

The two-way hollow deck

The way to new solutions



1

GENERAL

BubbleDeck, as a two-way hollow-body floor slab, is generally designed using the conventional design methods for solid floor slabs in accordance with the current reinforced-concrete construction standard DIN 1045 (1988) or DIN 1045 (2001). The reduced intrinsic load is taken into account here, resulting in advantages for the individual static verifications. The required solid zones are defined using the calculated shear load-bearing capacity of the BubbleDeck without shear reinforcement.

The advantages of BubbleDeck become apparent when it comes to the deformation calculation; bending-strength design; penetration design; load transfer to supports, walls and foundations; crack-reinforcement design; earthquake design; determination of resonant frequencies and determination of auxiliary supports during the construction phase.

The hollow balls are first combined with upper and lower reinforcement mats and lattice trusses at the factory to form a BubbleDeck module. This module can already include the necessary lower bending reinforcement. If the reinforcement is a purely structural reinforcement, the module is referred to as a BubbleDeck basic module.

BubbleDeck semi-precast modules are produced by pouring a concrete layer on the BubbleDeck module at the finished-component factory.

Both the ball grid spacings and the dimensions of the prefabricated modules are variable. The resulting flexibility ensures that the modules can be adapted to any floor plan and can accommodate lines, pipes and installation parts. Openings can also be included, even subsequently.

2

EXECUTION VARIANTS

Depending on requirements, BubbleDeck can be concreted in situ with conventional formwork or it can be designed as a semi-precast module with auxiliary support or as a finished component. Combination with other construction methods, e.g. prestressing, is also possible. Any concrete quality and density can be used. All connection details and similar requirements can be planned and executed in the same way as with a conventional solid slab.

3

TECHNICAL SPECIFICATIONS

All relevant data for designing BubbleDeck is contained in the following table. The axis spacing of the balls can be varied. The load reduction must then be adapted depending on the remaining number of balls per square metre.

Ball diameter	[cm]	18.00	22.50	27.00	31.50	36.00	40.50	45.00
Minimum axis spacing	[cm]	20.00	25.00	30.00	35.00	40.00	45.00	50.00
Maximum number of balls	[1/m²]	25.00	16.00	11.11	8.16	6.25	4.94	4.00
Recommended minimum slab thickness	[cm]	23.00	28.00	34.00	40.00	45.00	52.00	58.00
Load reduction per ball	[kN]	0.08	0.15	0.26	0.41	0.61	0.87	1.19
Maximum load reduction per sq. metre	[kN/m²]	1.91	2.39	2.86	3.34	3.82	4.29	4.77
Rigidity factor	[-]	0.88	0.87	0.87	0.88	0.87	0.88	0.88
Shear factor	[-]	0.60	0.60	0.60	0.60	0.60	0.60	0.60

4 BENDING-STRENGTH DESIGN

Bending-strength design for a rectangular cross section can be performed with conventional tools if the following limits are observed:

DIN 1045-1:	$\mu_{sds} = m_{sd} \cdot D_{BD} \cdot 1.96 / (d_B^3 \cdot f_{ck}) \leq 0.2$
where:	μ_{sds} = relative bending moment in the ball zone [-] m_{sd} = max. bending moment [MNm/m] D_{BD} = ball diameter [m] d_B = static height of the BubbleDeck® [m] f_{ck} = characteristic strength according to DIN 1045-1 [MN/m²]
DIN 1045:	$m_s = m \cdot D_{BD} \cdot 1.17 / (d_B^3 \cdot \beta_R) \leq 0.2$
where:	m_s = relative bending moment in the ball zone [-] m = max. bending moment under occupancy load [MNm/m] D_{BD} = ball diameter [m] d_B = static height of the BubbleDeck® [m] β_R = calculated strength according to DIN 1045 [MN/m²]

5 FIRE PROTECTION

According to the general building supervisory authority test certification P-SAC 02/IV-065, MFPA Leipzig e.V.:

The minimum concrete covering min c to the lower reinforcement depending on the fire-resistance duration and the steel stresses under the computed occupancy load can be determined according to the following table.

Steel stress σ_s (MN/m²) ≤	Steel utilisation σ_s (MN/m²) / 286 (MN/m²)*100 %	Fire resistance (minutes)				
		30	60	90	120	180
190	66 %	1.7 cm	1.7 cm	1.7 cm	1.7 cm	-
286	100 %	1.7 cm	2.9 cm	3.5 cm	4.2 cm	5.5 cm

The concrete covering to the ball can be 0.5 cm less than the aforementioned values. The hollow plastic balls consist of high-density polyethylene (HDPE) and must comply with construction material class B2 according to DIN 4102-1 at minimum. The upper concrete covering min c to the ball must be at least 2.50 cm.

