

FIBER REINFORCED DRAINAGE CONCRETE**FASERVERSTÄRKTER DRÄNBETON****BETON DE DRAINAGE ARME DE FIBRES**

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SUMMARY

Drainage concrete used as finishing coat on roads offers due to its open porous structure a large potential for reducing the noise of road traffic. As a consequence this open - porous structure leads to a very brittle material behaviour. To increase the ductility of this concrete polypropylene fibers were added and the influence of the fibers on the mechanical properties was investigated. Additionally tests on the freeze – thaw behaviour of fiber reinforced drainage concrete were accomplished. With the addition of the fibers a noticeable improvement of the ductility was achieved compared to drainage concrete without fibers. Furthermore fiber reinforced drainage concrete without other admixtures or additives shows a satisfying freeze – thaw resistance. This freeze – thaw resistance however can be improved by the use of polymeric dispersions.

ZUSAMMENFASSUNG

Dränbeton bietet infolge seiner offenporigen Struktur bei Verwendung als Straßendeckschicht ein großes Potential zur Reduzierung des Straßenverkehrslärmes. Diese Struktur des Betons führt aber zu einem sehr spröden Materialverhalten. Um die Duktilität dieses Werkstoffes zu erhöhen, wurden Polypropylenfasern zugegeben und deren Einfluss auf die mechanischen Eigenschaften untersucht. Zusätzlich wurde noch Versuche zum Frost – Tausalzwidestand von faserverstärktem Dränbeton durchgeführt. Es konnte eine deutliche Verbesserung der Duktilität im Vergleich zu Dränbeton ohne Fasern erreicht werden. Des Weiteren verfügt faserverstärkter Dränbeton ohne Zugabe weiterer Zusatzmittel oder Zusatzstoffe über einen ausreichenden Frost – Tausalzwidestand, der al-

lerdings durch Verwendung einer Polymerdispersion weiter verbessert werden kann.

RESUME

Le béton de drainage offre, grâce à sa porosité ouverte, un grand potentiel pour son utilisation comme couche de roulement. Cette porosité mène à un comportement très fragile. Pour augmenter la ductilité du matériau, des fibres de polypropylène ont été ajoutées et leur influence sur le comportement mécanique a été étudié. Le comportement au gel et dégel a également été testé. Une nette amélioration de la ductilité a été obtenue par rapport au béton de drainage sans fibres. Nous avons également constaté que le béton de drainage armé de fibres sans addition d'adjuvants ou d'additifs présente une résistance au gel et dégel satisfaisante. Celle-ci peut être encore améliorée par une addition d'une dispersion de polymères.

KEYWORDS: drainage concrete, polypropylene fiber, fracture energy, freeze thaw resistance

1. INTRODUCTION

The reduction of noise of road traffic is nowadays with a steady increasing number of vehicles of large interest. The road traffic noise is composed of the noise of the engine and the noise of rolling. Investigations have shown that noise of rolling is dominating at velocities higher than 70 km/h [8]. Here now the possibility exists to reduce the noise with a suitable road surface layer. With the concrete road building method different surface textures were already examined regarding the noise reduction. The treatment of the surface turned out suitably by means of broom line and/or jute cloth [8]. A clearly higher noise reduction is however possible by the employment of a porous material for the surface layer. Concrete can be manufactured purposefully in such a way that it has a freely accessible pore system which is able to absorb sound. Measurements of a test track from this open - porous concrete (drainage concrete) on a federal motorway showed that with passenger car at a speed of 120 km/h the sound energy can be reduced by 63 % and for a truck at 80 km/h by 80 % [3, 7]. Due to this open - porous structure this concrete shows however an extremely brittle material behaviour. Moreover doubts exist that due to the abrasion of the tyres single grains could loosen and be hurled around by the vehicles. In order to reduce

these dangers and to increase the ductility of drainage concrete polypropylene fibers were added and the fiber content was varied. In a further step investigations on the freeze and deicing salt resistance have been accomplished. Drainage concrete containing fibers shows a sufficient freeze – thaw resistance.

