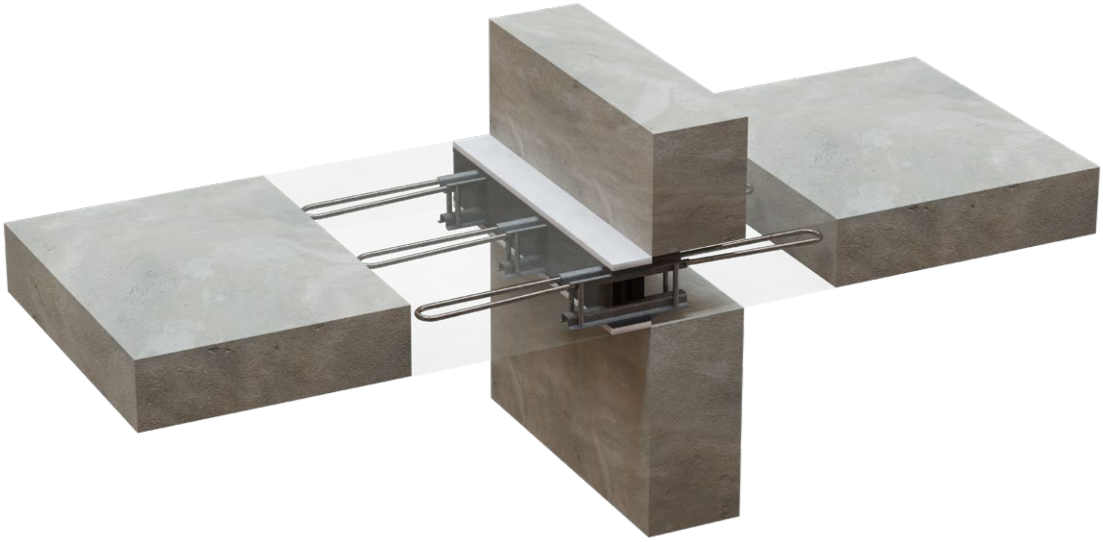


Fig. 3. TIPOMEGA® connector anchored in the floor slab using U1-shaped bars welded to the upper profile

The balcony is at a lower level than the internal floor slab.

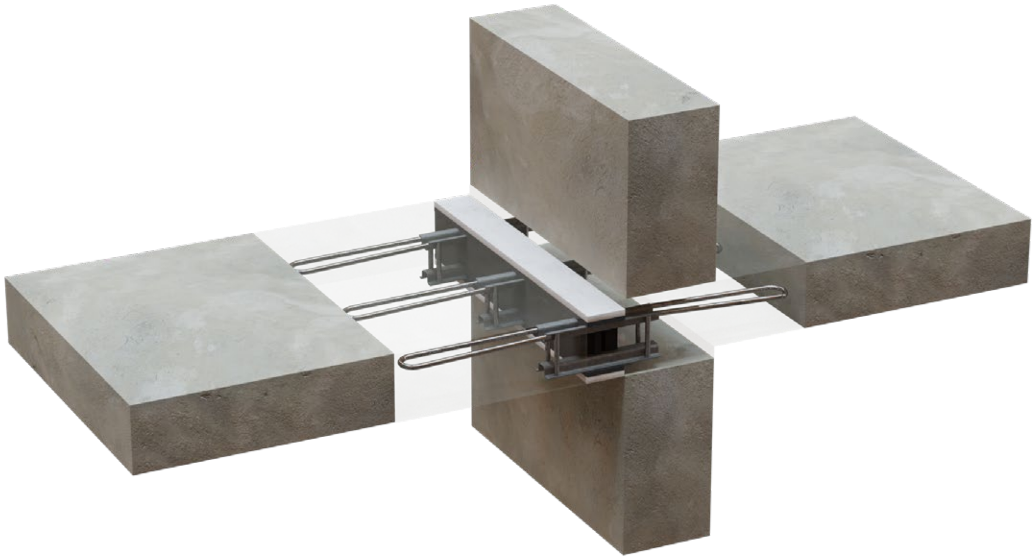
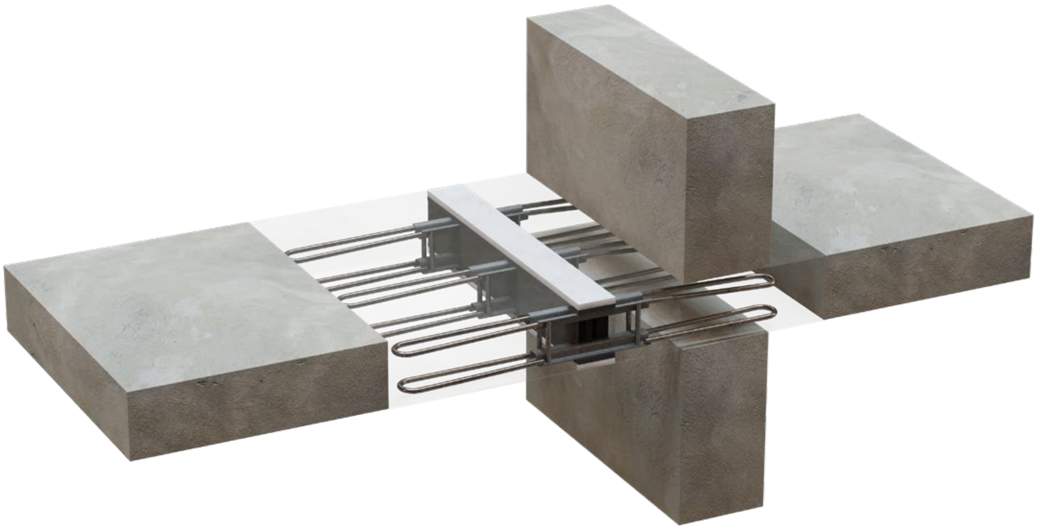


Fig. 4. TIPOMEGA® connector anchored in the floor slab using U1-shaped bars welded to the upper profile

3.2. Anchoring in continuous floor slab (intermediary support of balcony) using the OMEGA.XX.YY.U11.U11 frame

The balcony and the floor are at the same (top) level; TIPOMEGA® connectors transfer bending moments and shear forces in positive and negative directions.



Rys. 5. TIPOMEGA® connector anchored in the floor slab using U1-shaped bars welded to the upper and bottom profile.

3.3. Anchoring in the floor slab using the OMEGA.XX.YY.U10.U20 frame

The balcony and the floor are at the same (top) level; U2 bar has been used to allow for a corner location with another frame overlapping.

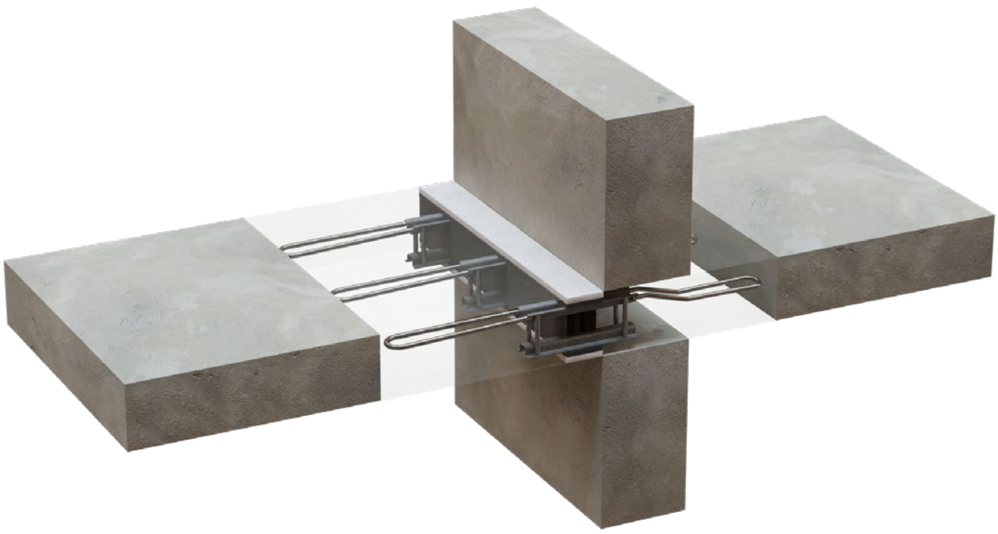


Fig. 6. The TIPOMEGA® connector anchored in the floor slab using U2-shaped bars welded to the upper profile

3.4. Anchoring in the wall or beam using the OMEGA.XX.YY.U10.UD30 frame

Anchoring downwards into a reinforced concrete wall; minimum width of wall – 180 mm.

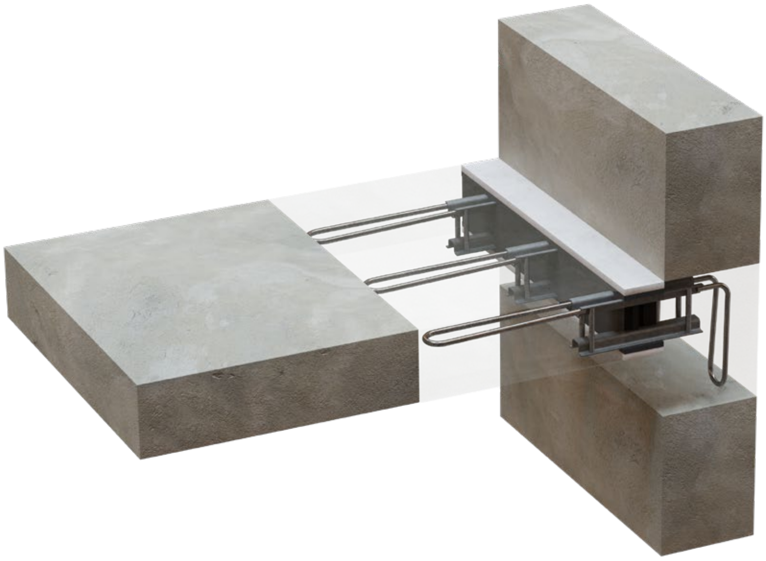


Fig. 7. The TIPOMEGA® connector anchored in the wall using UD3-shaped bars welded to the upper profile and bent downwards

Anchoring downwards into a reinforced concrete beam; minimum dimensions of the beam:
width – 180 mm, height – 360 mm.

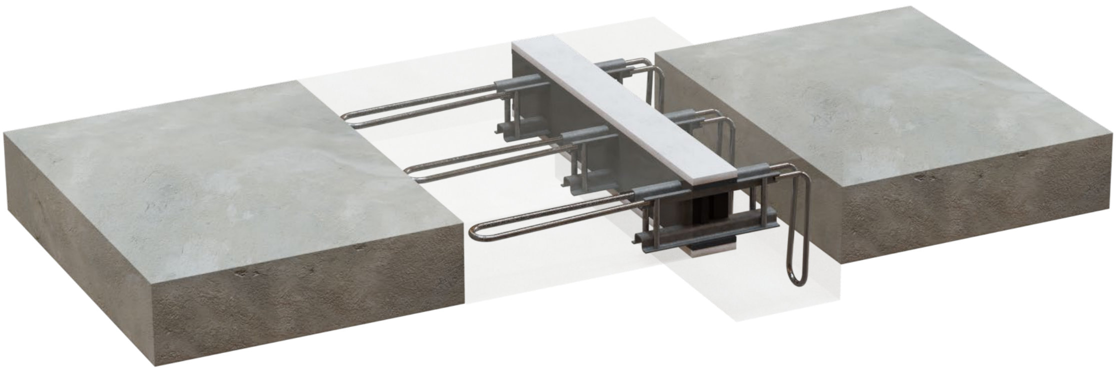


Fig. 8. TIPOMEGA® connector anchored in the beam using UD3-shaped bars, welded to the upper profile and bent downwards

3.5. Anchoring in the wall or beam using the OMEGA.XX.YY.U10.UG30 frame

Anchoring upwards into a reinforced concrete wall; minimum width of wall – 180 mm.

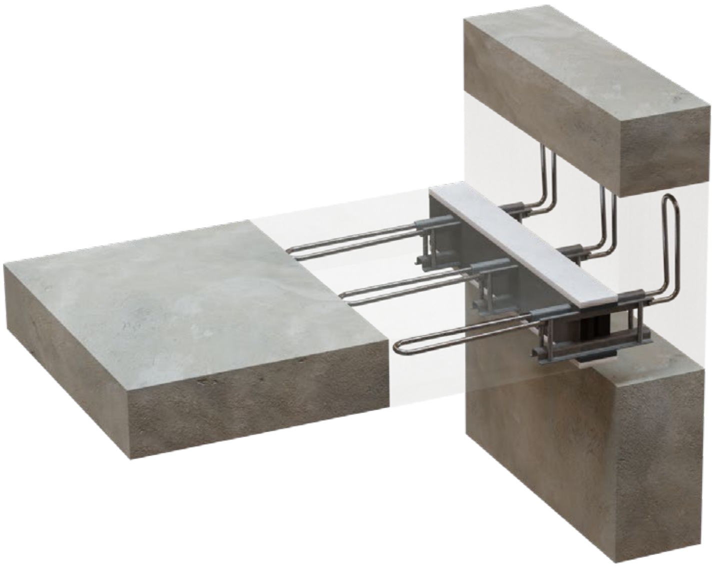


Fig. 9. The TIPOMEGA® connector anchored in the wall using UG3-shaped bars, welded to the upper profile and bent upwards

Anchoring upwards into a reinforced concrete beam; minimum dimensions of the beam:
width – 180 mm, height – 360 mm.

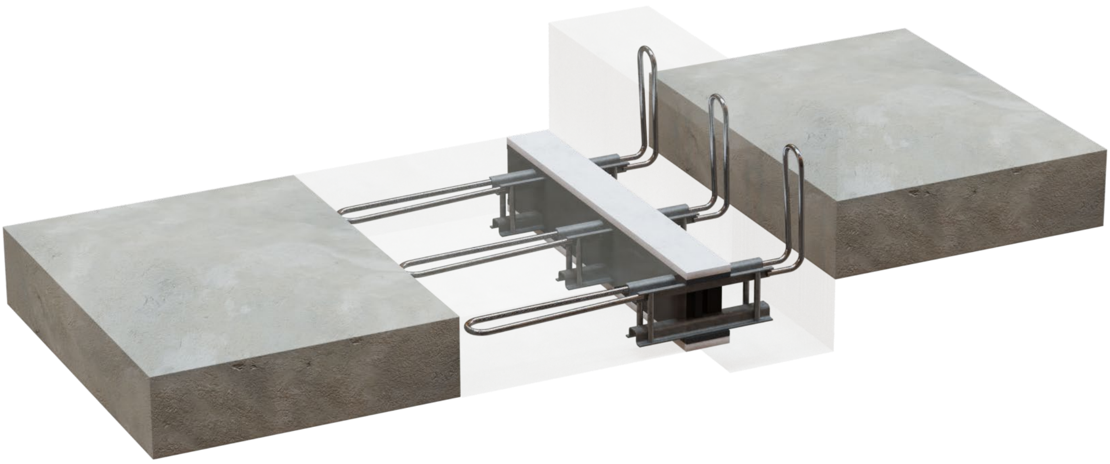


Fig. 10. The TIPOMEGA® connector anchored in the beam using UG3-shaped bars, welded to the upper profile and bent upwards

3.6. Anchoring in beam using the OMEGA.XX.YY.U10.UD40 frame

Anchoring downwards in a reinforced concrete beam with small dimensions:
width – 240 mm, height – 160 mm.

Fig. 11. The TIPOMEGA® connector anchored in the beam using UD4-shaped bars, welded to the upper profile and bent downwards

3.7. Anchoring in beam using the OMEGA.XX.YY.U10.UG40 frame

Anchoring upwards in a reinforced concrete beam with small dimensions:
width – 240 mm, height – 90 mm above the upper level of the balcony.

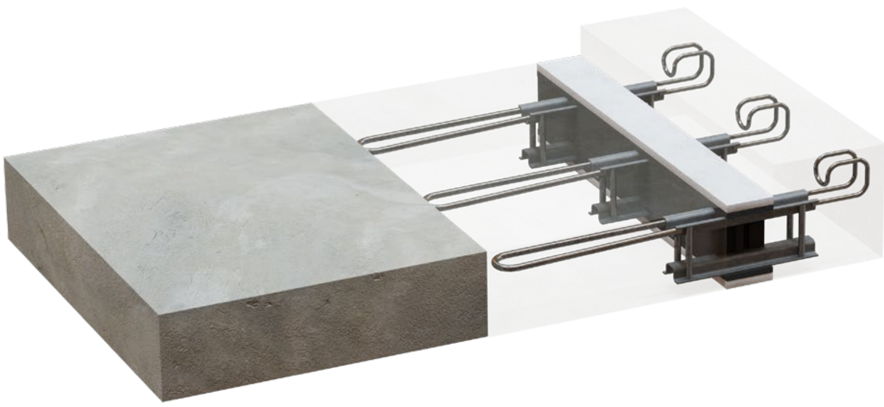


Fig. 12. The TIPOMEGA® connector anchored in the beam using UG4-shaped bars, welded to the upper profile and bent upwards

4. THERMAL PHYSICS

Selection of thickness of the thermal insulation of the TIPOMEGA® system (choice between TIPOMEGA.08, TIPOMEGA.12 and TIPOMEGA.16) should ensure meeting the requirements of the corresponding thermal and moisture conditions.

4.1. Basic definitions and symbols

Material	part of the product, independently of the type of delivery, shape and dimensions, without any lining or coating
Product	final form of the material ready to be used, with given shape and dimensions, with liners or coatings
Construction product	every product or a set manufactured or put on the market for permanent installation in the civil structures or their parts
Building component	building element or its part (main part of the building, e.g. wall, floor slab, roof)
Building partition	component separating the room from the external environment or other room
Heat	type of transfer of some part of the energy through the boundaries of the system due to the difference in temperatures
Heat density flux	amount of heat flowing from one medium to the other in a unit of time per unit of surface
Specific heat	amount of heat required, at constant pressure, to increase the temperature of 1 kg of mass of the given material by 1K
Thermal field	system of temperature values in the space, currently under consideration
Thermal conductivity coefficient	heat flux at steady state divided by the product of surface area and temperature difference on both sides of the partition /system/
Conduction coefficient	specifies the intensity of heat exchange through the given material; expresses the amount of heat in W, flowing in 1 s per 1 m2 of homogeneous layer of 1 m thick material perpendicularly to the surface, when the temperature difference on the opposite surfaces or this rectangular prism is 1 K
Total thermal resistance	sum of thermal resistances of all layers of material of the partition, considering thermal transfer resistances
Thermally homogeneous layer	layer of constant thickness and constant thermal properties, which may be considered as homogeneous in the form of conduction coefficient
Thermally non-homogeneous layer	layer with varying thermal properties in the form of conduction coefficient
Diffusion resistance	resistance of material for the flow of steam vapour
Diffusion-equivalent air layer thickness	a layer of steady air with the same diffusion resistance as a considered layer of material

U	thermal conductivity coefficient	[W/(m²·K)]
U_c	corrected thermal conductivity coefficient	[W/(m²·K)]
$U_{c(max)}$	maximum /limit/ extended value of thermal conductivity coefficient	[W/(m²·K)]
t_i	temperature of indoor air	[ºC]
t_e	temperature of outdoor air	[ºC]
t_{si}	temperature on the internal surface of the partition	[ºC]
t_{se}	temperature on the external surface of the partition	[ºC]
R_T	total heat resistance of partition consisting of flat homogeneous layers	[(m²·K)/W]
R_{si}	thermal transfer resistance on internal surface	[(m²·K)/W]
R_{se}	thermal transfer resistance on external surface	[(m²·K)/W]
R_{ni}	design thermal resistances for each layer	[(m²·K)/W]
d	thickness of layer	[m]
λ	conduction coefficient of material	[W/(m·K)]
R'_T	upper bound of total thermal resistance	[(m²·K)/W]
R''_T	lower bound of total thermal resistance	[(m²·K)/W]
R_{Ta}	total thermal resistances from the environment to the environment of the layer	[(m²·K)/W]
f_a	relative surface area of the layer	[-]
λ''	equivalent value of conduction coefficient	[W/(m·K)]
λ_{eq}	equivalent conduction coefficient	[W/(m·K)]

4.2. Thermal design of external partitions

Heat transfer analysis in the buildings may be performed with the division of the structure into typical partitions: walls, windows, doors, floors, roofs, for which the heat losses may be calculated separately based on the single-dimensional model of heat flow, assuming the uniform design of the partition, consisting of parallel layers, to which the heat flux is perpendicular.

Heat losses through the individual building elements, with some simplifications, may be determined using heat transfer coefficient U [W/(m2·K)] (see fig. 13).