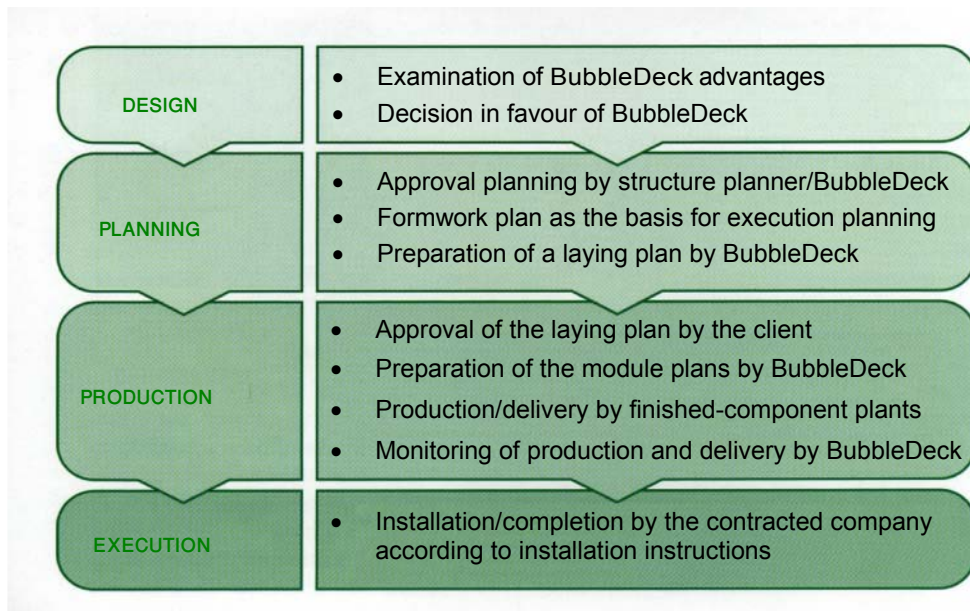
6 SOUND INSULATION

According to the general building supervisory authority test certification P-SAC 02/IV-065, MFPA Leipzig e.V.:

Evaluated sound reduction index R_W	Equivalent evaluated standard footstep sound level $L_{n,w,eq,R}$	Slab thickness	Ball size
55 dB	77 dB	23 cm	18 cm
57 dB	73 dB	34 cm	27 cm

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PROCEDURE

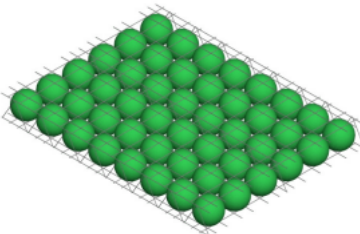


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EXECUTION SEQUENCE

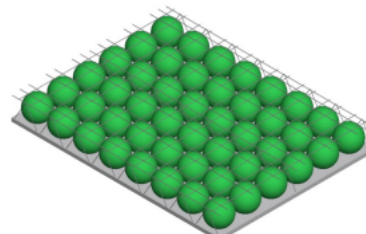
In-situ concrete variant

- Formwork preparation
- Laying the lower reinforcement
- Installation of the basic modules
- Laying the upper reinforcement
- Pouring the bottom concrete layer
- Pouring the top concrete layer



Semi-precast module variant

- Auxiliary-support preparation
- Edge formwork preparation
- Laying the semi-precast modules
- Laying the edge reinforcement
- Laying the upper reinforcement
- Pouring the top concrete layer



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EXAMPLE

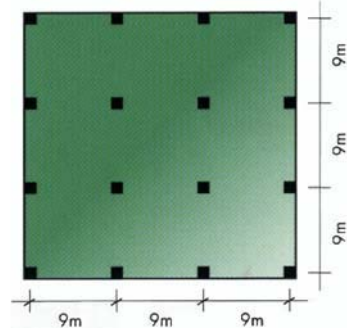
System: Locally supported slab with three fields in each direction

Span: 9 m x 9 m

Load: imposed floor load 5 kN/m²
additional load 1.5 kN/m²

Construction materials: C45/55 concrete, BSt 500 S reinforcing steel

Slab thickness: 35 cm



Selected ball size: 27 cm => technical specifications as per 3

Determination of intrinsic load: $0.35 \text{ m} \cdot 25 \text{ kN/m}^3 - 2.86 \text{ kN/m}^2 = 5.89 \text{ kN/m}^2$

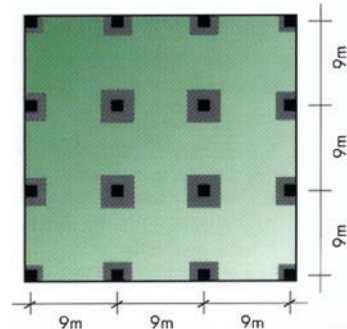
Deformation estimate: Taking a rigidity factor of 0.87 into account:

- Deformation in State I with 30 % of the imposed floor load: $f_{I,1} = 7.4 \text{ mm}$
- Deformation in State I from intrinsic load: $f_{I,2} = 4.8 \text{ mm}$
- Deformation in State II taking shares of time-dependent deformation into account:
 $f_{II,1} = 7.4 \text{ mm} \cdot 4 = 29.6 \text{ mm}$
 $f_{II,2} = f_{II,1} - f_{I,2} = 25 \text{ mm} \leq 12.7 / 500 = 25 \text{ mm}$

Transverse-force verification:

Limit value for solid slab (MD):
 $V_{Rd,ct} \text{ (MD)} = 0.134 \text{ MN/m}$

Limit value for BubbleDeck® (CB):
 $V_{Rd,ct} \text{ (CB)} = 0.60 \cdot 0.134 \text{ MN/m} = 0.080 \text{ MN/m}$



Zones with a transverse force $\geq 0.080 \text{ MN/m}$ must be solid

Bending-strength design: According to an FE calculation (e.g. FEM-Tripla, Dr. Tornow), the maximum design value for the bending moment is 152 kNm/m

Relative bending moment according to 4:
 $\mu_{sds} = 0.152 \cdot 0.27 \cdot 1.96 / (0.3^3 \cdot 45) = 0.066 \leq 0.2$

Design can be performed with conventional methods.