2. STATE OF THE ART

Drainage concrete is a concrete with a raw ore structure that contains only a single fraction of aggregates. As bonding agent portland cement CEM I 32,5 R is used, whereby the amount of cement paste is designed in that way that the aggregate grains are totally coated, however the gaps between the aggregates remain empty. The DIN 1045 can not be applied for this type of concrete. Only the strength classification is adopted [4, 5, 11]. In well known investigations [1, 2, 3, 6, 7] always similar mixtures were used. Usually 300 - 350 kg/m³ cement CEM I 32,5 R and about 1500 kg/m³ moraine crushed stone with a particle size distribution between 5 - 8 mm was used. The water - cement ratios varied between 0,24 and 0,30 and with the mix composition a void content of 15 – 25 volume -% was planned. This void content is necessary for an appropriate sound absorption of this concrete. Moreover a polymeric dispersion was added to improve the freeze - thaw resistance of the drainage concrete. To get a sufficient freeze – thaw resistance additionally silica fume is necessary according to [1, 2].

3. RANGE OF INVESTIGATIONS

The determination of the compressive strength and the splitting tensile strength was after DIN 1045 T. 5. The compressive strength of all manufactured mixtures was determined by means of 3 cubes with a length of the edges of 150 mm at an age of 28 days. The bending tensile strength of the concretes was determined according to the ZTV Beton StB (2001) [12] with beams with the dimensions 700 mm x 150 mm x 100 mm (l x w x h). The standard plans for this measurement that this is accomplished strength - steered. Since at the same time in addition, the load - deflection line should be measured for the evaluation of the ductility, the tests had to be performed deformation controlled. Therefore the results of the bending tensile measurements can't be compared directly with results from other investigations. The displacement rate at these tests was 1 mm/min. The deflection of the specimens was determined by the displacement of the plunger of the testing machine. As the evaluation and comparison of the

ductility of the individual mixtures among themselves exclusive on the basis of the load - deflection lines is difficult, additionally the fracture energy using the following equation (1) for the individual mixtures was determined:

$$G_f = \frac{1}{A} \cdot \int_0^f P(f) df \quad (1)$$

with:

G_f = fracture energy [N/mm]

A = cross sectional area [mm²]

P = load [N]

f = deflection [mm]

The splitting tensile strength was determined with the oddments of the bending tests. 4 measurements were performed for each mixture.

The freeze – thaw resistance of the concretes was tested according to the CDF – test. The dimensions of the specimens were 150 mm x 150 mm x 75 mm. Deviating from the CDF – test demountable plastic formwork with dimensions of 200 mm x 200 mm x 200 mm have been used. They were not treated with a separating agent. The cubes manufactured with this formwork were subsequently cut to the necessary specimen size with a stone saw. As inspection surface the sides resting against the formwork were used. The further procedure corresponded to the recommendations of the CDF - procedure [13].

4. CONCRETE MIX PROPORTIONS

The cement used for these investigations was a portland cement CEM I 32,5 R. As aggregates moraine crushed stone with a grain distribution from 5 – 8 mm was employed. For the investigations on the mechanical properties a polymeric dispersion (furthermore called dispersion 1) was added. The dispersion has a density of 1,04 kg/dm³ and contains about 50 % water and 50 % solids. The effective components are a copolimerisat on styrene basis and acrylic acid ester. For the investigations on the freeze – thaw resistance another dispersion was used. It was an acrylate resin dispersion with cement - reactive mineral substances and active substances for the modification of cement - bound mortars and bonding layers (called in further dispersion 2). The density of this dispersion amounts to 1,25 kg/dm³. The fraction of solids is about 56 %. All mix-

tures were designed with a total voids content of 20 volume -%. The detailed mix proportions are shown in table 1.

Table 1: Composition of the concretes for the investigations on the mechanical properties.

Mixture	Fiber content [Vol.-%]	Cement [kg/m ³]	w/c [-]	Aggregates [kg/m ³]	Dispersion content [% of cement]
R3	0,0	300	0,29	1554	20
F23	1,0	300	0,29	1527	20
F24	2,5	300	0,29	1488	20
OZ1	1,0	400	0,29	1341	20
OZ2	2,5	400	0,29	1302	20
OZ3	1,0	350	0,29	1434	20
OZ4	2,5	350	0,29	1395	20
OF1	1,5	400	0,29	1328	20
OF2	2,0	400	0,29	1315	20
OF3	0,5	400	0,29	1354	20

For the investigations on the freeze – thaw resistance different additives and admixtures were added to a basic mixture containing 400 kg/m³ cement CEM I 32,5 R, a water - cement ratio of 0,29 and a fiber content of 1,5 volume -%. The purpose was to test the influence of these additives and admixtures on the freeze – thaw resistance of the drainage concrete. The designed void content of these mixtures was also 20 volume -%.

