LEAFLET

Association Steel Fibre Technology

MINIMUM STEEL FIBRE CONTENTS TO ACHIEVE PERFORMANCE CLASSES ACCORDING TO DAfStb GUIDELINE "STEEL FIBRE REINFORCED CONCRETE", JUNE 2021

When evaluating numerous beam tests as part of the creation of a database by the steel fibre reinforced concrete subcommittee of the German committee for reinforced concrete (DAfStb), variation coefficients of approximately 25 % were found in bending beam tests in accordance with the DAfStb "Steel fibre reinforced concrete" guideline[1]. In tests based on the European test standard DIN EN 14651[2], the variation coefficients are approximately 20 %. This leaflet is intended to enable the user to classify their own performance class tests more easily and to determine whether the tests carried out are in the upper or lower range of expectations. If very good results are achieved in the classification tests, a allowance (see AST leaflet "Steel fibre reinforced concrete mix designs for industrial floors in Germany"[3]) should be set in which the delivered concrete accurately achieves the guaranteed properties or performance class. Minimum steel fibre contents are recommended below for various commercially available steel fibre types to achieve performance classes. The following recommended minimum steel fibre contents do not replace necessary bending beam tests, but rather enable results to be correctly evaluated within the usual range of variations.

The following minimum steel fibre contents are based on the publication "Empirical approach to determining the residual flexural tensile strength"[4]. In the publication mentioned, a formula developed based on the DAfStb database for estimating the performance class, taking into account of 680 test series for the 4-point bending text according to the guideline, is presented.

$$f_{flm,Li} = \frac{1}{0.37} \cdot k \cdot V_f \cdot (1 - k \cdot V_f) \cdot \frac{f_{ctm,fl}}{0.37} \cdot \zeta_{Li} \cdot \eta_V$$

with:

ζ_{Li} Factor to take into account the fibre effect depending on the fibre length and the deflection considered

$$f_{flm,Li} = 1.66 - \frac{7{,}5 \cdot l_f}{1000} \quad \text{for L1} \rightarrow \delta_{L1} = 0.5\text{mm}$$

$$f_{flm,Li} = 0.74 + \frac{5{,}0 \cdot l_f}{1000} \quad \text{for L2} \rightarrow \delta_{L2} = 3.5\text{mm}$$

η_v Factor to take into account the nonlinear approach depending on the fibre content

$\eta_v = 1/(0.7 + 0.42 \cdot V_f)$

With the help of this empirical approach, average values are estimated that represent the recommended minimum dosages, which are shown below for the two concrete compressive strength classes C25/30 and C30/37 for steel wire fibres with a simple end hook and a tensile strength of the steel fibres of 1,100 to 1,500 N/mm².

Concrete compressive strength class C25/30

- Steel wire fibres with a simple end hook
- Tensile strength of the steel fibres 1,100 to 1,500 N/mm²

Performance class	Recommended minimum steel fibre contents [kg/m³] for different fibre lengths and diameters [mm]			
	50/1.0	60/1.0	60/0.9	60/0.75
0.9/0.6	20	17	16	13
0.9/0.9	26	20	18	15
1.2/0.9	26	24	21	18
1.2/1.2	35	28	25	21
1.5/1.2	35	30	27	22
1.5/1.5	44	35	32	26
1.8/1.5	44	36	33	27
1.8/1.8	54	43	39	32

Concrete compressive strength class C30/37

- Steel wire fibres with a simple end hook
- Tensile strength of the steel fibres 1,100 to 1,500 N/mm²

Performance class	Recommended minimum steel fibre contents [kg/m³] for different fibre lengths and diameters [mm]			
	50/1.0	60/1.0	60/0.9	60/0.75
0.9/0.6	17	15	14	12
0.9/0.9	23	18	16	14
1.2/0.9	23	21	19	16
1.2/1.2	31	24	22	18
1.5/1.2	31	26	24	20
1.5/1.5	39	31	28	23
1.8/1.5	39	32	29	24
1.8/1.8	47	37	34	28

As already explained above, the specified minimum dosages given are recommendations. In experiments, the stated performance classes can also be achieved with higher or lower dosages, based on the usual variations.

MINIMUM PERFORMANCE CLASSES OR -STEEL FIBRE CONTENT IN JOINTLESS INDUSTRIAL FLOORS

In addition to the specified minimum dosages, minimum performance classes based on the size of the joint field should also be considered for jointless industrial floors. Here the residual flexural strength, which can be derived from the respective performance class, should be higher than the expected tensile stress from centric shortening due to constraint. It is important to note here that a mathematical crack width limitation cannot be reliably demonstrated using pure steel fibre reinforced concrete. However, experience shows that larger joint distances also require higher performance classes and fibre contents.

The design value of the centric residual flexural strength should be higher than the design tensile stress from the shortening due to the shrinkage process.

The following is an estimate of the minimum performance classes depending on the size of the joint field for a 20 cm thick floor slab on two foils with a coefficient of friction of 0.6. The design value of the centric residual flexural strength is determined in accordance with the DAfStb guideline “Steel fibre reinforced concrete”.

Performance class L1	Basic value of the mean residual flexural tensile strength $f^f_{ct0,L1}$ [N/mm²]	Calculated value of the centric residual flexural tensile strength $f^f_{ctR,L1}$ with K^f_F=1.7 and K^f_G=1.0 [N/mm²]	Design value of the centric residual flexural tensile strength $f^f_{ctd,L1}$ with α^f_c=1.0 and γ^f_{ct}=1.0 [N/mm²]
0.6	0.24	0.408	0.408
0.9	0.36	0.612	0.612
1.2	0.48	0.816	0.816
1.5	0.60	1.020	1.020
1.8	0.72	1.224	1.224

Assuming a realistic surface load of 15 to 20 kN/m² applied over the full area of the floor slab, the following minimum performance classes result depending on the field sizes. It should be noted that these are load assumptions that will cause the floor slab to shorten permanently over the first 2 years hinders the shrinkage process. Based on these assumptions, the following minimum performance classes result for a 20 cm thick floor slab.

Field size in m	Minimum performance classes L1
20 x 20	1.2
25 x 25	1.2
30 x 30	1.2 bis 1.5
35 x 35	1.5 bis 1.8

Based on the example considerations, it becomes clear that the performance class L1 for industrial floors with few joints is usually in the range of performance classes 1.2 to 1.8. This results in the following recommended minimum dosages.

Performance class L1	Minimum steel fibre contents [kg/m³] for different fibre lengths and diameters [mm]			
	50/ 1.0	60/ 1.0	60/ 0.9	60/ 0.75
1.2	23	21	19	16
1.5	31	26	24	20
1.8	39	32	29	24

References:

[1] DAfStb-guideline “Steel fibre reinforced concrete”, June 2021
[2] DIN EN 14651 “Test method for concrete with metallic fibres – Determination of the flexural tensile strength (proportionality limit, residual flexural tensile strength)”, December 2007
[3] AST-Leaflet “Dosage of steel fibres for the production of test specimens for initial testing to determine the performance class”, October 2022 https://www.ast-ev.com/en/leaflet/SFRC_performanceclass
[4] Concrete and reinforced concrete construction special issue of steel fibre concrete April 2021 “Empirical approach to determining the residual flexural tensile strength”, Oettl, Schulz, Lanwer

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