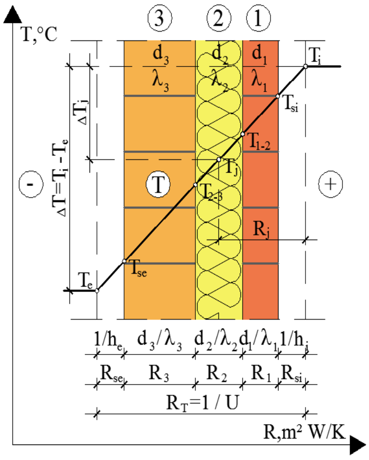


Fig. 13. Heat penetration through the partition

Designing the partition requires considering the local climate in the building surroundings and microclimate of the rooms. The following factors have the largest impact on the shaping of the thermal and moisture properties of the partitions:

- temperature,
- relative humidity,
- solar radiation intensity.

Thermal conductivity coefficient U [W/(m2·K)] determines the loss of heat related to the unit difference of internal and external temperature and the unit surface of the building area:

$$U = \frac{1}{R_T}$$

where:

R_T – total heat resistance of partition consisting of flat homogeneous layers, m²·K/W, calculated with the equation:

$$R_T = R_{si} + R_n + R_{se}$$

where:

R_{si} – thermal transfer resistance on the internal surface [(m2·K)/W],

R_n – design thermal resistances for each layer [(m ·K)/W],

R_{se} – thermal transfer resistance on the external surface [(m2·K)/W].

$$R_n = \frac{d}{\lambda}$$

where:

d – thickness of layer [m],

λ – design conduction coefficient of the material, W/(m·K), is assumed based on PN-EN 12524:2003. tables from literature, manufacturer data.

Corrected thermal conductivity coefficient U_C [W/(m²·K)] is obtained by introduction of the correction unit ΔU:

$$U_C = U + \Delta U$$

Correction unit ΔU [W/(m²·K)] is expressed with the following formula:

$$\Delta U = \Delta U_g + \Delta U_f + \Delta U_r$$

where:

ΔU_g – correction for leaks [W/(m²·K)],

ΔU_r – correction for the impact of precipitation for the roofs with a reversed system of layers [W/(m²·K)],

ΔU_f – correction for mechanical connectors [W/(m²·K)].

Material capability for heat conduction is determined using conduction coefficient – λ [W/(m·K)]. It is the amount of heat conducted per unit of time for 1 m2 of the area of the 1 mm thick partition, with temperature difference on both sides of the partition equal to 1K, per unit of time. The standardization introduces two concepts related to the value of conduction coefficient for the materials (or thermal resistance of the components):

- declared value (λ_D), intended for production quality control, corresponding to the laboratory conditions,
- declared value (λ_{ob}), intended for designing, corresponding to the conditions of use of the material in building,

Weather conditions (inside and outside) of the building have an impact on the heat conduction amount of the materials. Consideration of the impact of the specific weather conditions on the building element allows for the precise assessment of the actual heat losses. Determination of the design value is based on taking into account the difference in temperature and moisture content between the conditions for which the declared value of thermal conductance has been specified and the conditions at which this material is actually operating. Moisture content is very important for building applications. Changes in temperature are considered first and foremost for the materials intended for thermal insulation. The design stage should foresee the conditions of operation for the materials and it should include the conversion of λ_D coefficient to the value λ_{ob}. Material conductivity is a function of its density, moisture content, temperature and time from material production:

$$\lambda_{ob} = \lambda_D \cdot F_T \cdot F_M \text{ (lub } F_\psi) \cdot F_a$$

where:

λ_{ob} – design value of conduction coefficient [W/(m·K)],

λ_D – declared value of conduction coefficient [W/(m·K)],

F_T – temperature conversion coefficient [-],

F_a – conversion factor dependent on the time of material production [-],

F_M – moisture conversion factor considering the mass humidity of the material or volumetric humidity of the material (F_ψ) [-].

4.3. Thermal parameters of TIPOMEGA®

Equivalent conduction coefficient λ_{eq} [W/(m·K)] of the building element consisting of several building materials determine the thermal conductance of uniform, equivalent building material in the shape of a rectangular prism with the same dimensions, which in the location of the whole building element in the assembled condition allows obtaining the same thermal effect. The method compliant with EAD (European Assessment Document/) includes the detailed calculations for the thermal bridges in three dimensions with a load-bearing thermal insulation component. This case contains the detailed model of the complex structure of the thermal insulating load-bearing component and determined heat loss of the thermal bridge. The equivalent conduction coefficient λ_{eq} and equivalent thermal resistance R_{eq} are calculated based on the occurring heat loss. The calculations are carried out using professional computer software for the calculation of physical parameters of thermal bridges (using boundary conditions acc. to PN-EN ISO 6946).

Value of conduction coefficient (λ''/ λ_{eq}/) is used for further calculations of physical parameters of external partitions and their connectors:

- thermal conductivity coefficient for solid, flat external partition U [W/(m^2·K)],
- linear thermal conductivity coefficient for the thermal bridge Ψ [W/(m·K)],
- minimum temperature on the internal surface of the partition in the location of thermal bridge $t_{min.}$ [°C],
- temperature medium f_{Rsi} [-] determined based on $t_{min.}$ [°C].

4.3.1. Calculation procedure

Calculation procedure for the conduction coefficient for the precast fittings as a component of the system of TIPOMEGA® isothermal connectors using computer software TRISCO 3D.

1. Determination of heat flux flowing through the component assuming the boundary conditions:

t_i – temperature of indoor air (t_i=20°C),

t_e – temperature of outdoor air (t_e=20°C),

R_{si} – thermal transfer resistance on the internal surface of the divider R_{si}=0,13 (m^2·K)/W,

R_{se} – thermal transfer resistance on the external surface of the divider R_{se}=0,04 (m^2·K)/W.

2. Determination of thermal conductivity coefficient for the component according to the formula:

$$U = \frac{\Phi}{A \cdot (t_i - t_e)}$$

where:

Φ – size of heat flux flowing through the component [W],

A – area of the component, through which the transfer occurs [m^2],

(t_i – t_e) – temperature difference [°C].

3. Determination of total thermal resistance according to the formula:

$$R_T = \frac{1}{U}$$

where:

R_T – total thermal resistance of a component from the environment to the environment [(m²·K)/W],

U – thermal conductivity coefficient for the component [W/(m²·K)].

4. Determination of thermal resistance of the component:

$$R_i = R_T - (R_{si} + R_{se}) \ / \ R_{eq} = R_T - (R_{si} + R_{se}) \ /$$

where:

R_i – thermal resistance of a component [(m²·K)/W],

R_{eq} – equivalent thermal resistance of a component [(m²·K)/W],

R_T – total thermal resistance of a component from the environment to the environment [(m²·K)/W],

R_{si} – thermal transfer resistance on the internal surface of the divider [(m²·K)/W],

R_{se} – thermal transfer resistance on the external surface of the divider [(m²·K)/W].

5. Determination of conduction coefficient for thermally heterogeneous component

$$\lambda'' = \frac{d_i}{R_i} \ / \ \lambda_{eq} = \frac{d_i}{R_{eq}} \ /$$

where:

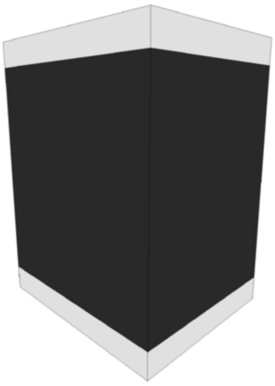
d_i – component thickness [m],

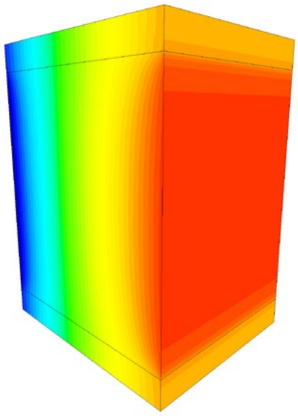
R_i – thermal resistance of a component [(m²·K)/W],

R_{eq} – equivalent thermal resistance of a component [(m²·K)/W].

4.3.2. Assumption for calculations

- t_i=20°C, R_{si}=0,13 (m²·K)/W,
- t_e=-20°C, R_{se}=0,04 (m²·K)/W,
- graphite styrofoam λ_{ob}= 0,031 W/(m·K),
- fire-resistant slabs λ_{ob}= 0,292 W/(m·K),
- stainless steel λ_{ob}= 15 W/(m·K).



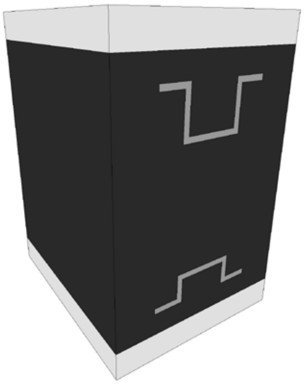


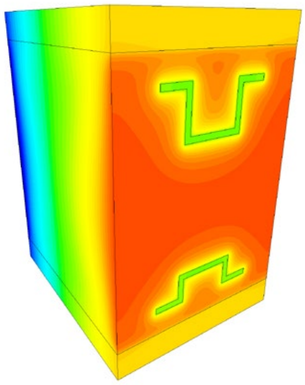
Tab. 1. Thermal parameters of model fittings of 10 cm in length, without the OMEGA frame

Parameters of component in y = 80 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	0,41	0,43	0,46	0,49	0,52
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,38	1,51	1,57	1,63	1,67
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,058	0,053	0,051	0,049	0,048

Parameters of component in y = 120 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	0,31	0,33	0,35	0,37	0,39
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,90	2,03	2,11	2,22	2,31
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,063	0,059	0,057	0,054	0,052

Parameters of component in y = 160 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	0,25	0,27	0,28	0,30	0,31
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	2,39	2,50	2,67	2,76	2,91
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,067	0,064	0,060	0,058	0,055





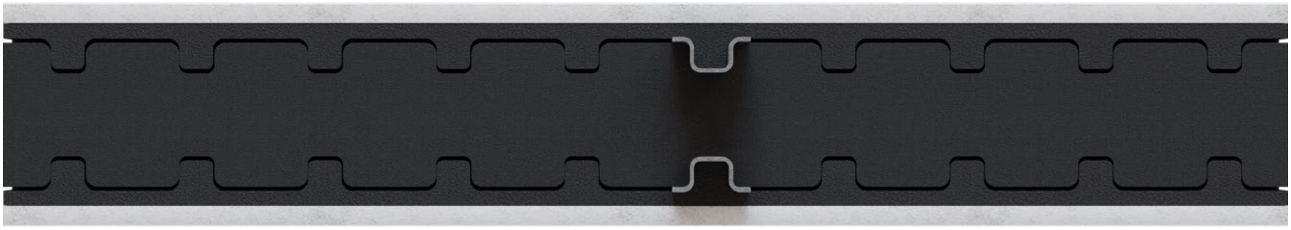
Tab. 2. Thermal parameters of model fittings of 10 cm in length, with the OMEGA frame

Parameters of component in y = 80 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	0,87	0,91	0,93	0,96	0,99
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,57	0,62	0,69	0,75	0,80
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,140	0,129	0,116	0,107	0,100

Parameters of component in y = 120 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	0,84	0,87	0,89	0,91	0,93
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,59	0,66	0,73	0,80	0,86
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,203	0,182	0,165	0,151	0,139

Parameters of component in y = 160 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	0,81	0,84	0,86	0,87	0,89
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,62	0,69	0,76	0,84	0,91
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,258	0,232	0,211	0,191	0,176

4.3.3. Thermal parameters in varied systems of model fittings

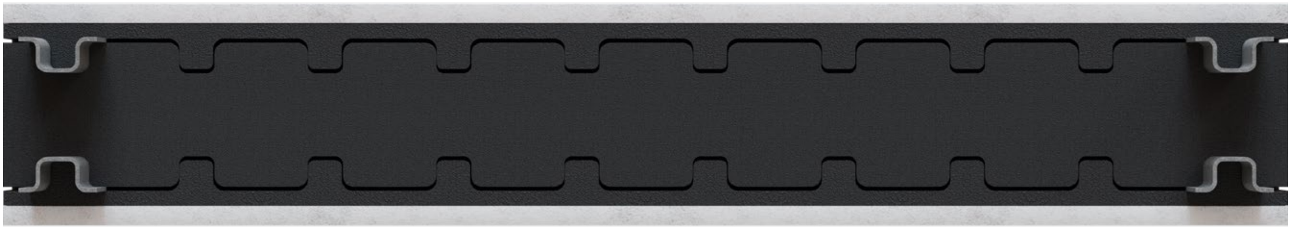


Tab. 3. Thermal parameters of a 100cm long components system with one OMEGA frame

Parameters of component in y = 80 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	4,55	4,82	5,09	5,36	5,64
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,23	1,33	1,40	1,48	1,54
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,065	0,060	0,057	0,054	0,052

Parameters of component in y = 120 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	3,67	3,86	4,05	4,24	4,43
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,57	1,69	1,81	1,91	2,00
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,076	0,071	0,066	0,063	0,060

Parameters of component in y = 160 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	3,11	3,27	3,42	3,56	3,71
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,89	2,03	2,17	2,30	2,42
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,084	0,079	0,074	0,070	0,066

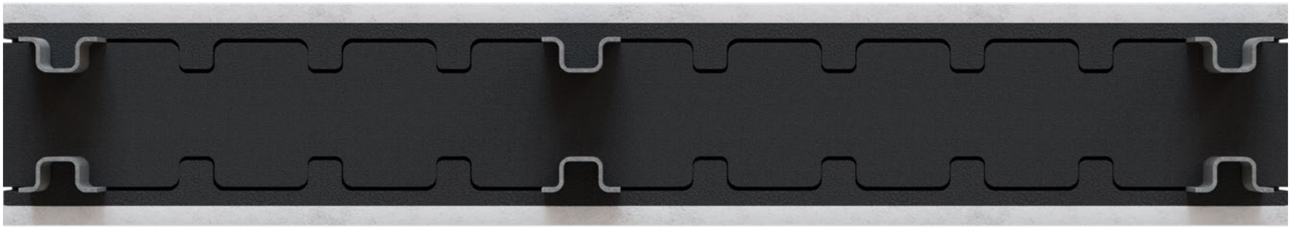


Tab. 4. Thermal parameters of a 100cm long components system with two OMEGA frames

Parameters of component in y = 80 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	5,01	5,29	5,64	5,84	6,26
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,11	1,19	1,25	1,33	1,36
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,072	0,067	0,064	0,060	0,059

Parameters of component in y = 120 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	4,20	4,40	4,60	4,79	4,98
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,35	1,47	1,57	1,67	1,76
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,089	0,082	0,076	0,072	0,068

Parameters of component in y = 160 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	3,67	3,84	3,99	4,14	4,29
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,57	1,71	1,84	1,96	2,06
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,101	0,093	0,087	0,082	0,077

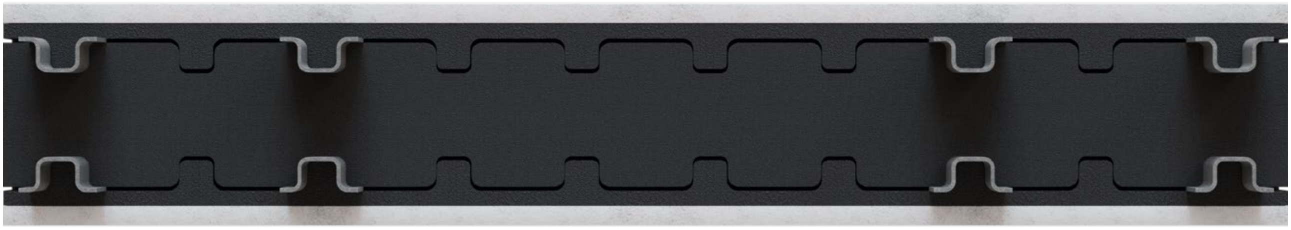


Tab. 5. Thermal parameters of a 100cm long components system with three OMEGA frames

Parameters of component in y = 80 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	5,49	5,77	6,04	6,32	6,59
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,00	1,08	1,16	1,23	1,29
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,080	0,074	0,069	0,065	0,062

Parameters of component in y = 120 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	4,75	4,96	5,16	5,35	5,54
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,18	1,28	1,38	1,47	1,56
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,101	0,093	0,087	0,081	0,077

Parameters of component in y = 160 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	4,27	4,44	4,60	4,75	4,90
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,33	1,45	1,57	1,68	1,79
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,120	0,110	0,102	0,095	0,090

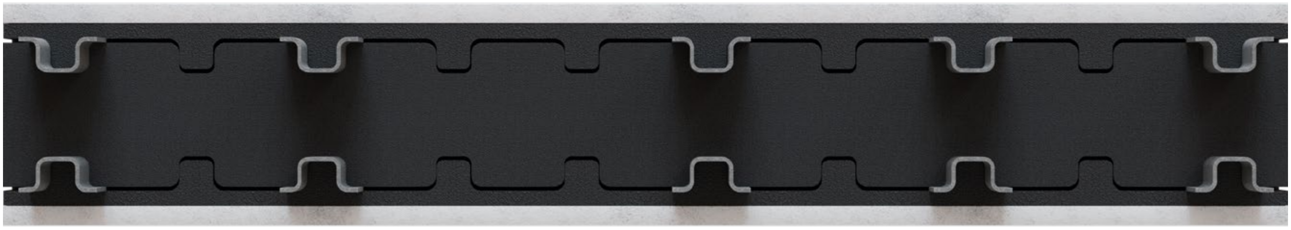


Tab. 6. Thermal parameters of a 100cm long components system with four OMEGA frames

Parameters of component in y = 80 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	5,96	6,25	6,52	6,80	7,07
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,91	0,99	1,05	1,13	1,19
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,088	0,081	0,076	0,071	0,067

Parameters of component in y = 120 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	5,30	5,52	5,72	5,91	6,11
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,04	1,13	1,23	1,32	1,40
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,115	0,105	0,098	0,091	0,086

Parameters of component in y = 160 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	4,85	5,04	5,20	5,35	5,50
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,15	1,26	1,37	1,47	1,58
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,139	0,127	0,117	0,108	0,102

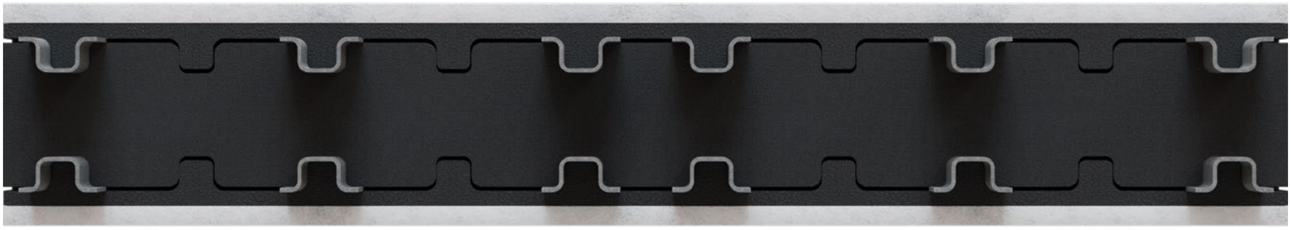


Tab. 7. Thermal parameters of a 100cm long components system with five OMEGA frames

Parameters of component in y = 80 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	6,43	6,72	7,00	7,28	7,55
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,82	0,90	0,98	1,04	1,10
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,097	0,089	0,082	0,077	0,073

Parameters of component in y = 120 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	5,85	6,08	6,28	6,48	6,67
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,92	1,01	1,10	1,19	1,27
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,130	0,118	0,109	0,101	0,095

Parameters of component in y = 160 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	5,44	5,63	5,80	5,95	6,11
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	1,00	1,11	1,21	1,31	1,40
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,159	0,144	0,132	0,122	0,114

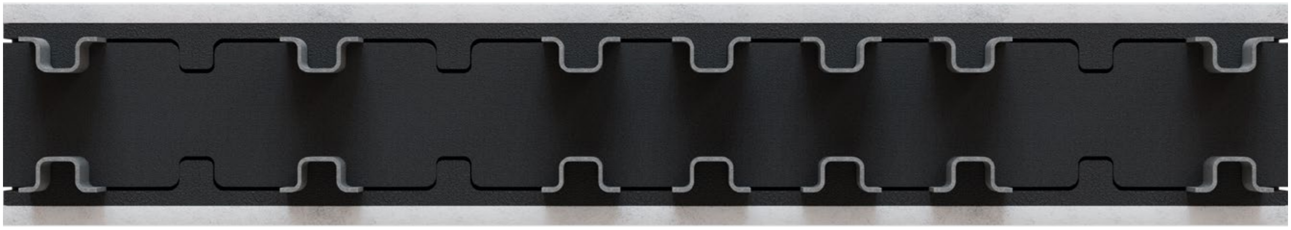


Tab. 8. Thermal parameters of a 100cm long components system with six OMEGA frames

Parameters of component in y = 80 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	6,90	7,19	7,47	7,75	8,03
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,75	0,83	0,90	0,96	1,03
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,106	0,096	0,089	0,083	0,078