The mix proportions for the CDF – tests are shown in table 2.

Table 2: Composition of the concretes for the investigations on the freeze – thaw resistance.

Mixture	Aggregates [kg/m ³]	Dispersion	Dispersion content [% of cement]	Silica fume [% of cement]	Fly ash [% of cement]	further additives
CF1	1328	1	20	0	0	
CF2	1426	-	0	0	0	
CF3	1362	2	20	0	0	
CF4	1425	-	0	0	0	Sperrpulver (8g/kg cement)
CF5	1425	-	0	0	0	Innenversiegler (15ml/kg cement)
CF6	1425	-	0	0	0	Luftporenbildner (1,5 ml/kg cement)
CF7	1425	-	0	0	0	Microhohlkugeln (1kg/m ³)
CF8	1403	-	0	10	0	
CF9	1311	-	0	0	25	
CF10	1288	-	0	10	25	

5. TEST RESULTS AND DISCUSSION

5.1 Influence of cement content on the mechanical properties.

The results of the compressive strength against the cement content of the mixtures is shown in figure 1.

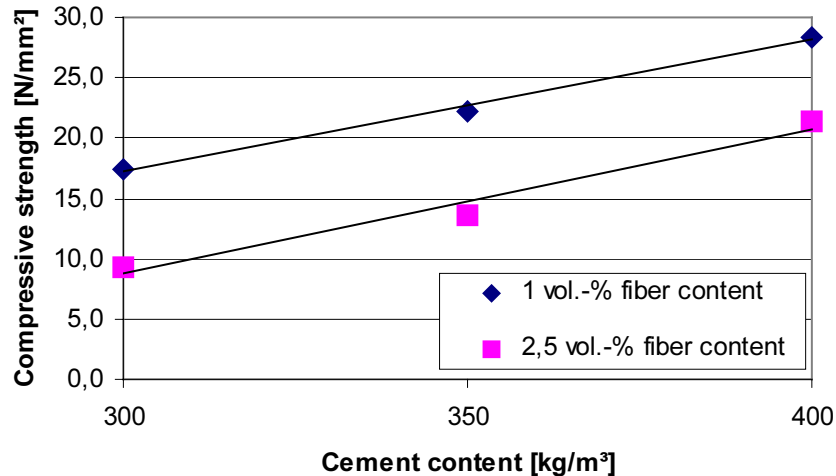


Fig. 1: Compressive strength against the cement content.

It can be seen that both with a fiber content of 1 volume -%, and with 2,5 volume -% the compressive strength rises with increasing cement content. The increase of the strength can be explained by two different causes. On the one hand the voids content of the mixtures becomes smaller with rising cement content and on the other hand the aggregate content decreases with increasing cement content. This leads to a smaller specific surface with rising cement paste content and thus to a better connection of the aggregates and the fibers.

Also with the splitting tensile strength and the bending tensile strength an increase can be recognised with increasing cement content (figure 2). The reasons for the improved strength are the same as mentioned for the compressive strength.

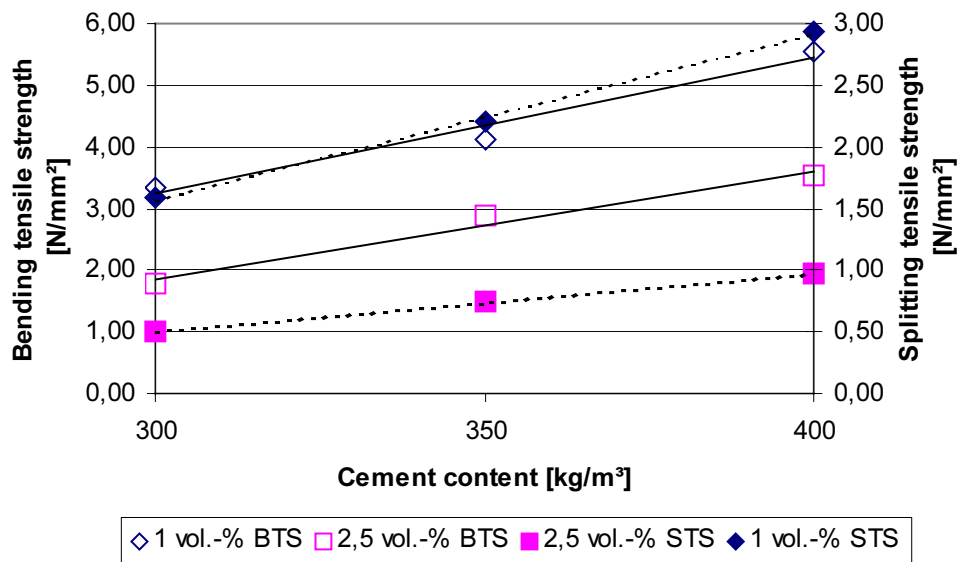


Fig. 2: Bending tensile strength and splitting tensile strength against the cement content.

With both fibre contents an increase of the fracture energy is connected with the increasing amount of cement (see figure 3). With a fiber content of 2,5 volume -% the fracture energy is approximately doubled by the increase of the cement content, while with 1 volume -% fiber content the increase amounts approx. to 50 %. Due to the increasing cement paste content the fibers are embodied better in the matrix and can therefore participate for a longer time period in bearing the load.

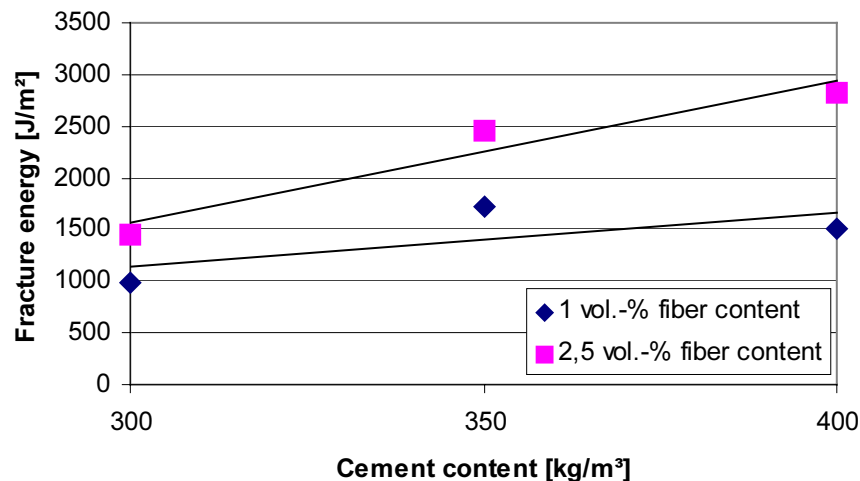


Fig. 3: Fracture energy against the cement content.

5.2 INFLUENCE OF FIBER CONTENT ON THE MECHANICAL PROPERTIES

With increasing fiber content a reduction of the compressive strength can be recognised (see figure 4). The compressive strength of 20 N/mm² of the mixture with a fiber content of 2,5 volume -% is about 30 % less than the compressive strength of the concrete with 0,5 volume -% fiber content. The increase of the fiber content within the mix design leads to a reduced fraction of aggregates. The specific surface of the fibers is however much bigger than the specific surface of the aggregates so that the replacement of aggregates with fibers induces a great enlargement of surface that has to be connected by the cement paste.

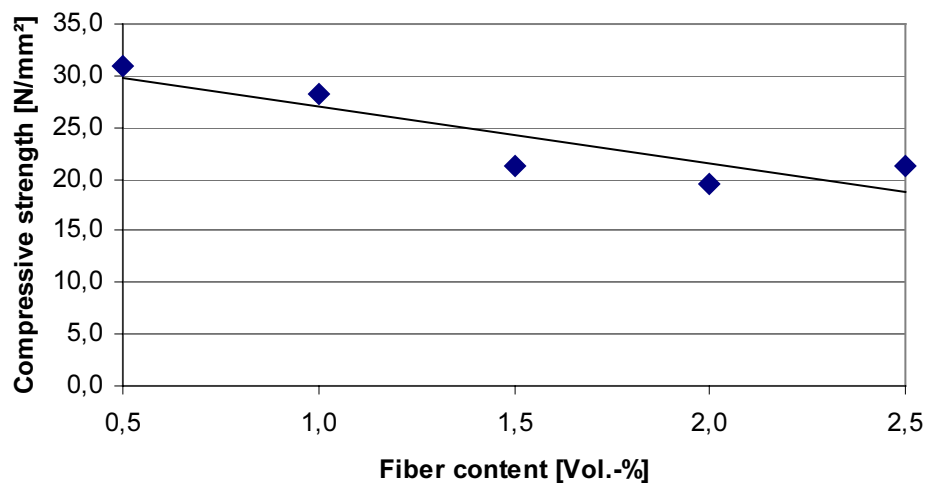


Fig. 4: Compressive strength against the fiber content.