Parameters of component in y = 120 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	6,38	6,62	6,82	7,02	7,22
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,83	0,92	1,00	1,08	1,16
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,144	0,131	0,120	0,111	0,103

Parameters of component in y = 160 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	6,00	6,20	6,37	6,53	6,68
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,90	0,99	1,09	1,18	1,27
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,178	0,161	0,147	0,136	0,126

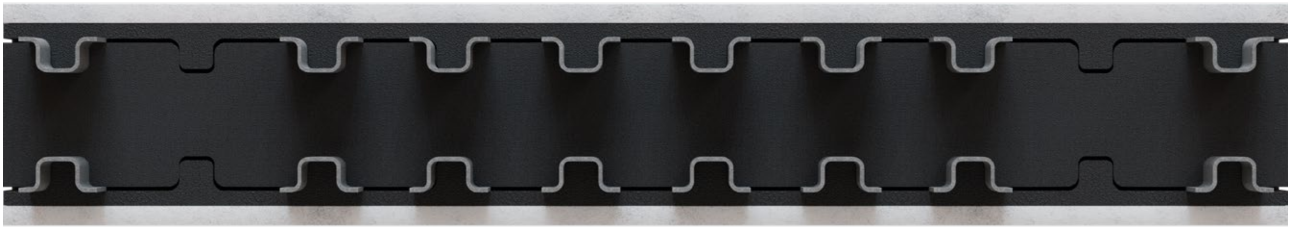


Tab. 9. Thermal parameters of a 100cm long components system with seven OMEGA frames

Parameters of component in y = 80 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	7,36	7,66	7,94	8,22	8,49
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,70	0,77	0,81	0,90	0,96
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,114	0,104	0,099	0,089	0,083

Parameters of component in y = 120 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	6,90	7,14	7,35	7,55	7,74
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,76	0,84	0,92	1,00	1,07
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,158	0,143	0,131	0,121	0,112

Parameters of component in y = 160 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	6,53	6,75	6,92	7,08	7,24
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,81	0,90	0,97	1,07	1,16
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,196	0,178	0,162	0,149	0,138

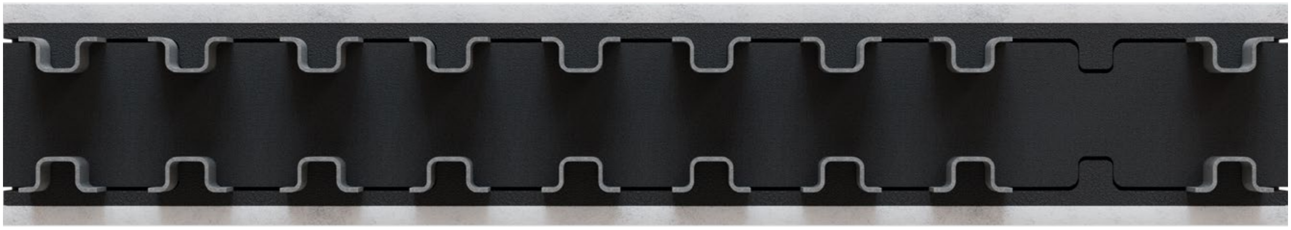


Tab. 10. Thermal parameters of a 100cm long components system with eight OMEGA frames

Parameters of component in y = 80 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	7,82	8,12	8,40	8,68	8,96
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,65	0,71	0,78	0,84	0,90
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,123	0,112	0,102	0,095	0,089

Parameters of component in y = 120 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	7,41	7,66	7,87	8,08	8,27
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,68	0,77	0,85	0,92	0,99
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,173	0,155	0,142	0,131	0,121

Parameters of component in y = 160 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	7,06	7,29	7,47	7,63	7,79
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,74	0,82	0,90	0,98	1,06
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,217	0,196	0,178	0,163	0,151

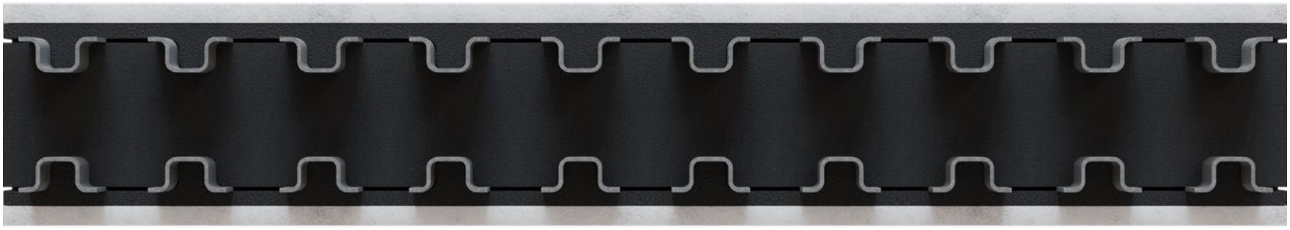


Tab. 11. Thermal parameters of a 100cm long components system with nine OMEGA frames

Parameters of component in y = 80 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	8,27	8,58	8,87	9,15	9,43
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,61	0,67	0,73	0,79	0,85
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,132	0,120	0,109	0,101	0,094

Parameters of component in y = 120 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	7,93	8,18	8,40	8,60	8,80
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,64	0,71	0,78	0,85	0,92
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,188	0,170	0,153	0,141	0,130

Parameters of component in y = 160 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	7,59	7,83	8,02	8,18	8,34
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,67	0,75	0,83	0,91	0,98
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,237	0,213	0,193	0,177	0,163



Tab. 12. Thermal parameters of a 100cm long components system with ten OMEGA frames

Parameters of component in y = 80 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	8,73	9,04	9,33	9,61	9,89
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,56	0,63	0,69	0,75	0,80
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,142	0,128	0,116	0,107	0,100

Parameters of component in y = 120 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	8,43	8,70	8,92	9,12	9,32
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,59	0,66	0,73	0,79	0,86
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,203	0,182	0,165	0,151	0,139

Parameters of component in y = 160 mm direction					
H – slab thickness [mm]	160	180	200	220	240
hr – frame height [mm]	106	126	146	166	186
Φ – heat flux [W]	8,11	8,36	8,55	8,72	8,88
Ri /Req/ – thermal resistance of components system [(m2·K)/W]	0,62	0,69	0,76	0,84	0,91
λ"/ λeq/ – conduction coefficient of components system [W/(m·K)]	0,258	0,232	0,211	0,191	0,176

5. DESIGN OF THE OMEGA LOAD-BEARING FRAMES

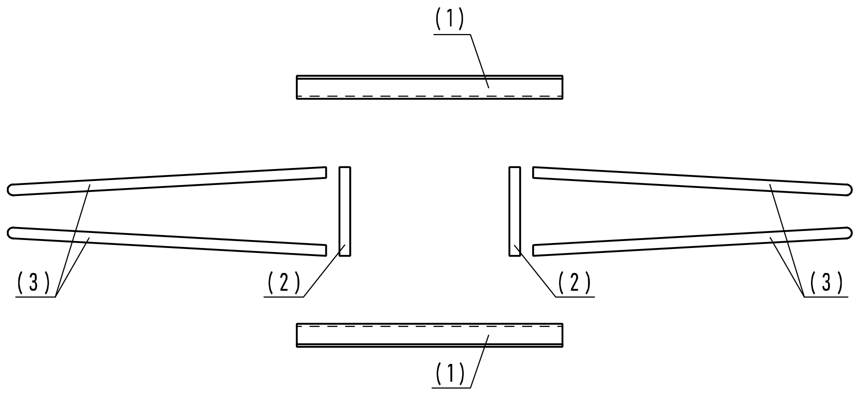


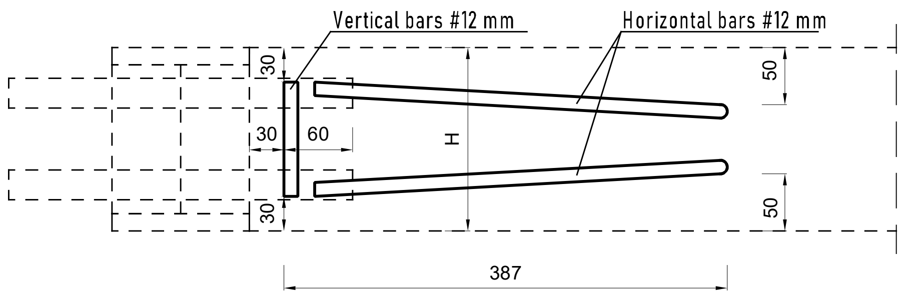
Fig. 14. Components of the OMEGA.XX.YY.U11.U11 frame

Omega-shaped cold-formed stainless steel profiles (1), 3 mm thick, are laid in pairs, one profile above the other. Each pair of profiles, laid in parallel relative to each other and faced with backs relative to each other, is joined with four vertical bars Ø12 mm (2). Horizontal bars Ø12mm (3), intended for proper anchoring of the profiles in reinforced concrete components, are welded to the stainless steel profiles.

To avoid corrosion in the insulation area, the profiles are made of ferritic-austenitic stainless steel sheet 1.4462 in accordance with PN-EN 10088-1:2014. The 1.4462 stainless steel used ensures a very high, fourth class of corrosion resistance (CRC) and high pitting resistance equivalent number (PREN). It ensures an unlimited lifetime of the TIPOMEGA® balcony connectors without maintenance.

Both vertical and horizontal bars Ø12 mm are made of ribbed reinforcement steel of characteristic yield point fyk ≥ 500 MPa and properties specified for the reinforcement steel of ductility class at least B according to PN-EN 1992-1-1:2008.

a)



b)

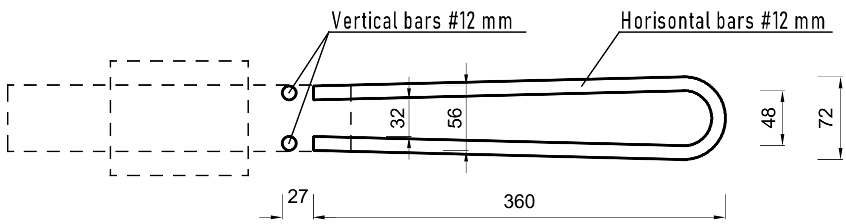
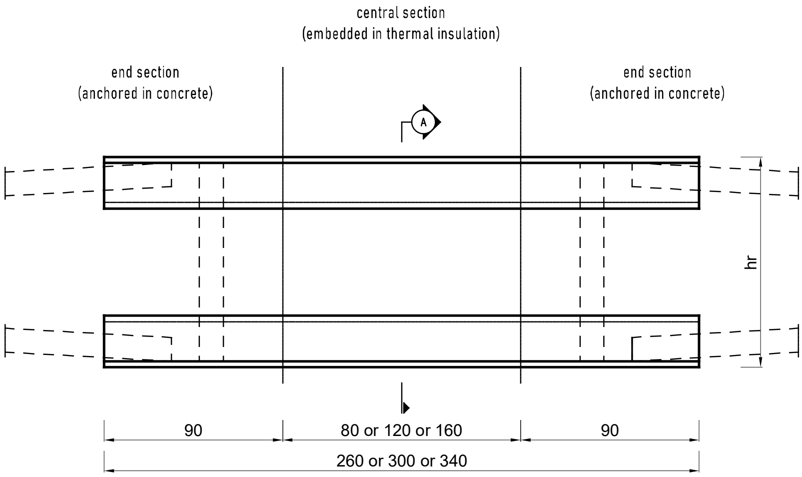
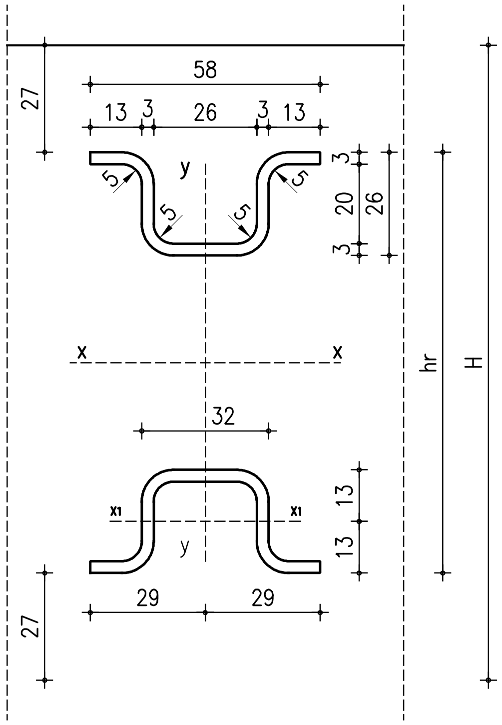


Fig. 15. Bars Ø12 mm in the OMEGA.XX.YY.U11.U11 frame (only one side of the frame is visible)
a) side view; b) top view

All cold-formed stainless steel profiles used in the TIPOMEGA® have the same shape and thickness. These profiles can be divided into three areas: two 90mm long end sections which are anchored in the reinforced concrete components and the central section of the profile embedded in the thermal insulation. The central section of the profile intended for the TIPOMEGA.08 is 8cm long, for the TIPOMEGA.12 system the length is 12 cm, while for the TIPOMEGA.16 system the length is 16 cm (see fig. 16).



Section A-A



Surface area of cross-section of one profile A[cm2] = 2.79

Fig. 16. Stainless steel cold-formed profiles in the OMEGA frame a) side view; b) vertical cross-section

The dimensions and shape of the load-bearing units depend on the geometrical dimensions and shapes of the reinforced concrete components being joined and the thickness of the insulation used in the system. Heights of steel OMEGA (hr) frames depend on the slab thickness (H). This relationship is given in Table 13.

Tab. 13. Relationship of the height of the steel OMEGA frame on the slab thickness

Slab thickness (H) [mm]	160	180	200	220	240
Frame height (hr) [mm]	106	126	146	166	186

6. USE OF "U" BARS

Vertical bars Ø12 mm, intended for correct anchoring of the profiles in the reinforced concrete components, marked with "U", are ended with a properly shaped loop. Depending on the shape and relative location of the reinforced concrete external components and internal components of the building connected using the TIPOMEGA® system, the "U" reinforcement bars are available in four versions: U1, U2, U3 and U4. Furthermore, U3 and U4 bars may be directed upwards (UG3, UG4) or downwards (UD3, UD4).

6.1. Shape U1

The examples of the use of the U1 bars intended for anchoring in the slab are given below. The upper level of the cantilevered balcony slab is located at the same level as that of the floor slab (see fig. 17, fig. 18). Where the floor slab is at a higher level than the balcony slab, one must consider providing a minimum concrete cover of 40mm for the internal U1 bar (see fig. 18c).

If the structural design requires transfer of bending moment by the TIPOMEGA® connectors both in the positive and negative direction (e.g.: with intermediate support of balcony slab), then it is required to use the OMEGA.XX.YY.U11.U11 load-bearing frames with U1 bars welded both to upper and bottom stainless steel profiles (see fig. 17).

a)

b)

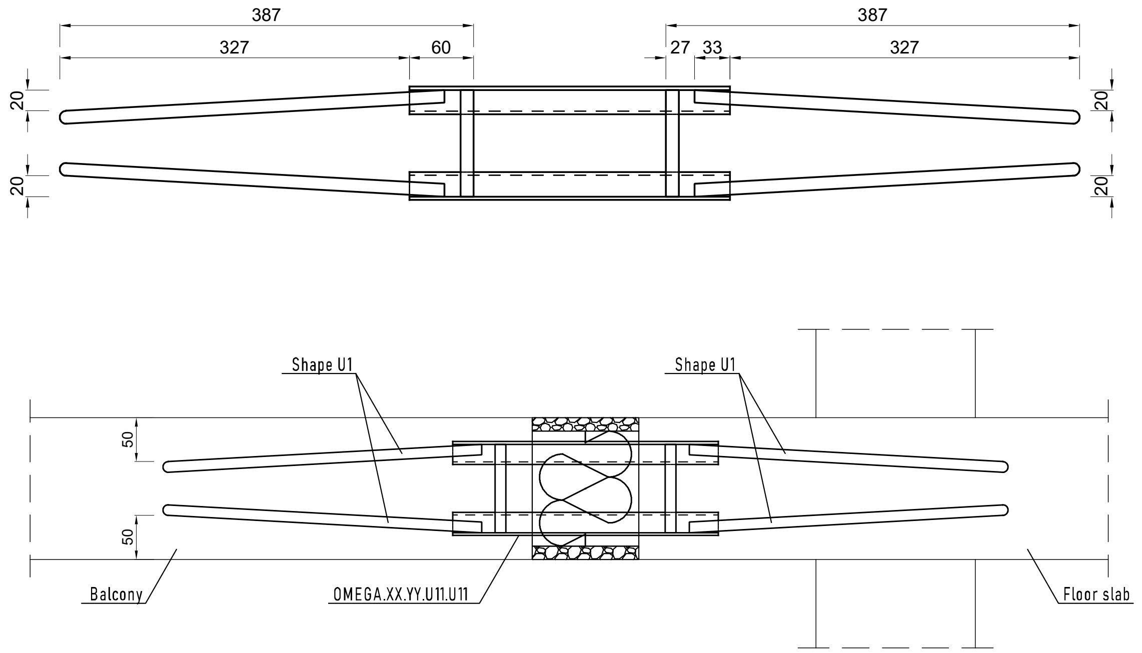
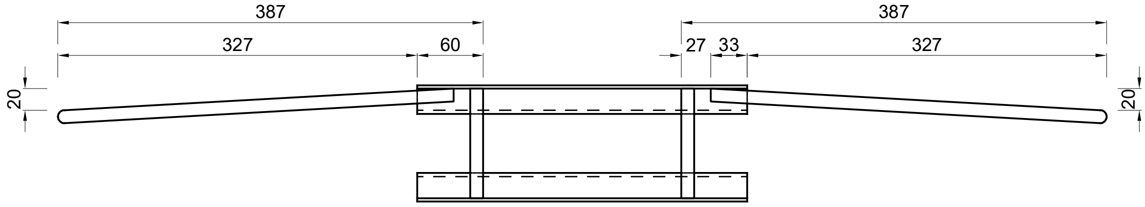
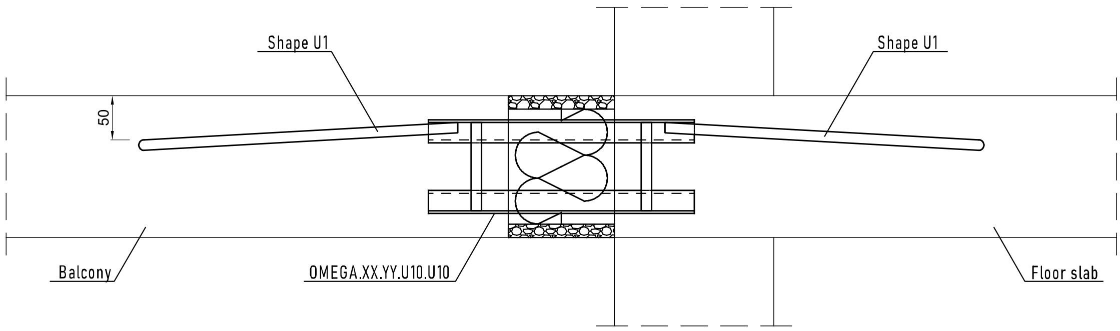


Fig. 17. Use of the OMEGA.XX.YY.U11.U11 frame in continuous floor slab (intermediate support of balcony slab)
a) side view; b) example of use

a)



b)



c)

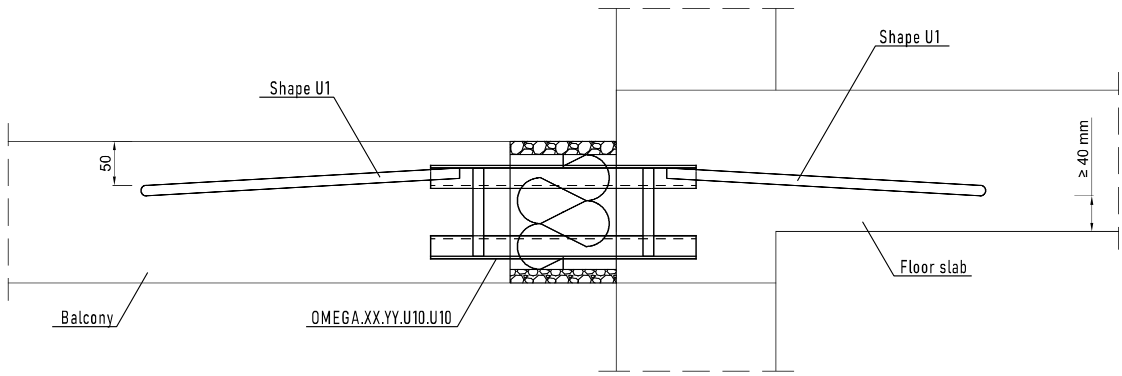


Fig. 18. Application of the OMEGA.XX.YY.U10.U10 frame
a) side view; b), c) examples of use

6.2. Shape U2

To avoid the possibility of conflict of the U1 bars in two or more overlapping load-bearing OMEGA frames (e.g. corner balconies) it is possible to use properly formed U2 anchoring bars (see fig. 19).