The specific surface of 0,5 volume -% fibers is about 40 times bigger than the specific surface of the corresponding aggregates. Since the amount of cement paste was held constant a weakening of the matrix occurred and therefore the compressive strength decreases.

As can be seen in figure 5 the splitting tensile strength as well as the bending tensile strength also decreases with the fiber content.

The reason for the reduction of strength is a weakened matrix due to the bigger specific surface at a constant cement paste content.

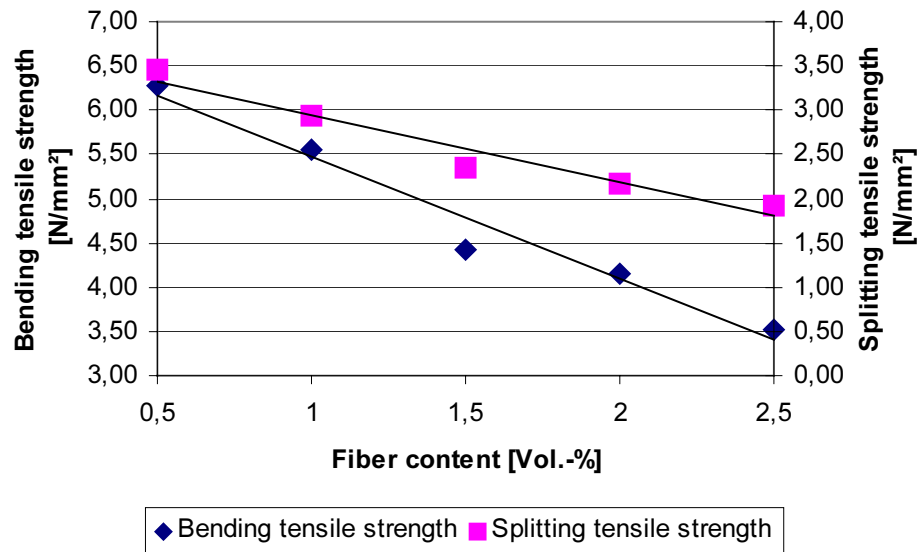


Fig. 5: Bending tensile strength and splitting tensile strength against the fiber content.

The increasing fiber content produces a noticeable gain in fracture energy. The extension of the fiber content from 0,5 volume -% to 2,5 volume -% leads to a 3 times bigger fracture energy (see figure 6). The difference in fracture energy between a fiber content of 2,0 volume -% and 2,5 volume -% is however small.

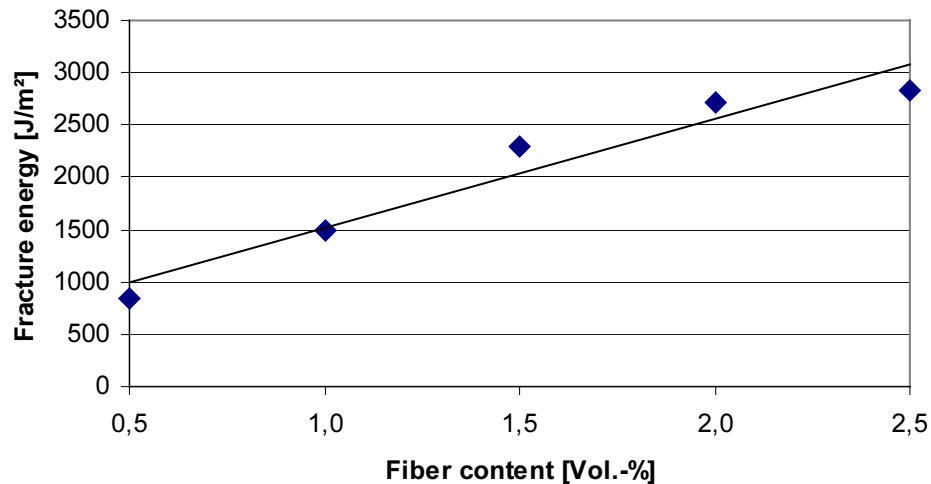


Fig. 6: Fracture energy against the fiber content.