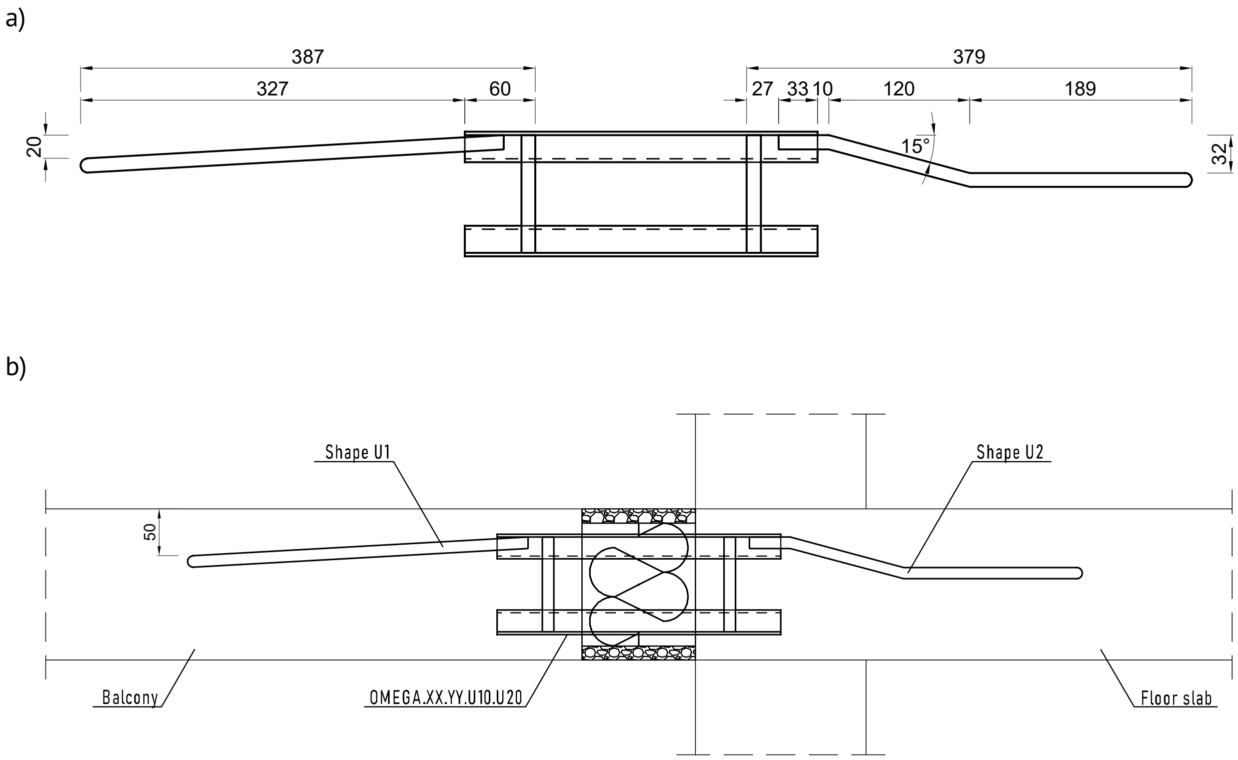


Fig. 19. Application of the OMEGA.XX.YY.U10.U20 frame
a) side view; b) example of use

6.3. Shape U3

Where no internal floor is located at the same level as the external cantilevered balcony slab, it is possible to use OMEGA frames with properly formed U3 bars. In such a case the frames are anchored in the beam or reinforced concrete wall downwards (UD3) or upwards (UG3) of relative to the level of the balcony slab. The minimum width of the beam or wall, where the OMEGA frames are fixed, is 180 mm (see fig. 20. fig. 21).

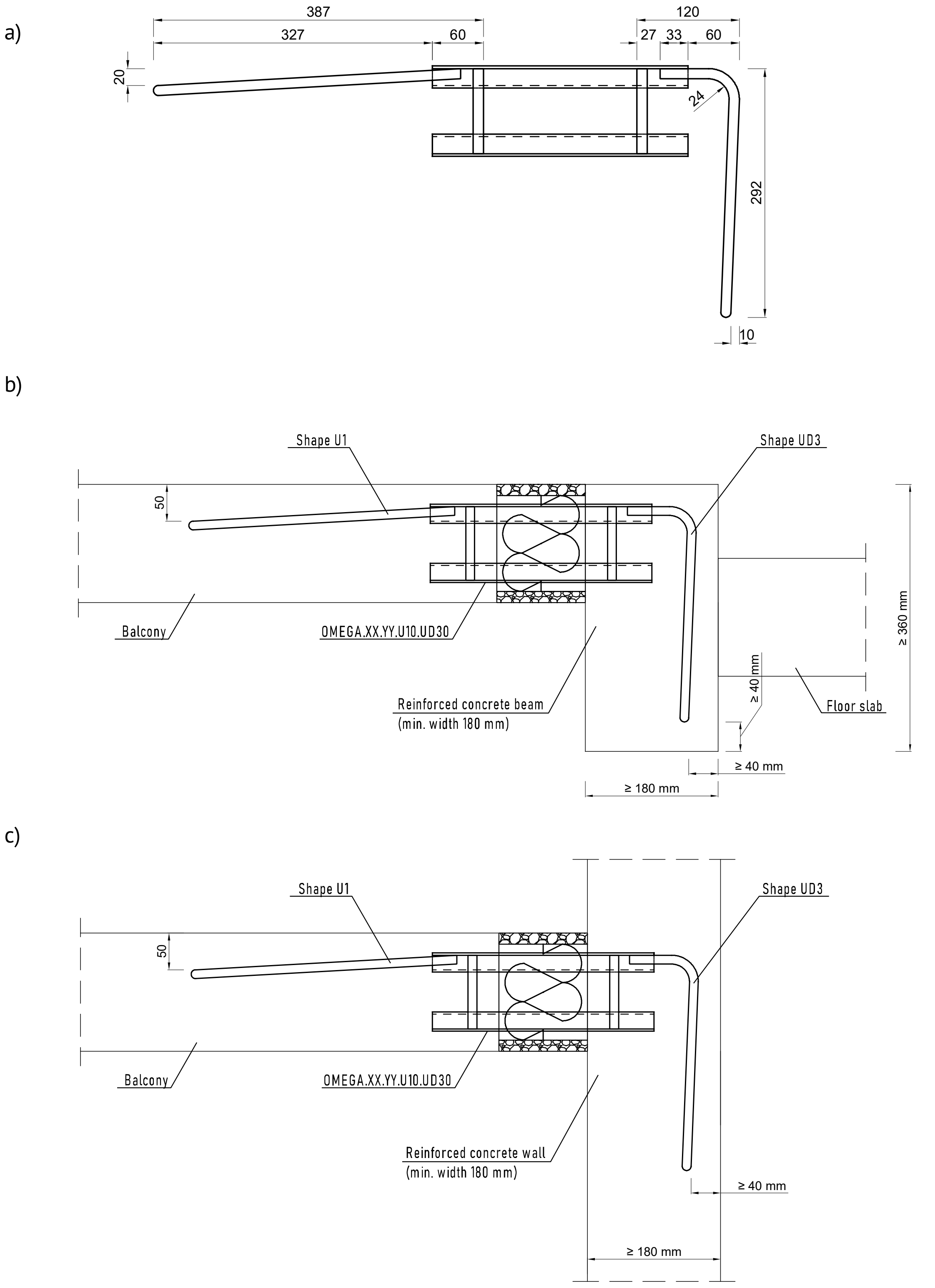
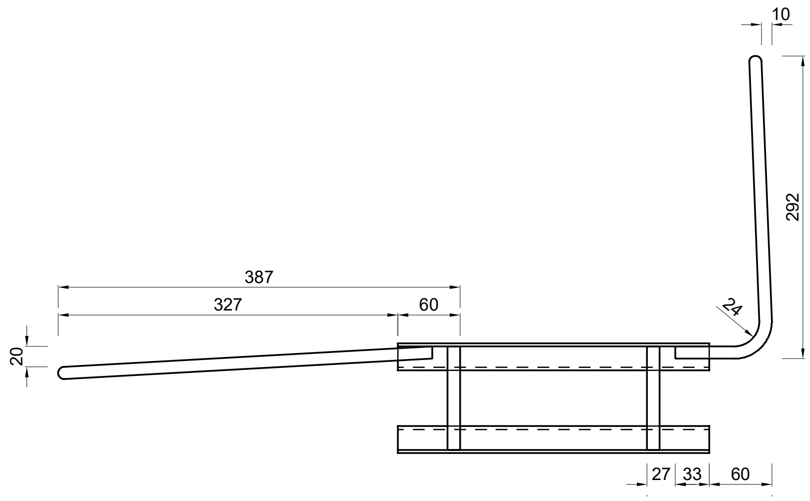
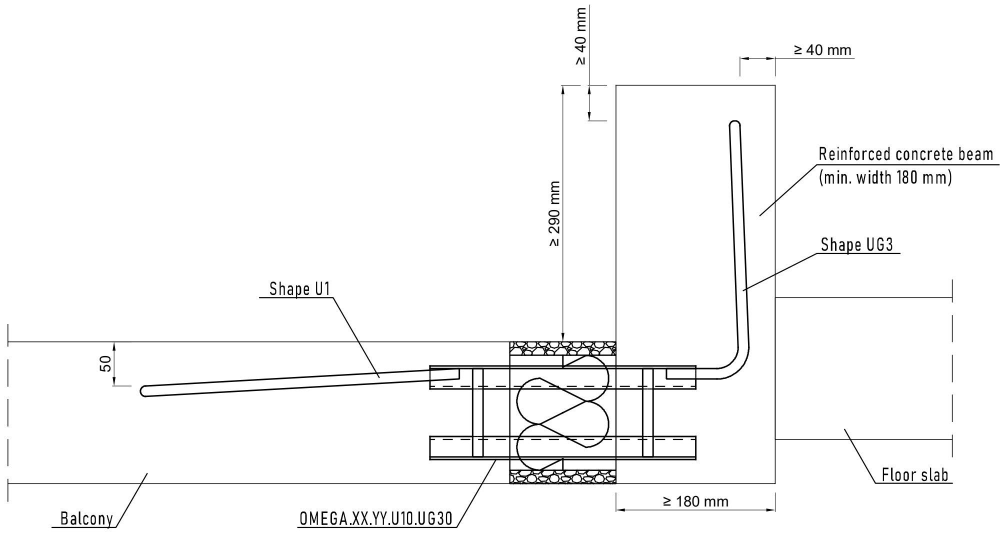


Fig. 20. Application of the OMEGA.XX.YY.U10.UD30 frame
a) side view; b), c) examples of use

a)



b)



c)

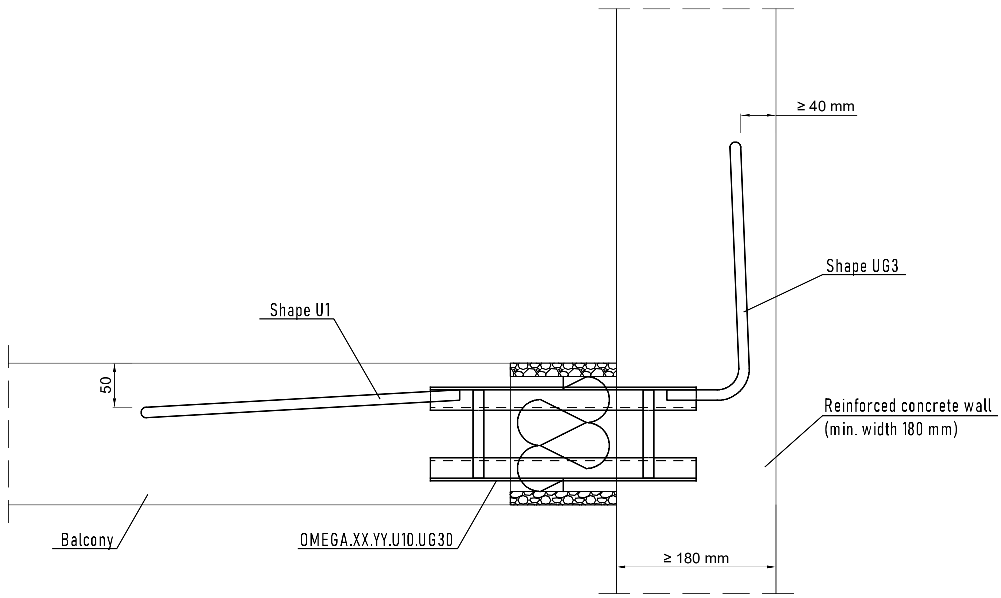
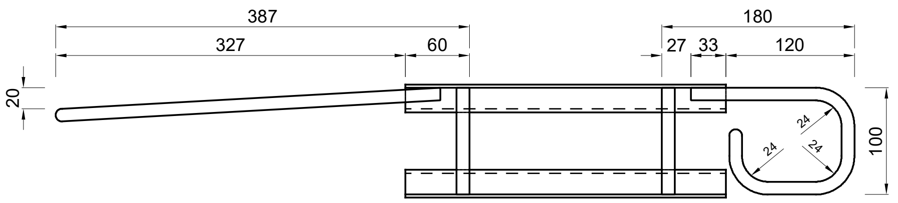


Fig. 21. Application of the OMEGA.XX.YY.U10.UG30 frame
a) side view; b), c) examples of use

6.4. Shape U4

To support the balcony slab on the reinforced concrete beam with small dimensions (beam width min. 240 mm) it is required to use the OMEGA frames with properly formed U4 bars. The frames can be anchored in the reinforced concrete beam located downwards (UD3) or upwards (UG3) relative to the level of the balcony slab (see fig. 22, fig. 23).

a)



b)

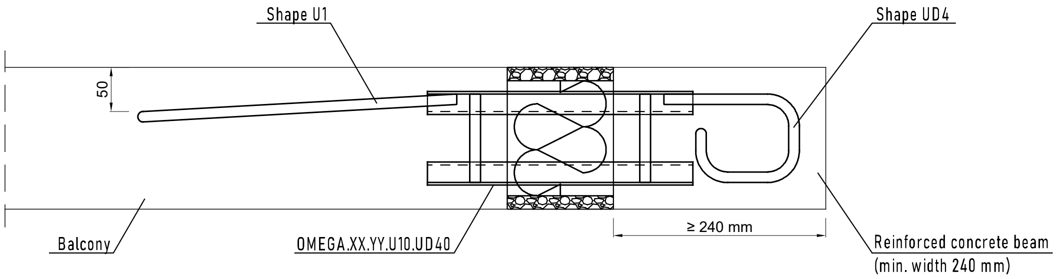
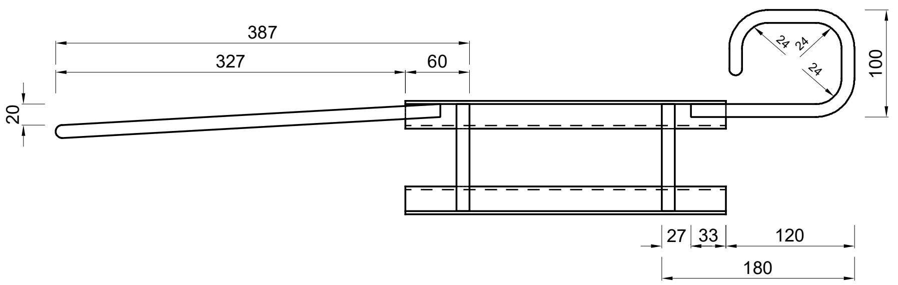


Fig. 22. Use of OMEGA.XX.YY.U10.UD40 frames
a) side view; b) example of use

a)



b)

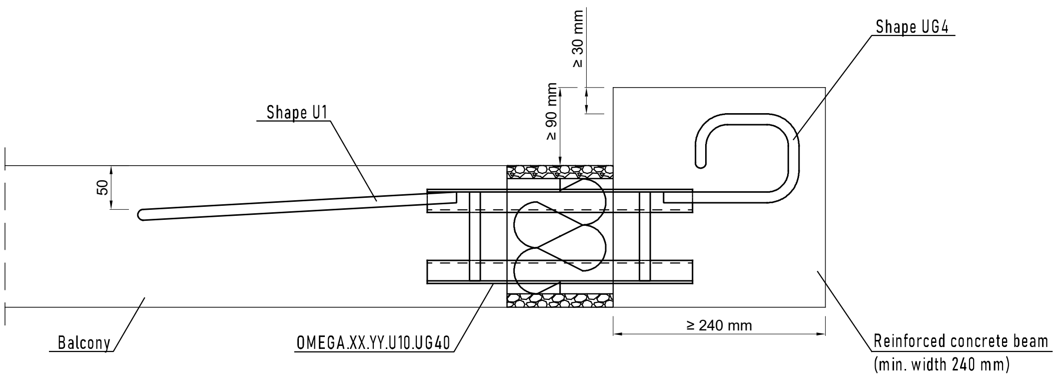


Fig. 23. Use of OMEGA.XX.YY.U10.UG40 frames
a) side view; b) example of use

7. DESIGN REQUIREMENTS FOR COMPONENTS MADE OF REINFORCED CONCRETE

Application of the TIPOMEGA® system requires meeting the following conditions:

- The connected reinforced concrete structural components should be made of an ordinary concrete of grade not lower than C20/25 according to PN-EN 206+A1:2016; thickness of reinforcement cover should be min. 3 cm and thickness of cover for the steel profiles min. 2.5 cm.
- Due to the corrosivity of the environment, the reinforced concrete components should be designed in accordance with the requirements given in Annex A to PN-EN 1993-1-4:2007.
- The joined structural components made of reinforced concrete should be properly reinforced; amount and type of reinforcement should be selected based on the static and dynamic structural calculations, in compliance with the dimensioning rules (meeting the requirements of limit states of load capacities and operation) and the requirements of PN-EN 1992-1-1 (EC2).
- External reinforced concrete slabs should have expansion joints; distances between expansion joints should be selected based on the static and dynamic calculations made based on PN-EN 1992-1-1 (EC2) and should meet the requirements specified in item 10.3.

8. FIRE PROTECTION

Reinforced concrete balcony slabs connected with reinforced concrete structural components using the TIPOMEGA® reinforcement connectors have been classified according to the criteria of PN-EN 13501-2:2016 in the fire resistance rating REI 120. Fire protection is executed on all surfaces or linear connector not covered with concrete, that is along the whole connection from the top and bottom of the connector and on both its side faces (see fig. 24).

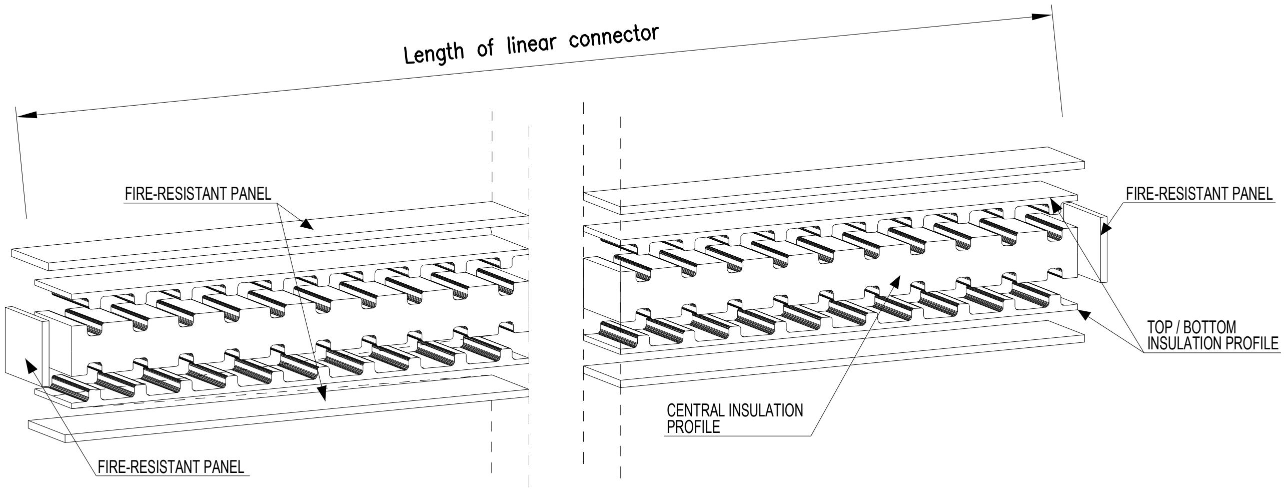


Fig. 24. Fire insulation class REI 120 of the TIPOMEGA® system

Sections of balcony slabs connecting with the building not requiring reinforcement, can be executed with the TIP insulation profiles used on the other sections of connection, free from reinforcement, but with fire insulation in the form of fire-retardant panels made of the mcr TECBOR magnesium boards 15 mm in thickness. Alternatively, a section of connection of the balcony slab not requiring the reinforcement, of min. height 160 mm, can be filled with mineral rock wool of min. density 65 kg/m3 – for the linear connection EI 30 or EI 60 or with mineral rock wool of min. density 150 kg/m3 - for the linear connector EI 120. It is also possible to use other solutions for sealing of linear connectors, placed on the marked in accordance with the applicable regulations and meeting the requirements of fire resistance rating not lower than the required fire resistance rating of the balcony slab.

9. TECHNICAL PARAMETERS OF THE OMEGA FRAMES

9.1. Compliances

Vertical (k_V) and horizontal (k_H) elastic compliance of the individual OMEGA module in connections of the reinforced concrete components using the TIPOMEGA® system should be assumed according to Table 14:

Tab. 14. Relationship of vertical and horizontal rigidity in connections with the TIPOMEGA® system

	Vertical stiffness (k_V)	Horizontal stiffness (k_H)
OMEGA.08 [kN/m]	227 000	665 000
OMEGA.12 [kN/m]	70 000	197 000
OMEGA.16 [kN/m]	30 000	83 000

The rotational elastic stiffness (kφ) of the individual OMEGA frame depends on the thickness of slab (H) and the thickness of thermal insulation of the TIPOMEGA® system and it has been specified in Table 15.

Tab. 15. Dependency of bending rigidity of connection in the TIPOMEGA® system

Slab thickness (H) [mm]	160	180	200	220	240
OMEGA.08 [kNm/rad]	2 250	3 500	5 000	6 800	8 900
OMEGA.12 [kNm/rad]	1 500	2 300	3 350	4 550	5 950
OMEGA.16 [kNm/rad]	1 100	1 750	2 500	3 400	4 450

9.2. Operation analysis

In thermal insulation area (L) each OMEGA frame is subject to the action of transverse forces (V) and flexural moments (M). Values of these forces in the design model result from the static analysis of the balcony slab carried out by the designer. The other internal forces, including torsional moments and normal forces, should be negligibly small (see fig. 25).

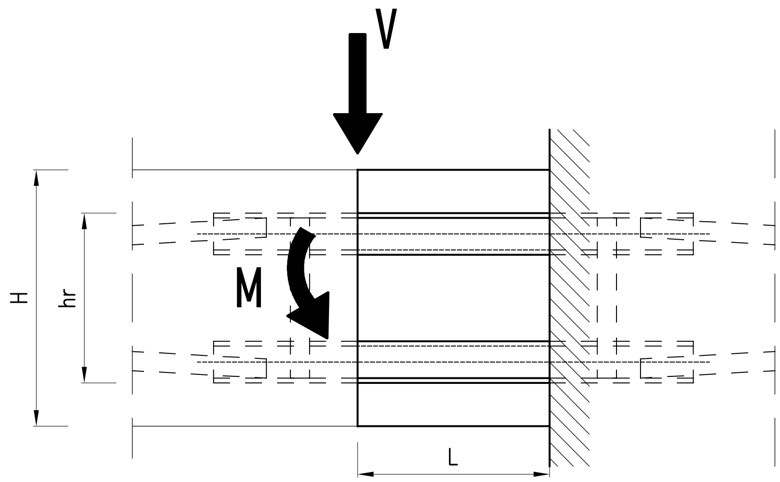


Fig. 25. Static diagram of stainless profiles in the thermal insulation area

Analyzing the operation of both stainless steel profiles in the OMEGA frame we obtain the impact of the force V, causing the occurrence of the normal stresses in cross-section of stainless steel profiles and generating the shear stresses V and bending moment M. Considering the action of force V on the individual profile we obtain a diagram of shear forces T_V and bending moments M_V (see fig. 26 and fig. 27).

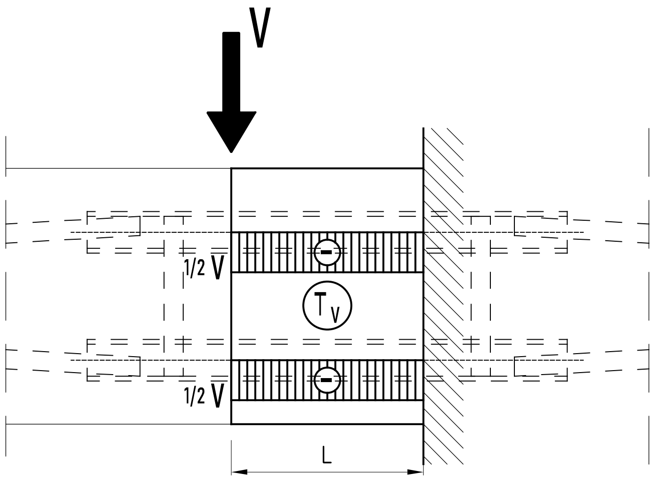


Fig. 26. Diagrams of shear forces induced by the action of force V

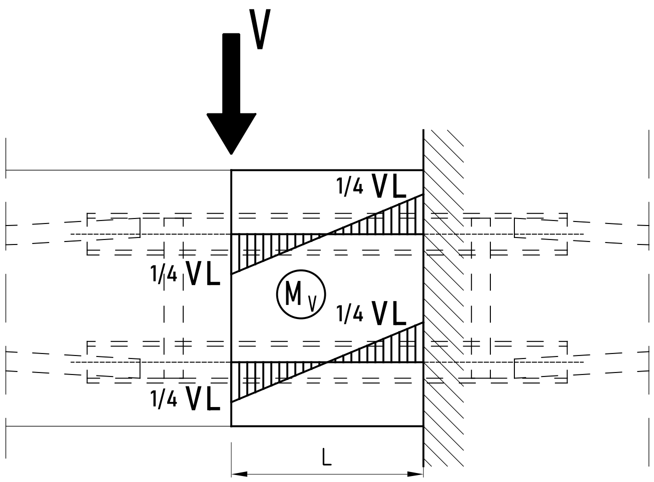


Fig. 27. Diagrams of bending moments induced by the action of force V

9.3. Design capacities

The design capacities for the OMEGA frames, given in item 11. specify a set of such pairs of forces (M, V), that will not lead to failure of the stainless steel profiles in the OMEGA frame and exceeding limit conditions or the OMEGA frames anchoring areas in the concrete on both sides of the element. It has been assumed that stainless steel profiles will be operating in the linear elastic condition. Analyses of load capacities of the OMEGA frames and anchoring areas in the concrete have been performed based on the Eurocode standards.

Shear strength V (expressed in [kN]) and resistance to bending moment M (expressed in [kNm]) of the individual OMEGA module depends on the thickness of insulation and height of insulation identical with the thickness of connected reinforced concrete components. Considering the load capacity of units concreting area also a concrete strength class and spacing of the units should be taken into account. Pairs of maximum design bending moments and maximum design transverse forces and design shear strength and resistance to bending moments made using the TIPOMEGA® connectors are shown on the interaction diagrams (see Diag. 1, Diag. 2, Diag. 3) and are listed in the tables below these diagrams.

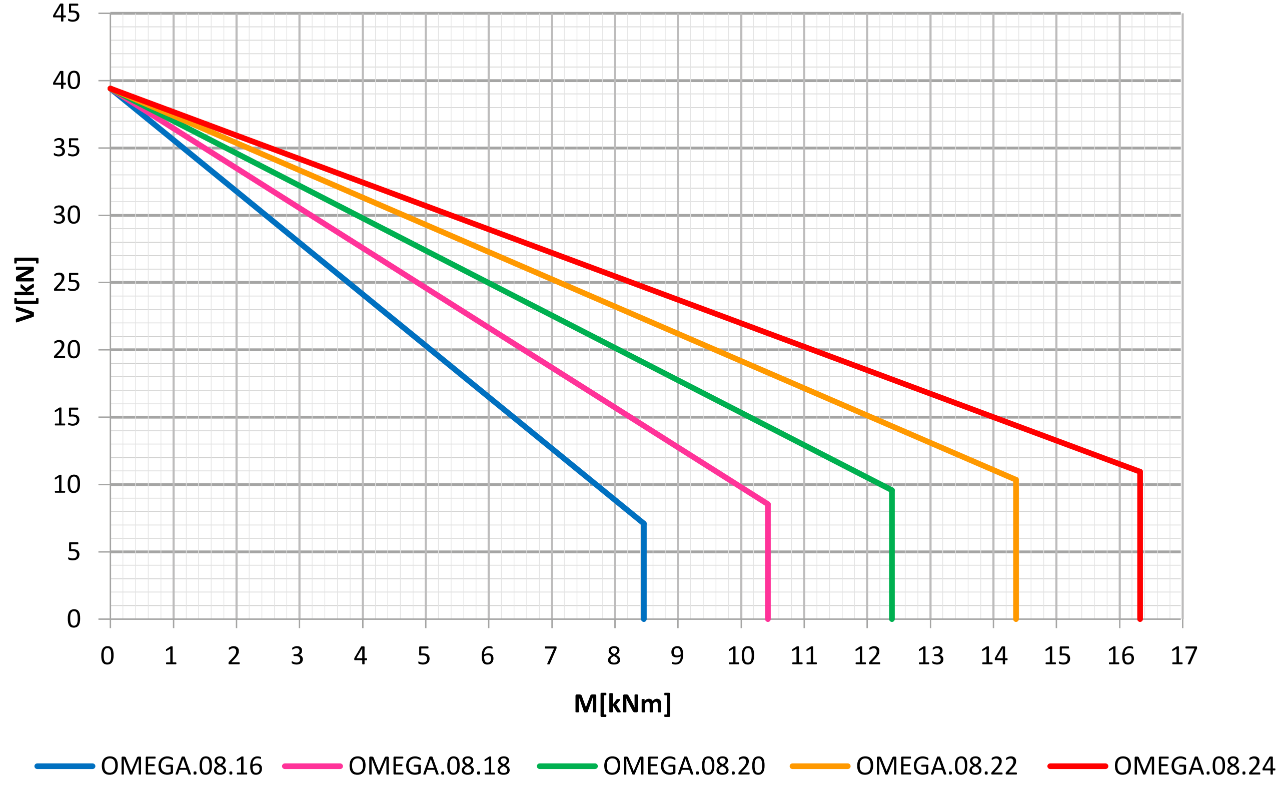
In all variants of the shape of the "U" reinforcement bars, the OMEGA frame allows transferability of transverse forces V in both directions (both in the positive and negative direction). Additionally, in the case of use of the U1 bars in the frame, welded both to upper and bottom profile (OMEGA.XX.YY.U11.U11 profile see fig. 5 and fig. 17), the above property applies also to transfer of flexural moments M.

The OMEGA load-bearing units ensure transferability of interaction parallel to the building (H), which is given in Table 16. Resistance to interaction parallel to the connection applies to the cases of occurrence of only H force in the connection, without force V and moment M. It means that H force should be only interaction on the connector (this force must not be considered as an additional interaction resulting from the vertical load acting on the balcony slab). The analysed situation may occur e.g.: during the connection of vertical walls to the structure of the building.

Tab. 16. Design capacity of the single OMEGA frame to interaction parallel to the connection

	Horizontal load capacity (H)
OMEGA.08 [kN]	71,15
OMEGA.12 [kN]	47,43
OMEGA.16 [kN]	35,57

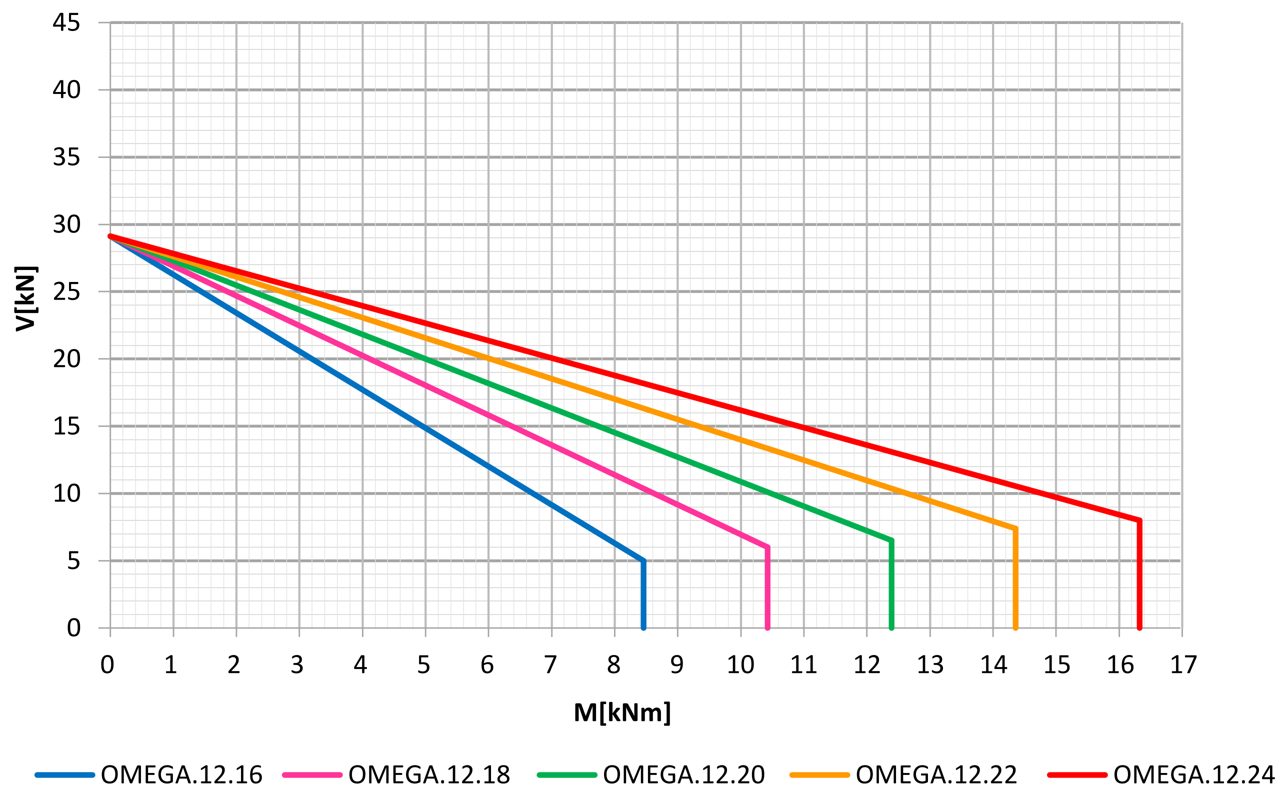
OMEGA.08 M-V interaction



Diag. 1. M-V interaction diagram for OMEGA.08 units

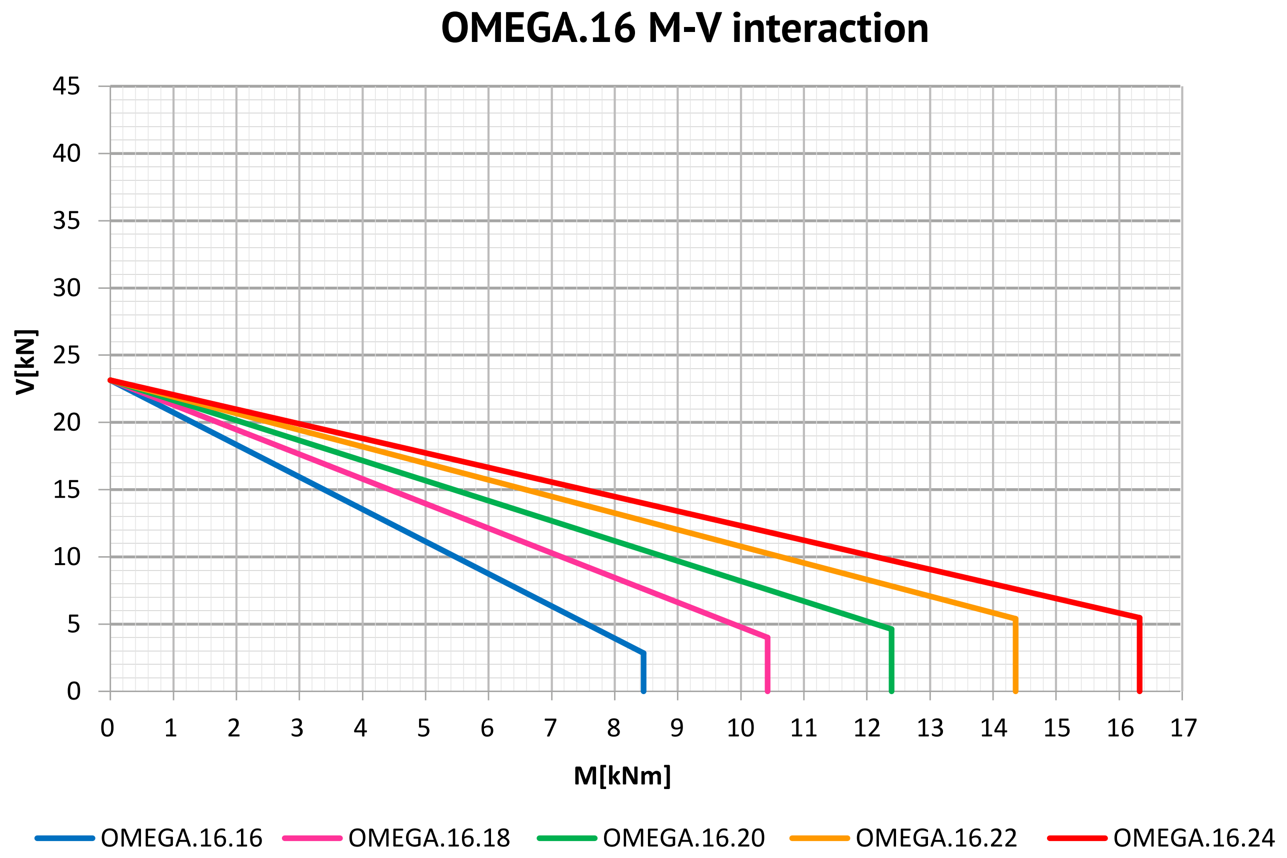
OMEGA.08.16	V	[kN]	39,41	38,00	36,00	34,00	32,00	30,50	29,00	27,50	26,00	24,50	23,00	21,50	20,00	18,50	17,00	15,00	13,00	11,00	9,00	7,10	0,00						
	M	[kNm]	0,00	0,37	0,89	1,42	1,94	2,33	2,73	3,12	3,51	3,90	4,30	4,69	5,08	5,48	5,87	6,39	6,92	7,44	7,96	8,46	8,46						
OMEGA.08.18	V	[kN]	39,41	38,00	36,00	34,00	32,50	31,00	29,50	28,00	26,50	25,00	23,00	21,00	19,00	17,00	15,50	15,00	13,50	12,00	10,50	9,00	8,56	0,00					
	M	[kNm]	0,00	0,48	1,15	1,83	2,33	2,84	3,35	3,85	4,36	4,87	5,54	6,22	6,89	7,57	8,08	8,24	8,75	9,26	9,76	10,27	10,42	10,42					
OMEGA.08.20	V	[kN]	39,41	38,00	36,50	35,00	33,50	32,00	30,50	29,00	27,50	26,00	25,00	24,00	23,00	22,00	21,00	19,50	18,00	16,50	15,00	13,50	12,00	10,50	9,58	0,00			
	M	[kNm]	0,00	0,59	1,21	1,83	2,45	3,08	3,70	4,32	4,95	5,57	5,99	6,40	6,82	7,23	7,65	8,27	8,89	9,52	10,14	10,76	11,39	12,01	12,39	12,39			
OMEGA.08.22	V	[kN]	39,41	38,00	36,50	35,00	33,50	32,00	31,00	30,00	29,00	28,00	27,00	26,00	25,00	24,00	23,00	22,00	21,00	20,00	18,50	17,00	15,50	14,00	12,50	11,00	10,34	0,00	
	M	[kNm]	0,00	0,70	1,44	2,18	2,92	3,66	4,15	4,65	5,14	5,64	6,13	6,63	7,12	7,61	8,11	8,60	9,10	9,59	10,33	11,07	11,81	12,55	13,29	14,04	14,36	14,36	
OMEGA.08.24	V	[kN]	39,41	38,00	37,00	36,00	35,00	34,00	33,00	32,00	31,00	30,00	29,00	27,50	26,00	24,50	23,00	21,50	20,00	19,00	18,00	17,00	16,00	15,00	14,00	13,00	12,00	10,95	0,00
	M	[kNm]	0,00	0,81	1,38	1,96	2,53	3,10	3,68	4,25	4,82	5,40	5,97	6,83	7,69	8,55	9,41	10,28	11,14	11,71	12,28	12,86	13,43	14,00	14,58	15,15	15,73	16,33	16,33