The increase of the fracture energy with fiber content is possibly a consequence of a better distribution of the load in the fracture cross section due to the growing number of fibers. The fibers are obviously pulled out of the matrix slower in spite of the weakened cement paste matrix.

6. RESULTS OF THE CDF – TESTS

Figure 7 shows the results of the CDF – tests after 28 freeze – thaw cycles. There are great differences in the behaviour of the different concretes. The best freeze – thaw resistance have the mixtures with both 20 volume -% polymeric dispersion whereby the mix CF3 with dispersion 2 is the best one. Remarkable is the result of the mixture CF2. This concrete contained no admixtures and/or additives and however showed a good freeze – thaw behaviour.

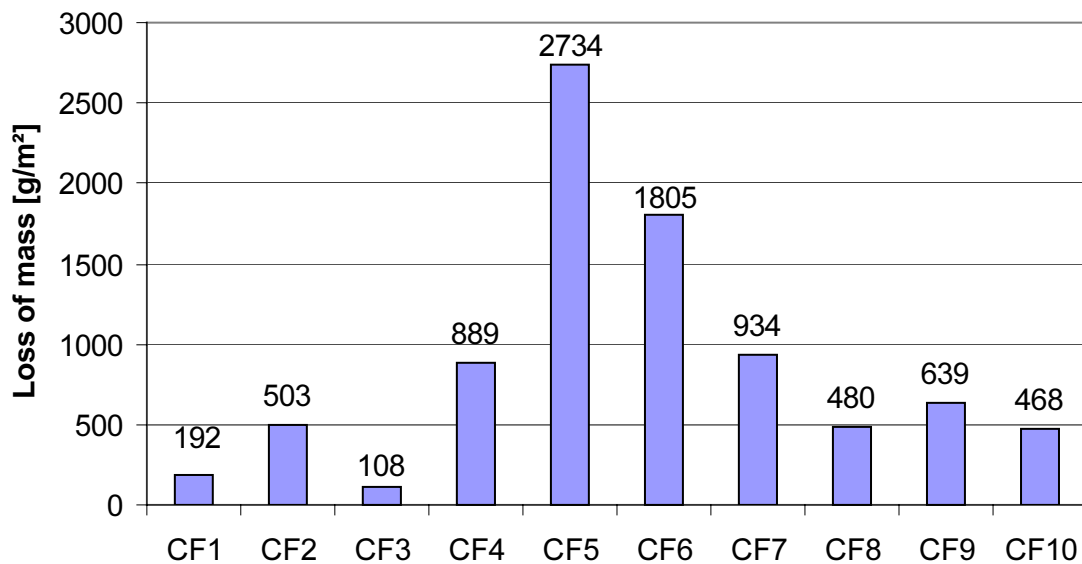


Fig. 7: Results of the CDF – tests.

This proves that the addition of a polymeric dispersion is not absolutely necessary to get a sufficient freeze - thaw resistance. The notably good behaviour of the mixtures with the polymeric dispersion is possibly a consequence of a denser transition zone between the aggregates and the matrix. For this purpose the dispersion 2 seems to be more suitable due to the reactive ingredients.

7. CONCLUSIONS

The results of the investigations show that the ductility of drainage concrete can be improved noticeably by the addition of fibers. But with increasing fiber content the compressive strength and the tensile strength decreases. This can be counteracted by increasing the amount of cement. In the end one has to find a compromise between the ductility and the compressive and tensile strength. A reasonable fiber content seems to be 1,5 volume -% with an amount of cement of 400 kg/m³.

CDF – tests concerning the freeze – thaw behaviour were conducted with concretes composed like this. Different additives and admixtures were added to investigate their influence on the freeze – thaw resistance. The mixtures with a polymeric dispersion produced the best results. However the fiber reinforced drainage concrete without any admixtures or additives and an average loss of weight of 503 g/m² after 28 freeze – thaw cycles has a satisfying freeze – thaw resistance.

With a further addition of the cement content the compressive and tensile strength can possibly be increased at a fiber content of 1,5 volume -%. Simultaneously the water – cement ratio should be further reduced.

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