OMEGA.12 M-V interaction



Diag. 2. M-V interaction diagram for OMEGA.12 units

OMEGA.12.16	V	[kN]	28,90	28,00	27,00	26,00	25,00	24,00	22,50	21,00	19,50	18,00	16,50	15,00	13,50	12,00	10,50	9,00	8,00	7,00	6,00	4,88	0,00						
	M	[kNm]	0,00	0,32	0,67	1,02	1,37	1,73	2,25	2,78	3,31	3,84	4,37	4,90	5,42	5,95	6,48	7,01	7,36	7,71	8,07	8,46	8,46						
OMEGA.12.18	V	[kN]	28,90	28,00	27,00	26,00	25,00	24,00	23,00	22,00	21,00	19,50	18,00	16,50	15,00	13,50	12,00	11,00	10,00	9,00	8,00	7,00	5,96	0,00					
	M	[kNm]	0,00	0,41	0,86	1,32	1,77	2,23	2,68	3,13	3,59	4,27	4,95	5,63	6,32	7,00	7,68	8,13	8,59	9,04	9,50	9,95	10,42	10,42					
OMEGA.12.20	V	[kN]	28,90	28,00	27,00	26,00	25,00	24,00	23,00	22,00	21,00	20,00	19,00	17,50	16,00	15,00	14,00	13,00	12,00	11,00	10,00	9,00	8,00	7,00	6,73	0,00			
	M	[kNm]	0,00	0,50	1,06	1,62	2,18	2,74	3,30	3,86	4,41	4,97	5,53	6,37	7,21	7,77	8,33	8,89	9,44	10,00	10,56	11,12	11,68	12,24	12,39	12,39			
OMEGA.12.22	V	[kN]	28,90	28,50	28,00	27,00	26,00	25,00	24,00	23,00	22,00	21,00	20,00	19,00	18,00	17,00	16,00	15,00	14,00	13,00	12,00	11,00	10,00	9,00	8,00	7,50	7,30	0,00	
	M	[kNm]	0,00	0,27	0,60	1,26	1,93	2,59	3,26	3,92	4,59	5,25	5,92	6,58	7,25	7,91	8,57	9,24	9,90	10,57	11,23	11,90	12,56	13,23	13,89	14,22	14,36	14,36	
OMEGA.12.24	V	[kN]	28,90	28,50	28,00	27,00	26,00	25,00	24,00	23,00	22,00	21,00	20,00	19,00	18,00	17,00	16,00	15,00	14,00	13,00	12,00	11,00	10,00	9,50	9,00	8,50	8,00	7,75	0,00
	M	[kNm]	0,00	0,31	0,69	1,47	2,24	3,01	3,78	4,55	5,33	6,10	6,87	7,64	8,41	9,19	9,96	10,73	11,50	12,27	13,05	13,82	14,59	14,98	15,36	15,75	16,13	16,33	16,33



Diag. 3. M-V interaction diagram for OMEGA.16 units

OMEGA.16.16	V	[kN]	22,82	22,00	21,00	20,00	19,00	18,00	17,00	16,00	15,00	14,00	13,00	11,50	10,00	9,00	8,00	7,00	6,00	5,00	4,00	3,08	0,00						
	M	[kNm]	0,00	0,35	0,78	1,21	1,64	2,07	2,49	2,92	3,35	3,78	4,21	4,85	5,49	5,92	6,35	6,78	7,21	7,64	8,07	8,46	8,46						
OMEGA.16.18	V	[kN]	22,82	22,00	21,00	20,00	19,00	18,00	17,00	16,00	15,00	14,00	13,00	12,00	11,00	10,00	9,00	8,00	7,00	6,00	5,00	4,00	3,98	0,00					
	M	[kNm]	0,00	0,45	1,01	1,56	2,11	2,67	3,22	3,77	4,32	4,88	5,43	5,98	6,54	7,09	7,64	8,20	8,75	9,30	9,85	10,41	10,42	10,42					
OMEGA.16.20	V	[kN]	22,82	22,50	22,00	21,50	21,00	20,00	19,00	18,00	17,00	16,00	15,00	14,00	13,00	12,00	11,00	10,00	9,00	8,00	7,00	6,00	5,50	5,00	4,60	0,00			
	M	[kNm]	0,00	0,22	0,56	0,90	1,24	1,92	2,60	3,28	3,96	4,64	5,32	6,00	6,68	7,36	8,04	8,72	9,40	10,08	10,76	11,44	11,78	12,12	12,39	12,39			
OMEGA.16.22	V	[kN]	22,82	22,50	22,00	21,50	21,00	20,50	20,00	19,00	18,00	17,00	16,00	15,00	14,00	13,00	12,00	11,00	10,00	9,00	8,00	7,50	7,00	6,50	6,00	5,50	5,08	0,00	
	M	[kNm]	0,00	0,26	0,66	1,07	1,47	1,88	2,28	3,09	3,90	4,71	5,52	6,33	7,14	7,95	8,76	9,57	10,38	11,19	11,99	12,40	12,80	13,21	13,61	14,02	14,36	14,36	
OMEGA.16.24	V	[kN]	22,82	22,50	22,00	21,50	21,00	20,50	20,00	19,50	19,00	18,00	17,00	16,00	15,00	14,00	13,00	12,00	11,00	10,00	9,00	8,50	8,00	7,50	7,00	6,50	6,00	5,44	0,00
	M	[kNm]	0,00	0,30	0,77	1,24	1,71	2,18	2,65	3,12	3,59	4,53	5,47	6,41	7,35	8,29	9,23	10,17	11,11	12,04	12,98	13,45	13,92	14,39	14,86	15,33	15,80	16,33	16,33

10. DESIGNING THE BALCONY SLABS WITH THE TIPOMEGA® CONNECTORS

10.1. Spacing of the OMEGA frames

For system TIPOMEGA® it is possible to use an axial spacing of the OMEGA spacing units at multiples of 100 mm (that is: 100 mm, 200 mm, 300 mm, etc.). Spacing of the OMEGA frames should be selected in such a way to ensure that their linear capacity will not be less than design values of forces and moments in the connection, obtained as a result of static and dynamic calculations. The linear capacity should be understood as the quotient of the capacity of the single OMEGA unit and spacing of units on the given section. It is allowed to perform static and dynamic calculations assuming the continuous, linear composition of connected reinforced concrete structural components provided that the allowable distances between the frames are not exceeded. Maximum linear spacing for the OMEGA units is a value equal to 5H, where H is the thickness of the external reinforced concrete component. The minimum allowed distance from the axis of the load-carrying component to the perpendicular external edge of the connected reinforced concrete component is 100 mm. Maximum distance of the axis of the OMEGA frame to the external edge of the connection, at which the deformations occur (crosswise to the OMEGA modules) with dominant side load, leading to non-uniform loading of the units, is a value of 3H (see fig. 28). If it is necessary to exceed the maximum 3H and 5H values, then it is required to check punching shear strength and design, if necessary, the connected reinforced concrete components should be suitably reinforced.

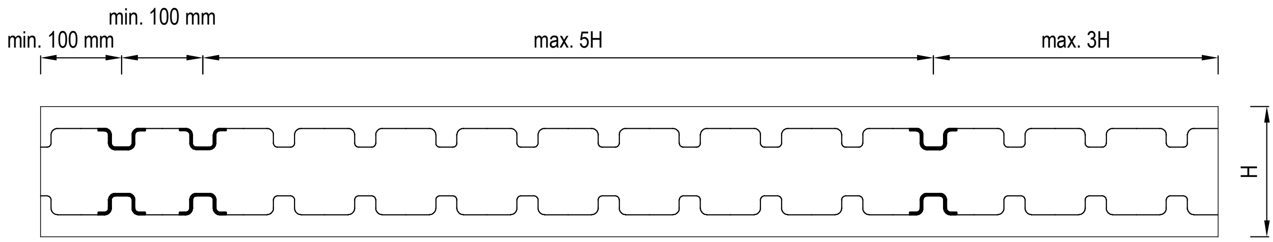


Fig. 28. Limitations of distance for the OMEGA modules assuming continuous, linear support

10.2. Grouping of the OMEGA frames

When the OMEGA units are grouped in the areas, where the local increase of internal forces occurs (e.g. in the corners or for the balcony slab overhand beyond the edge of the building) it is required to assume the maximum length of forces averaging equal to 80 cm. It means that for spacing of the OMEGA units equal to 20 cm, the forces may be averaged to 5 units (position 0-20-40-60-80 cm). Similarly, for the spacing of the OMEGA modules every 10 cm, the forces may be averaged to 9 units (position 0-10-20-30-40-50-60-70-80 cm). The necessary condition for the above cases is an occurrence of internal forces with the same signs for the whole group of units.

10.3. Expansion joints in slabs

To limit the adverse impacts caused by shrinkage and thermal interactions it is required to ensure - to certain limits - freedom of deformation for the balcony slabs. The TIPOMEGA® connectors operating as spring supports for the analysed slabs will be the factor limiting such freedom.

In compliance with PN-EN 1992-1-1 (EC2), the thermal effects should be always considered for checking of serviceability limit states. For serviceability limit states of the reinforced concrete structures, it is required to verify - generally - crack width and deformations of the structure (usually: net deflection). Assuming that changes in temperature of balcony slabs result in - without thermal insulation - its uniform heating/cooling, it is allowed to omit the verification of bending deformations (uniform change in temperature will not result in bending forces and deflections). Uniform cooling of the structure will result in shortening of the component, while heating - in its elongation. The important thing to consider is linear deformations occurring on the section between the connectors, on a direction perpendicular to the outreach of the support slab (so parallel to the edge of support). The presence of connectors will limit the freedom of linear deformations in the areas adjacent to the fixed edge. The effect of this limitation will be an occurrence of normal stresses on the direction of slab's edge: compressive (for uniform heating) and tensile (for uniform cooling) stress.

The recommended spacing for the expansion joints, allowing to omit the impact of shrinkage, creeping and temperature in the structural design is d_{joint} = 20.0 m. This value should be two times lower (see fig. 29) if the shift of one of the edges perpendicular to the fixed one is blocked.

Furthermore, it is required to use material solutions ensuring the exclusion of the negative effects of cracking. One of the most efficient methods is to use damp-proof elastic coatings on the surfaces of the reinforced concrete slabs.

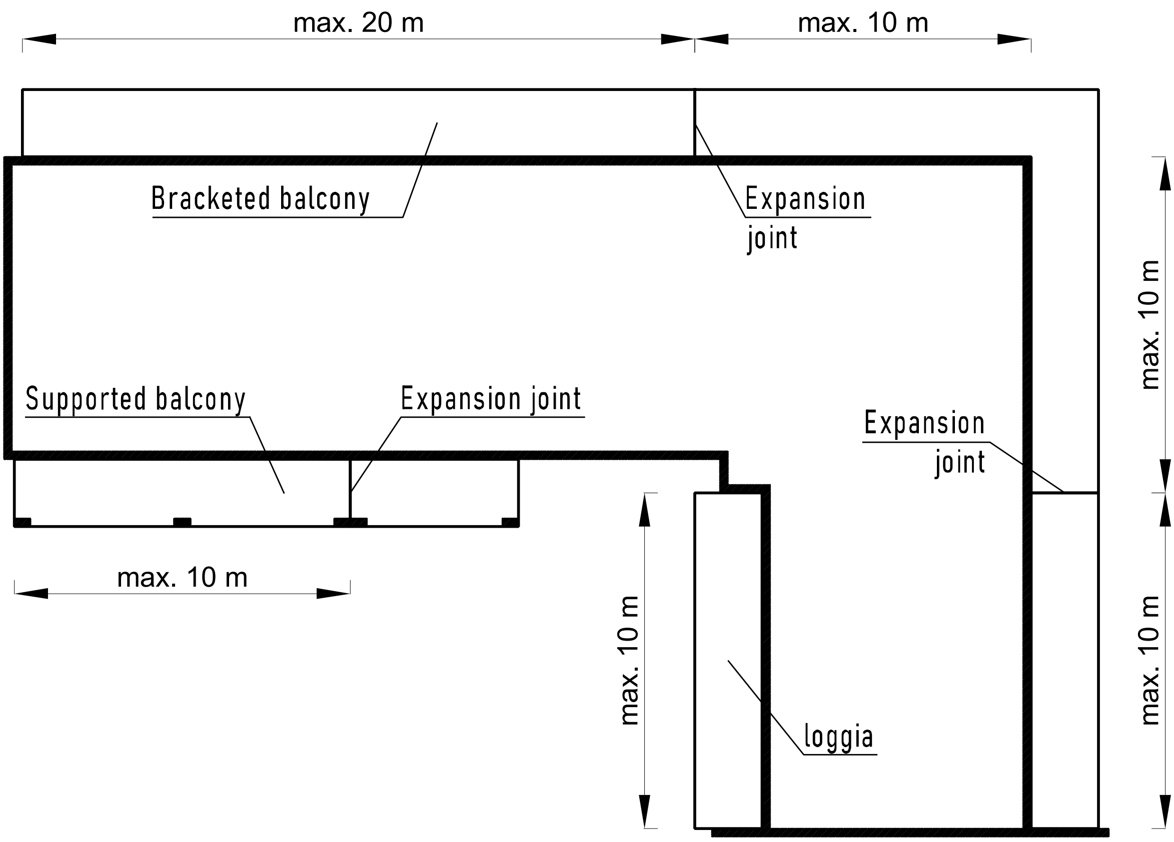


Fig. 29. Distances between expansion joints

If you decide not to use expansion joints for the structure of slabs fixed using the TIPOMEGA® connectors in compliance with the manufacturer guidelines given on Figure 29, it is required to perform analysis of superficial crack acc. to PN-EN 1992-1-1 (EC2). The structural design should consider the effects of deformations caused by the temperature, creeping (it has the biggest impact on deformation from the long-term loads) and shrinkage. It should be noted that crack width depends on the geometry of the structure, reinforcement ratio, type of concrete and stresses depending on the tensile force (in the absence of flexural moments).

From the view of the serviceability limit state, it is important to consider the impact of tensile stresses (so accompanying the cooling of the structure) and, as a consequence, scratches perpendicular to the central plane of the slab. Cracks width should be limited due to:

- aesthetics of the structure (to the level of 0.4 mm),
- the durability of the structure (to the level of 0.3 mm, except for the exposure class X0 and XC1).

In addition, it is important that for approximately axial tension, the formed cracks will pass through the whole thickness of the slab, which may lead to the undesired penetration of water through the component, which will result in:

- washing out of cement stone minerals and, as a consequence, loosening of the concrete structure, lowering its pH reaction and reduction of the concrete's capability to protect the reinforcement bars against corrosion,
- formation of salt stains and patches of efflorescence on the structure.

It is possible to completely eliminate cracking of the balcony slabs fixed using TIPOMEGA® connectors. Table 17 presents exemplary, maximum spacing of expansion joints, allowing to eliminate cracking caused by uniform cooling (for slabs made of concrete C25/30, assuming the difference in temperature Δt = -20°C).

Tab. 17. Maximum spacing of expansion joints allowing eliminating the scratching [m]

OMEGA frames spacing [mm]	TIPOMEGA® thickness [mm]	TIPOMEGA® Height [mm]				
		160	180	200	220	240
100	80	x	x	x	x	x
	120	x	3 m	3 m	3 m	4 m
	160	6 m	7 m	8 m	8 m	9 m
300	80	x	x	3 m	3 m	3 m
	120	7 m	9 m	10 m	10 m	10 m
	160	14 m	16 m	16 m	18 m	18 m
500	80	4 m	4 m	5 m	5 m	6 m
	120	12 m	12 m	14 m	14 m	16 m
	160	20 m	20 m	20 m	20 m	20 m
800	80	5 m	7 m	8 m	8 m	8 m
	120	16 m	16 m	18 m	20 m	20 m
	160	20 m	20 m	20 m	20 m	20 m

Notes:

- The “x” designation in the above table indicates that for the given combination of geometrical parameters of the structure it is not recommended to eliminate the cracks by using the expansion joints (in such cases the expansion joints should be located very densely, what is not acceptable from the technology, economy and aesthetics point of view).
- Spacing of the expansion joints has been selected in a way ensuring that tensile stresses in the direction of the fixed edge, caused by uniform cooling, do not exceed the average concrete strength in tension (for concrete grade C 25/30 f_{ctm}=2.6 MPa).
- The impact of reinforcement arranged along the fixed edge on the slab rigidity (this is a safe assumption) has been omitted for the purposes of the above table.
- If one slab’s edge perpendicular to the fixing has restrained freedom of transfer (e.g. balconies fixed in two edges perpendicular to each other), the distances given in the above table should be reduced by half.

In the case of a very variable diagram of internal forces passing along the length of the connection between the balcony with the building (e.g. external corner balconies), it is required to perform each time a detailed analysis of superficial cracking of the balcony slabs.

10.4. Guidelines for the arrangement of reinforcement in the balcony slabs

In compliance with PN-EN 1992-1-1 (EC2), to ensure the correct operation of the slab, the following conditions related to the arrangement of reinforcement should be met, that is:

- Where concentrated loads are present in the areas of maximum moment, the spacing of bars of the primary reinforcement (perpendicular to the supported edge) should not exceed 250 mm and 2x the thickness of the slab, while the spacing of the bars of secondary reinforcement (lateral) should not exceed 400 mm and 3x the thickness of the slab.

- The assumed surface of primary reinforcement should meet the conditions:

$$A_{s1,prov} \geq A_{s,min} = \max\begin{cases} 0{,}26\dfrac{f_{ctm}}{f_{yk}}bd \\ 0{,}0013bd \end{cases}$$

$$A_{s1,prov} \leq A_{s,max} = 0{,}004bh$$

where:
f_{ctm} – average concrete strength in tension [MPa],
f_{yk} – characteristic yield strength of reinforcement steel [MPa],
b – width of cross-section [m],
h – height of cross-section [m],
d – effective height of cross-section [m].

- The assumed surface of lateral reinforcement should meet the condition:

$$A_{S,LR} \geq 0{,}20A_{S1,prov}$$

Notwithstanding the above, the conditions for minimum spacing should be met:

$$s \geq \max\begin{cases} \varnothing \\ d_g + 5\text{ mm} \\ 20\text{ mm} \end{cases}$$

where:
Ø – diameter of overlapped bars [mm],
d_g – maximum grain size of aggregate [mm].

The above conditions are necessary conditions to ensure:
- that rigidity and load capacity of the slab is conditioned by the interaction of concrete and reinforcement,
- that brittle failure risk is limited,
- that spatial rigidity of the component is ensured,
- resistance of component to concentrated forces is improved,
- impact of shrinkage strain is limited,
- stabilize the position of bars of the primary reinforcement during concreting (applies to distribution bars).

Meeting the above conditions will cause that the balcony slab will be spatially rigid and will correctly interact with the embedded TIPOMEGA® connectors.

The following recommendations should be taken into account when planning the arrangement of the reinforcement bars of the balcony slab:

- In the case of a possible collision of reinforcement bars with the structure of the OMEGA frames, it is required to perform local modification of reinforcement mesh by shifting the bars in such a way that distance between them and connected will meet the previously stated conditions for the minimum spacing (it will ensure correct conditions for concreting).
- Primary bars assumed in the slab due to load capacity should effectively operate on the fixed edge. It requires correct anchoring.

Due to the connection method of the slab with the supporting structure using the TIPOMEGA® connectors, it is not possible to anchor the upper reinforcement bars of the balcony slab to ring beam and floor slab to ensure correct transfer of forces to the concrete. Therefore, it is recommended to anchor the upper tension reinforcement by bending them downwards and inserting them into the compression zone. Such a solution will additionally prevent the occurrence of wide cracks near the fixed edge and it meets the requirement of PN-EN 1992-1-1 (EC2) related to edge reinforcement (see fig. 30). This requirement applies to all slabs, but in the case of balconies, it is particularly important.

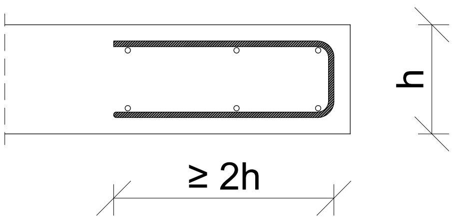
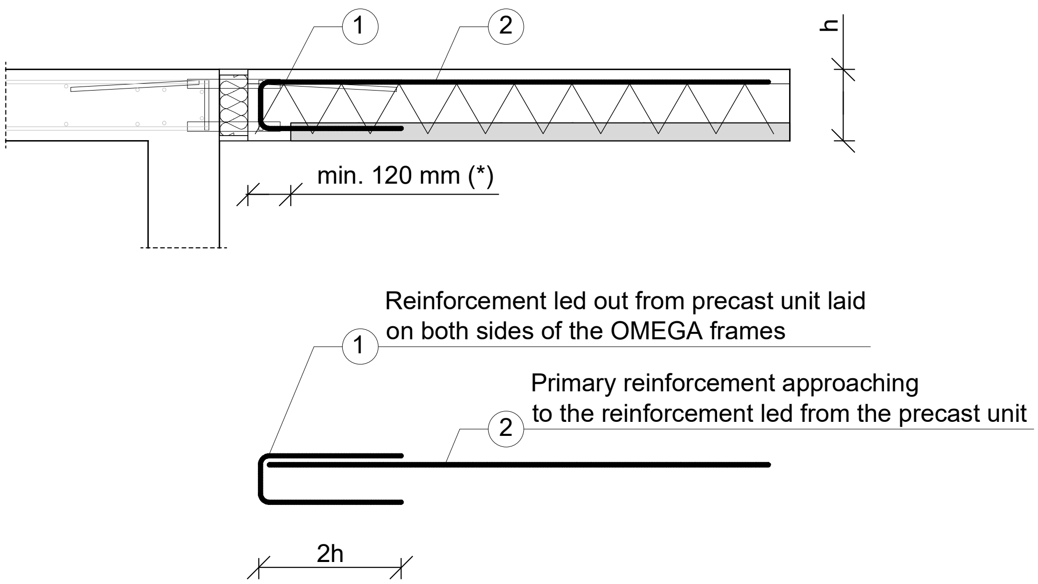


Fig. 30. Edge reinforcement of the slab acc. to PN-EN 1992-1-1 (EC2)

The above solution should also be used for balcony slabs that use precast predalle elements as sacrificial formwork (filigree type). Due to a risk of delamination of the precast unit with a concrete overlay, this reinforcement should be led out from the precast unit (see fig. 31).



(*) Full section depth in in-situ concrete where the connectors will be assembled on site

Fig. 31. Example of reinforcement design using precast predalle elements for the balcony slabs

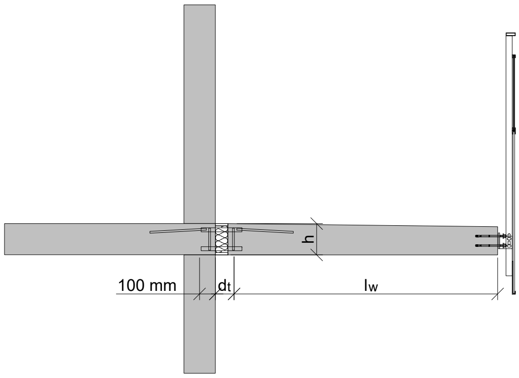
Checking the amounts of minimum and maximum reinforcement area given in this item should also include the reinforcement present in the applied TIPOMEGA® connectors.

ARCHITECT

DESIGNER

CONTRACTOR

10.5. Numerical example



Balcony geometry:

Balcony span	l_w=1.80 m
Balcony length	l_b=4.00 m
Thickness of balcony slab	h=20-18 cm
Insulation thickness	d_t=120 mm
Concrete grade	C20/25

Design outreach:

$l_o=l_w+d_t$+100 mm=1.80+0.12+0.10=2.02 m

Loads (acc. to PN-EN 1991-1):

Self weight	1.35•(0.20+0.18)/2•25 kN/m³ = 6.41 kN/m²
Finishing layers	1.35•0.50 kN/m² = 0.68 kN/m²
Live loads	1.50•4.00 kN/m² = 6.00 kN/m²
	∑= 13.09 kN/m²
Dead weight of railing	1.35•1.10 kN/m = 1.49 kN/m
Moment from railing	1.50•1.00 kNm/m = 1.50 kNm/m

Calculations:

Design bending moment:

M_{ED} = 13.09•(2.02)²•0.5+1.49•2.02+1.50 = 31.2 kNm/m

Design bending moment for whole length of the balcony:

$M_{ED,C}$ = 4.00•31.2 = 124.8 kNm

Design shear force:

V_{ED} = 13.09•2.02+1.49 = 27.9 kN/m

Design shear force for whole length of the balcony:

$V_{ED,C}$ = 4.00•27.9 = 111.6 kN

Selection of number of frames:

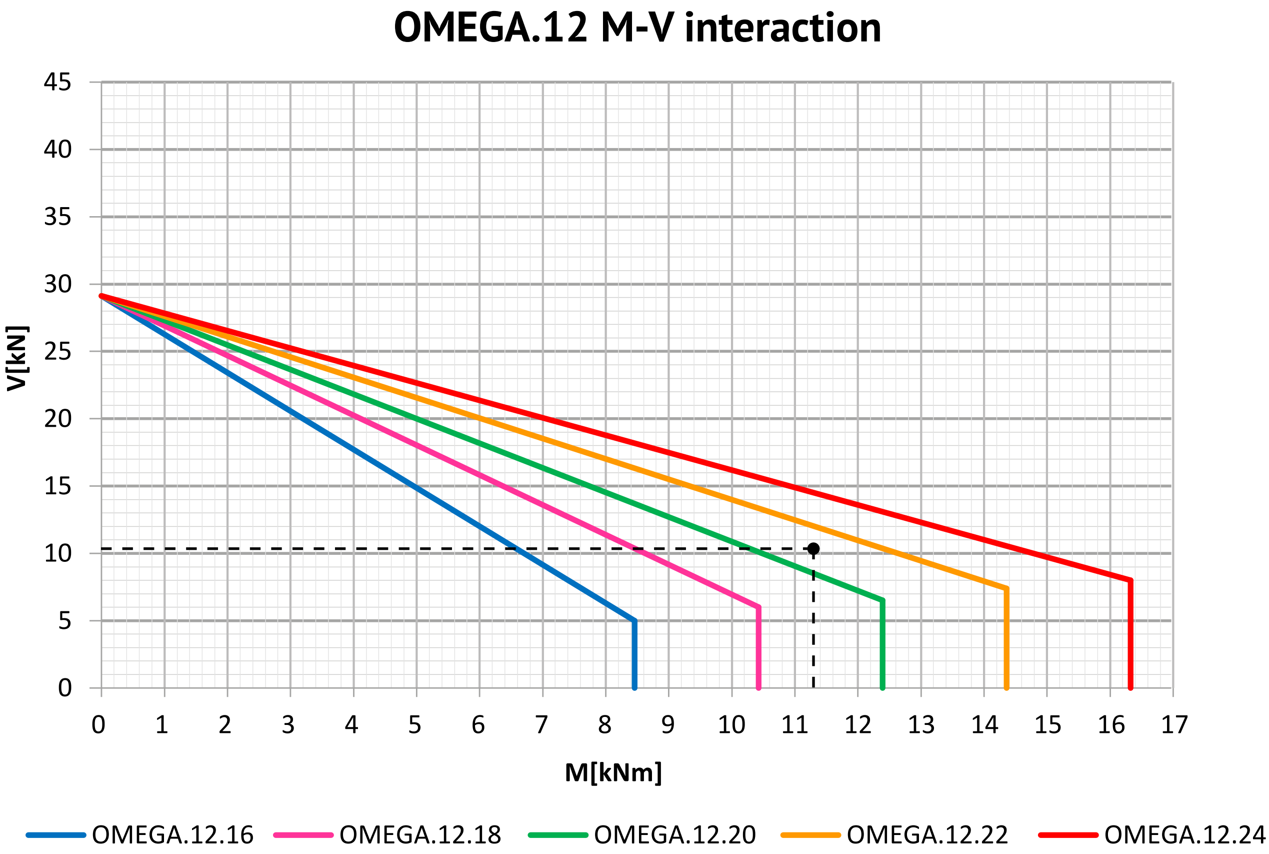
The number of the OMEGA frames is chosen based on the M-V interaction diagrams (see item 9.3. Design capacities). 11 pieces of the OMEGA.12.20. frames have been assumed.

Design bending moment for 1 frame:

$M_{ED,1}$ = 124.8/11 = 11.35 kNm/frame

Design shear force for 1 frame:

$V_{ED,1}$ = 111.6/11 = 10.15 kN/frame



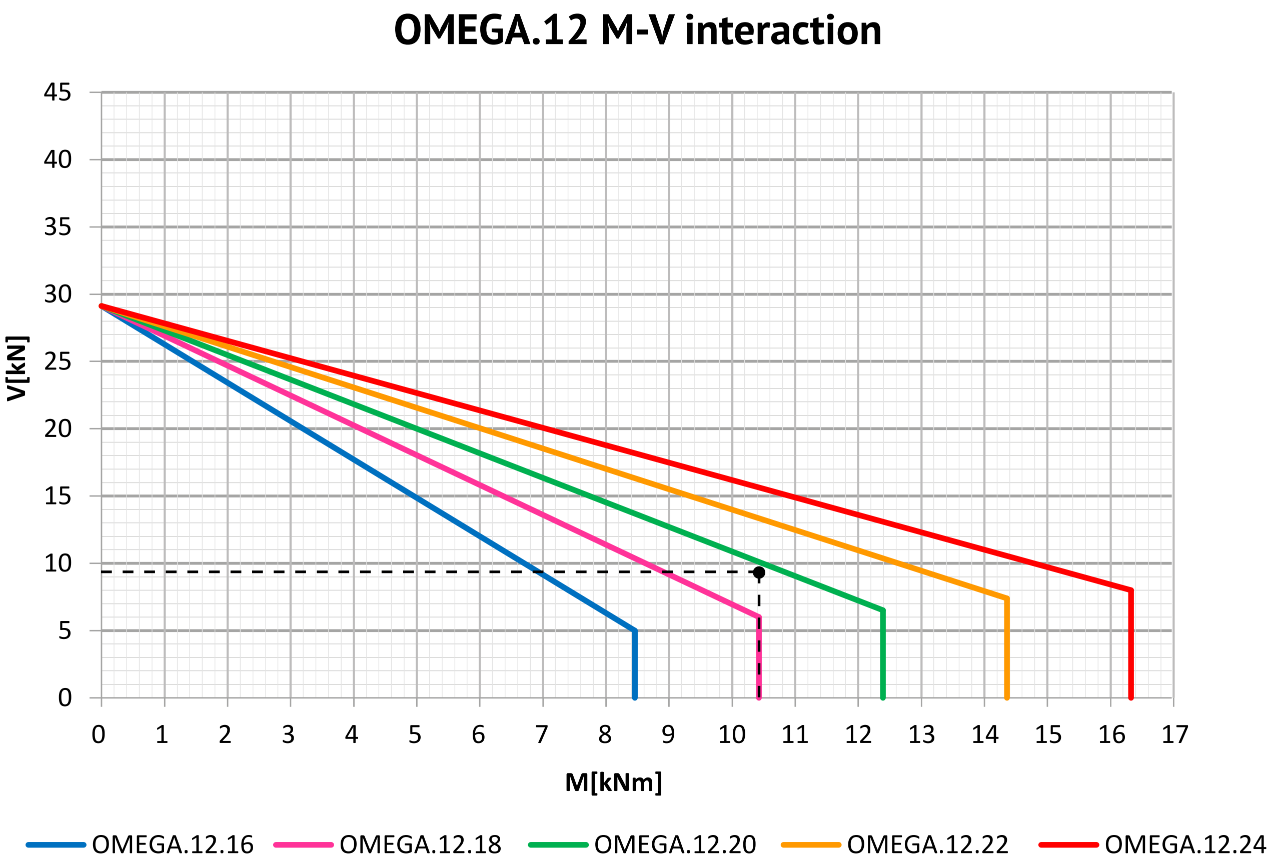
Intersection point is located above the diagram (green colour for OMEGA.12.20).

Number of the OMEGA frames has been chosen **incorrectly.**

12 pieces of the OMEGA.12.20. frames has been assumed.

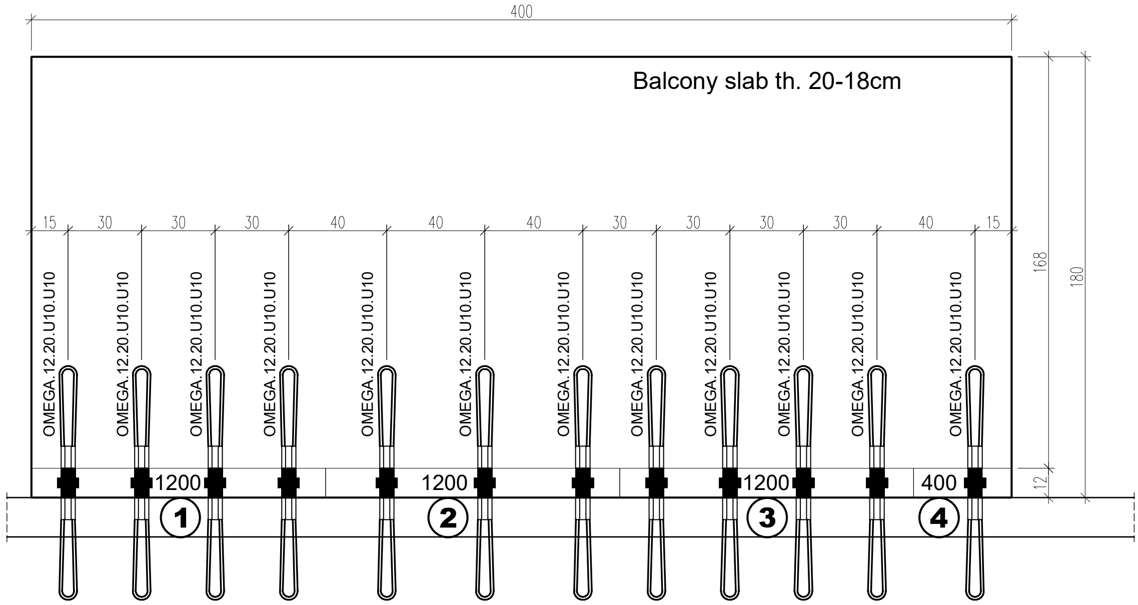
Design bending moment for 1 frame:
$M_{ED,1}$ = 124.8/12 = 10.40 kNm/frame

Design shear force for 1 frame:
$V_{ED,1}$ = 111.6/12 = 9.30 kN/frame



In this case the point of intersection is located below the diagram marked with yellow. A number of the OMEGA frames has been chosen **correctly**.

a)



b)

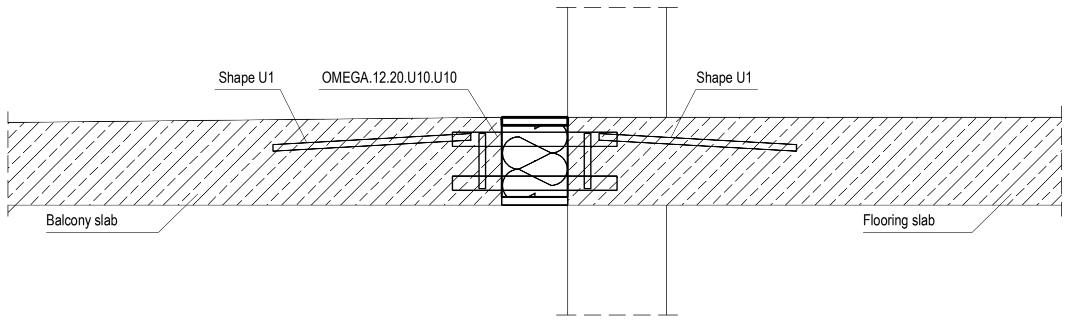


Fig. 32. Arrangement and type of the OMEGA support frames and TIP units in the “Numerical example” a) top view; b) vertical cross-section

11. ASSEMBLY OF TIPOMEGA®

The components of the TIPOMEGA® system are manufactured and delivered to the recipient by the manufacturer according to the individual design of the balcony or canopy. To facilitate transport, storage and assembly in the precast plant or at the construction site, the total length of the linear connector is divided into factory-prepared 1200 mm long TIP units. Each TIP unit has its own label (see fig. 33) The label contains information specifying the balcony number, successive number of the component in the balcony, directional arrow, method of installation into the formwork, date of manufacture and project identifier.

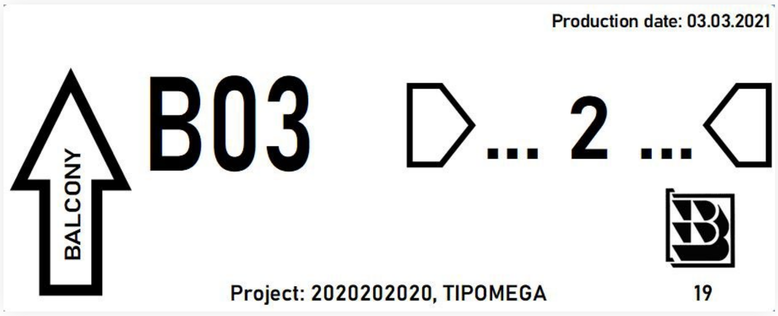


Fig. 33. Exemplary label of the TIP insulation unit

In the precast plant or on the formwork plates, the TIP insulation modules (see fig. 34) should be placed side by side, in the correct direction, on the vibration table in the correct order (according to the detail design).

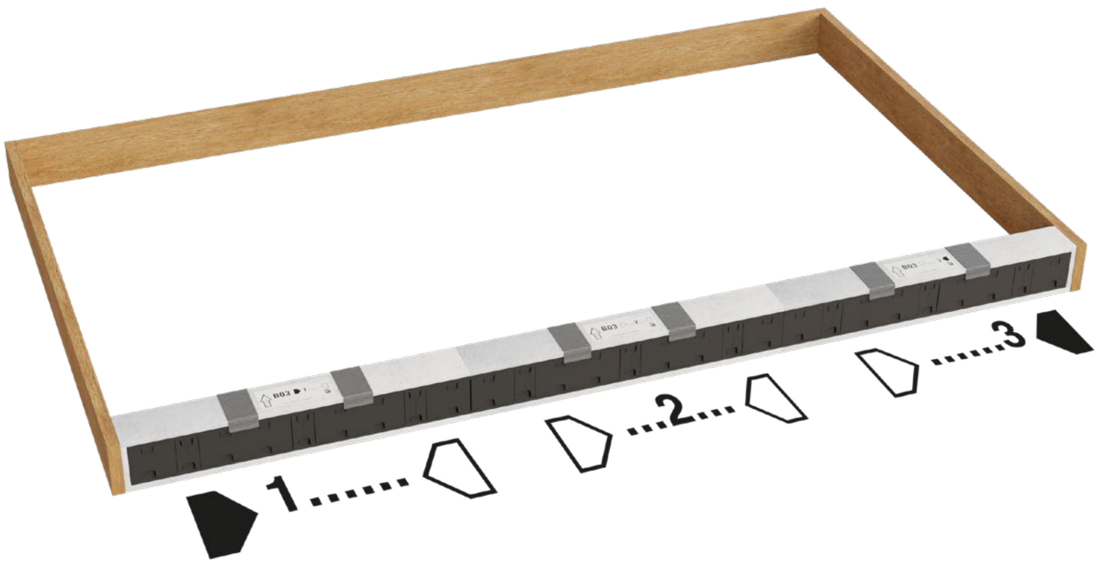


Fig. 34. Arrangement of the TIP components in formwork

Then, after removal of TIP profiles factory-integrated with the fire protection slab, it is required to take the loose parts of the central insulation profiles from the units and put them, keeping the symmetry, to the OMEGA support modules (see fig. 35).

Fig. 35. Symmetrical assembly of the TIP profiles in the OMEGA frames

The OMEGA frames prepared in such a way with thermal insulation should be once again put into the TIP insulation units, covered with TIP upper profiles and the whole unit should be tied with mounting tape (see fig. 36).

Fig. 36. Assembly of the OMEGA frames in the TIP insulation

After completing the assembly of the balcony slabs and floor slab the OMEGA frames and TIP upper profiles should be stabilized. It may be performed by tying the OMEGA frames to the reinforcement and TIP profiles to the OMEGA frames (see fig. 37).

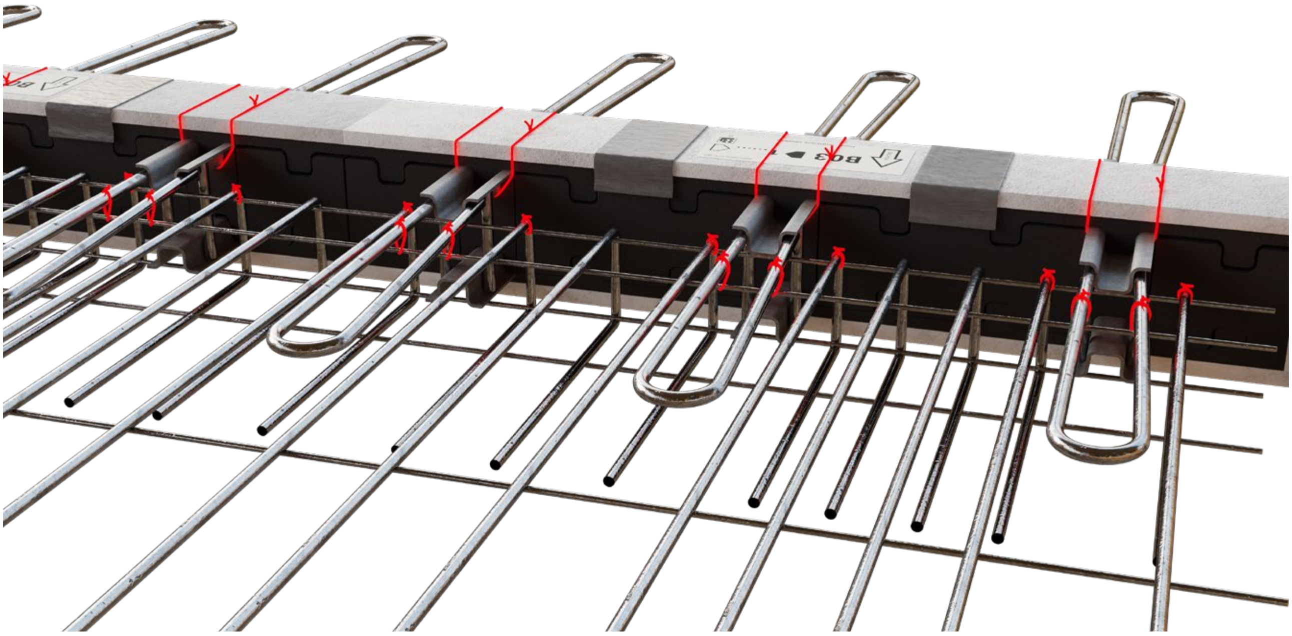


Fig. 37. Stabilisation of TIPOMEGA® connectors

12. GUIDELINES FOR REINFORCEMENT PLACEMENT

The structural reinforcement of the free edge of the slab should be executed according to the structural design and guidelines given in EN 1992-1-1 (EC2) described in item 10.4.

Considering the rigid connection of the upper profile with the bottom profile, the OMEGA frames in the TIPOMEGA® connectors, always work on the complete reinforced concrete cross-section and do not require typical additional reinforcements for correct operation of their structure in the concrete.

12.1. Structural and longitudinal reinforcement at the OMEGA frames

Considering the local concentration of stresses in the concrete near the OMEGA frames, the structural reinforcement of the reinforced concrete slab should be laid in such a way that the bars of the primary reinforcement will be placed within the 5 cm distance from the bars welded to the stainless bars, on each side of the frame (see fig. 38).

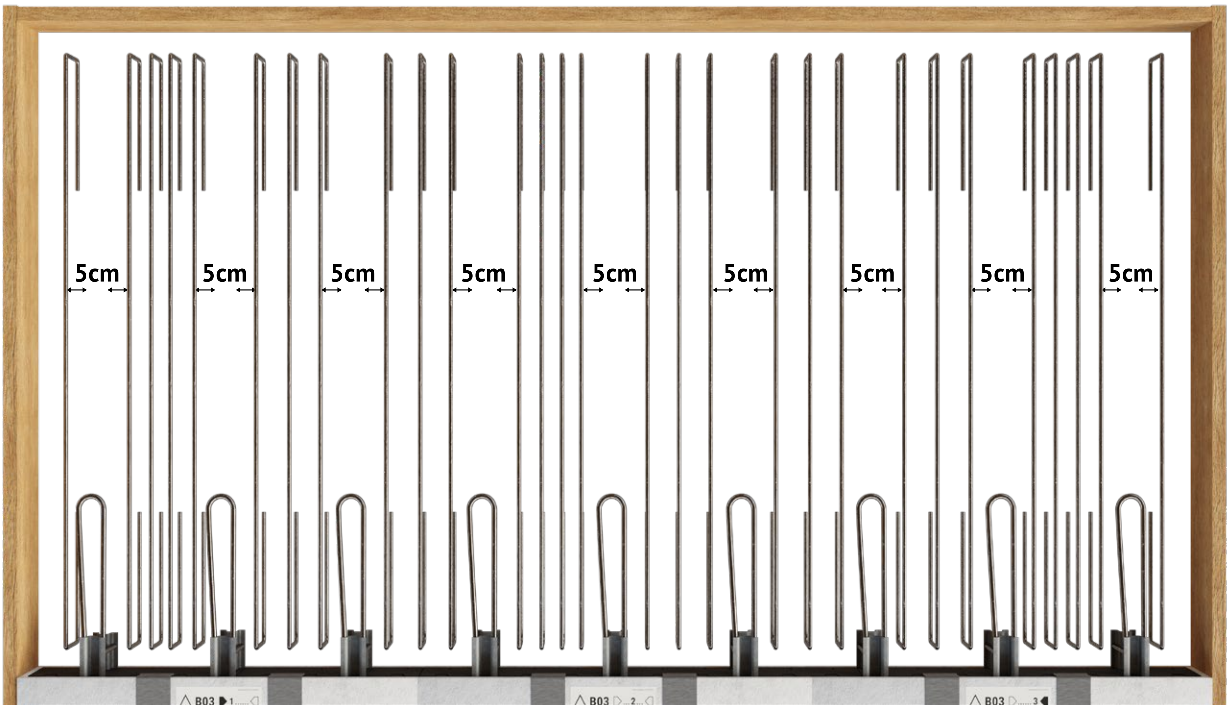
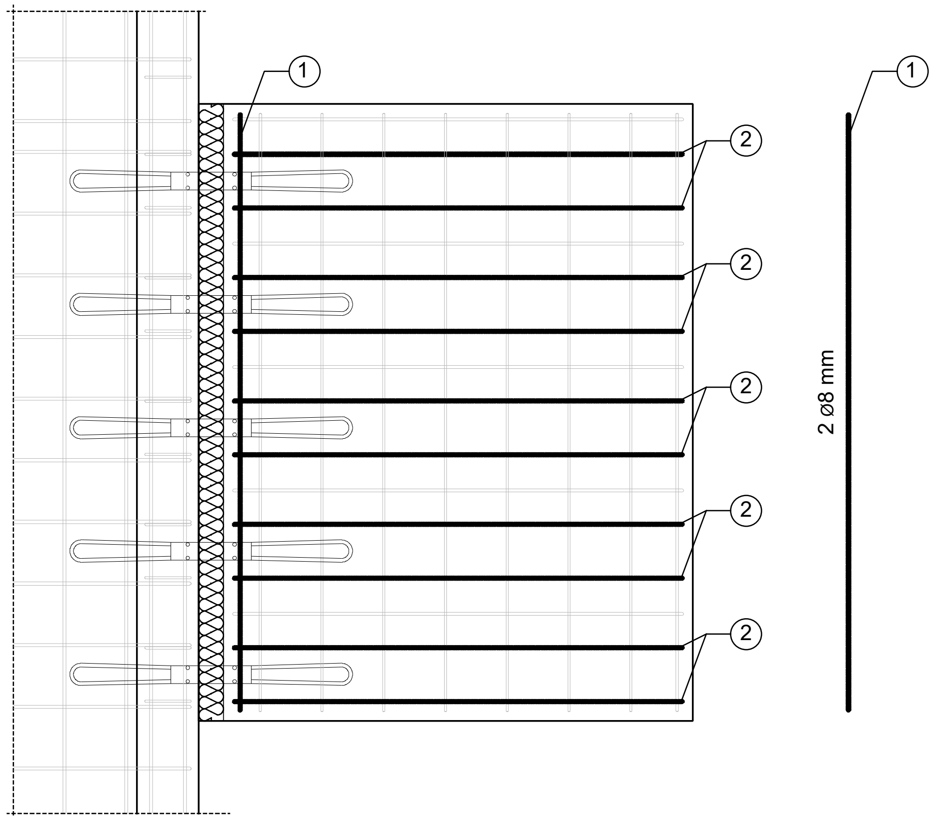


Fig. 38. Example of laying of primary reinforcement at the OMEGA frames

If it is not possible (for example in the case of the use of welded precast reinforcement mesh in the balcony slab) then it is required to add additional min. Ø10 mm bars with shape as on fig. 31 or operating in a similar way.

For correct operation of the set of the OMEGA frames along the whole linear connector, it is required to lay two bars of ribbed reinforcement steel of min. diameter 8 mm (1). The designed lateral reinforcement of the reinforced concrete slab (see fig. 39) may be used for this purpose.

a)



b)

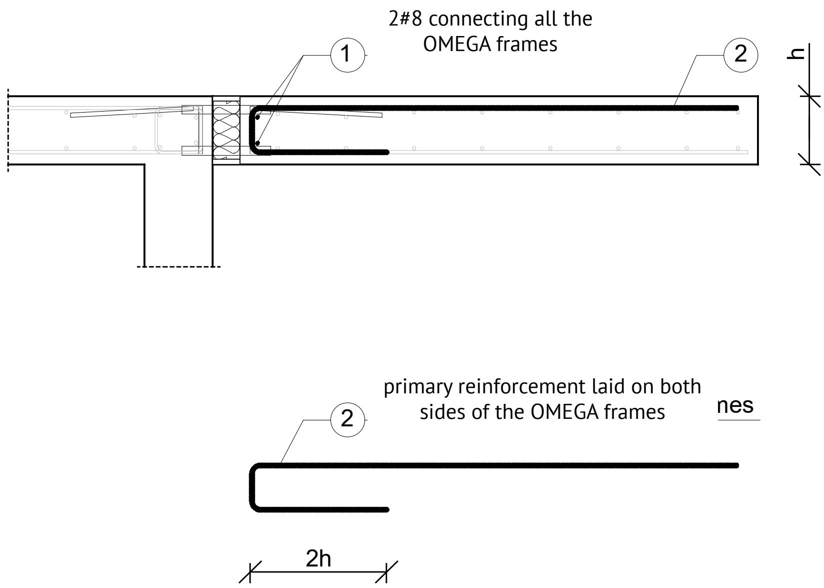


Fig. 39. Example of placement of the primary (2) and longitudinal (1) reinforcement near the OMEGA support modules
a) top view; b) side view

12.2. Reinforcement of corner balconies

In cantilevered corner balconies, due to the occurrence of very high internal forces (shear forces in particular) and, at the same time, high concentration of structural reinforcement, it is required to use, as the primary reinforcement in the OMEGA frames concentration area Ø14 (min) bars at 100mm spacing. These bars should be extended and laid min. 500 mm beyond the concentration zone, every 100 mm of load-bearing frames and beyond the edge of anchoring U bars (see fig. 40).

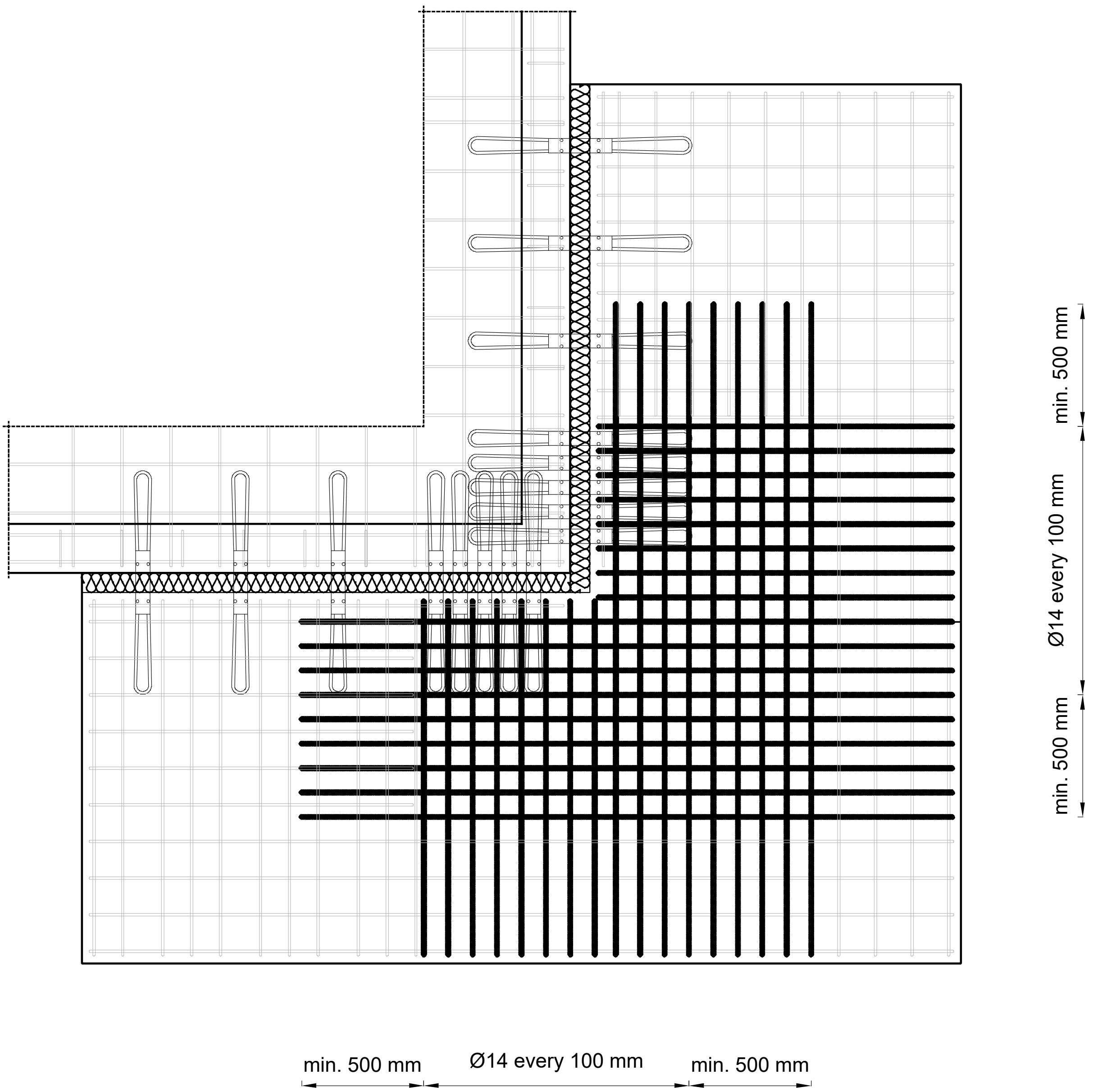


Fig. 40. Example of laying of the upper reinforcement in the corner cantilevered balconies

12.3. Reinforcement with intermediate support

For the external reinforced concrete component supported in the intermediate way (when the exterior wall is not located directly at the linear connector), then the reinforcement described in items 12.1 and 12.2 is required also on the floor slab side (see fig. 41).

a)

b)

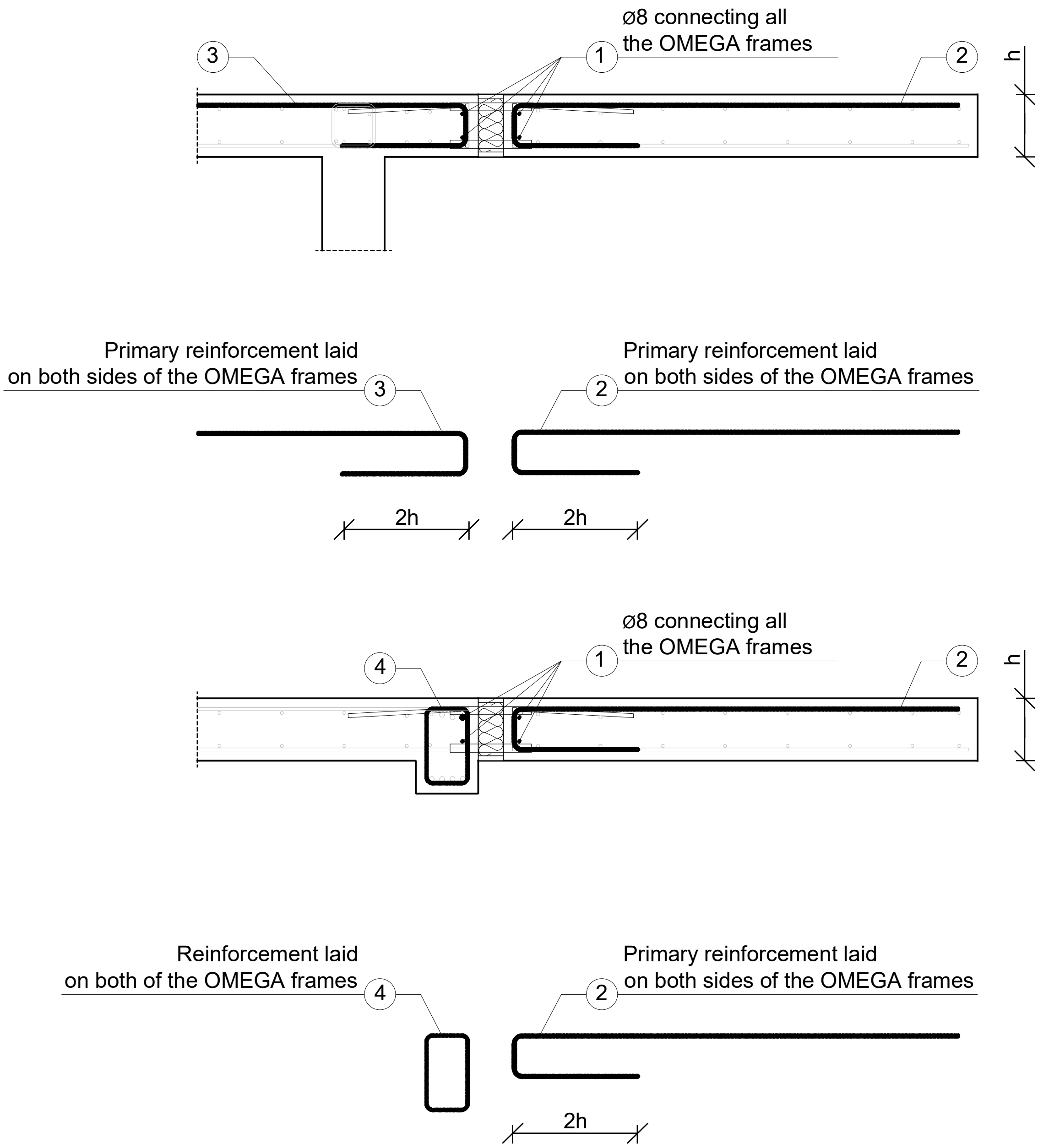


Fig. 41. Example of laying of primary reinforcement with intermediary support
a) in the slab; b) in a beam

The structural engineer e.g. due to a need to ensure proper anchoring of the reinforcement bars of balcony slab or in the case of use of semi-precast slab (filigree type) in the composite floor, may specify a different type and amount of reinforcement than that described in item 12.

AUTHORS OF SUBSTANTIVE VERIFICATION

Krzysztof Pawłowski – Ph.D., Eng.; scientific and didactic worker, assistant professor in the Faculty of Civil Engineering, Architecture and Environmental Engineering; Chair of Level-Headed Construction in Bydgoszcz University of Science and Technology. He is interested in problems with forming of material systems for external partitions and their connectors within the scope of thermal and moisture.
He is an author and co-author of 9 scientific monographs and more than 100 papers within the scope of general civil engineering, energy-efficient civil engineering, physics of buildings and building materials. He is licensed to prepare energy performance certificates for the buildings and premises. Furthermore, he is an author and co-author of expert's reports within the scope of civil engineering and technical assessment reports related to thermal and moisture protection of the buildings. He conducts lectures and exercises on the subjects related to energy-efficient and passive civil engineering and problems of the energy performance of buildings and premises. He is also a supervisor of dozens of engineer's and Master's theses and an organizer of the Conference of Students and Doctoral Students "Sustainable construction".

Łukasz Mrozik – Ph.D., Eng.; member of the teaching staff, assistant professor in the Faculty of Civil Engineering, Architecture and Environmental Engineering; Department of Building Construction in the Bydgoszcz University of Science and Technology. He is interested in the problems of modern concrete technologies, including among others hydraulically pressed, high-quality and light concrete and concrete structures. He is an author of more than 40 research papers within the scope of concrete technology and concrete structures. Regularly attends research and development works related to new structural and material solutions in the construction industry and preparation of expert's reports for the concrete structures. He conducts lectures and exercises from the subjects related to the research interests such as: concrete structures, reinforced concrete engineering structures, the technology of concrete and mortars, new generation concretes. He is a thesis supervisor or more than 160 engineer's and Master's thesis in the civil engineering field of study.

Tomasz Janiak – Ph.D., Eng.; scientific and didactic worker, assistant professor in the Faculty of Civil Engineering, Architecture and Environmental Engineering; Chair of Mechanics of Construction and Construction Materials in Bydgoszcz University of Science and Technology. He is interested in problems of linear and non-linear analysis of structure, numerical methods in the construction industry and diagnostics of civil structures and is an author of about 40 research papers and several documents with expert's opinions. Holds a building license for the design and management of construction works. Holds such classes as calculation methods, MES, and BIM.

NOTES

Date issued: 01.2022

TIPOMEGA P.S.A.
ul. Trzy Lipy 3. 80-172 Gdańsk
(Building of the Gdańsk Science and Technology Park)
kontakt@tipomega.eu
tipomega.eu