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Concrete with Glass Metal Reinforcement

Béton renforcé par des fibres en verre-métal

Bewehrung von Beton mit Metall-Glas-Fasern

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SUMMARY
This paper describes the fibre-reinforcement of concrete. The fibres used were glass-metal fibres. Special composition of concretes, as well as grading of aggregates were determined experimentally. In addition to strength tests, concretes with glass-metal reinforcement were tested under repeated loading. The main aim of the experiments was to promote the material for industrial use.

RÉSUMÉ
Des fibres de verre-métal ont été utilisées pour le renforcement du béton. Les compositions spéciales du béton et la granulométrie des agrégats ont été déterminées expérimentalement. Des essais de résistance ont permis de contrôler les bétons renforcés par des fibres en verre-métal également à la fatique, par des charges alternées. L'objectif principal des expériences était la promotion à l'échelle industrielle.

ZUSAMMENFASSUNG
Zur Bewehrung von Beton wurden Metall-Glas-Fasern verwendet. Die spezielle Zusammensetzung des Betons sowie die Abstufung der Zuschlagstoffe wurden durch Versuche bestimmt. Neben Festigkeitsuntersuchungen wurden die mit Metall-Glas-Fasern verstärkten Betonsorten auch auf Ermüdung geprüft. Das Ziel der Untersuchungen war eine industrielle Anwendung in der Baupraxis.

1. INTRODUCTION

Recently application of new fibre reinforcements for concretes arouse wide interest, so their behaviour differing from that of traditional concretes. In addition to investigations of synthetic fibre reinforcements and the composites reinforced therewith, mortars having been reinforced with glass metal fibres stood in the centre of interest at the end of the seventies [1-3] . The tests showed advantageous mechanic behaviour, simultaneously theoretical suppositions relating to the reinforcement of mortars having been reinforced with discontinuous glass metal fibres became verified. The aim of the present study is to extend the investigations to concretes, as well as to promote industrial introduction.

2. COMPOSITION OF THE COMPOSITE

2.1 Concrete

Concrete having been used in course of said tests were not of standarized composition, optimal composition was determined experimentally. Composition of the concrete expressed in weight: 64 % graded sand and gravel with a maximal grain size of 8 and 16 mm, 28,5 % C 550 Portland Cement, 7,2 % water and 0,3 % plasticizer Mighty 100.

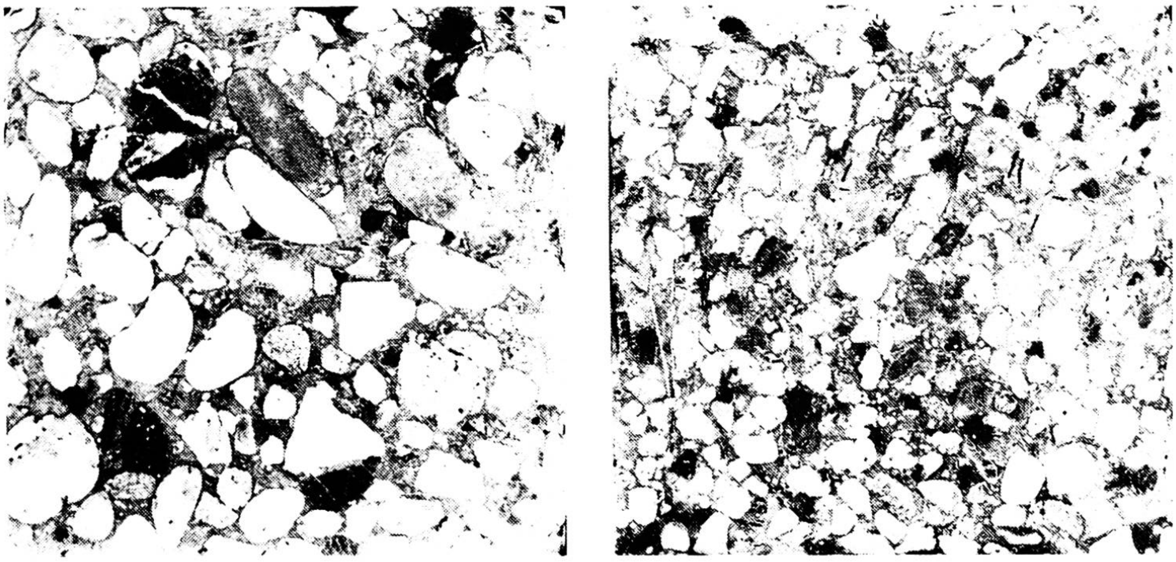


Fig.1 Fibre-reinforced concretes, of 8 mm and 16 mm grain size

Glass metal fibres were added to the mixture in course of dry-mixing. After having finished mixing, fibre-reinforced concrete was poured into the moulds and compacted by a table-vibrator. From the composite with the maximal grain size of 8 mm prisms 40x40x160 mm, from the composite with the maximal grain size of 16 mm prisms 70,7x70,7x250 mm were prepared. Curing under water was continued maximally for 28 days.
Characteristic sections of concretes tested are illustrated in Fig.1.

2.2 Glass metal fibre

The applied glass-metal fibre was prepared in the Iron and Metal Works Csepel with a composition of $Fe_{74}Cr_6B_{14}Si_6$. The length of the glass metal fibre amounted to 40 mm, average thickness to 0,036 mm and width to 1,65 mm.

One side of the glass metal band was smooth, the other one rough. According to the examinations having been performed on individual fibres Young-modulus of the applied glass metal fibre was 153 GPa while it's tensile strength was 1,3 GPa.

3. TESTING OF FIBRE-REINFORCED CONCRETES

3.1 Mechanical tests

Specimens having been cured in water were subjected to strength tests at the age of 7, 28 and 90 days. In course of the tests ductility being proportional with fibrebatches and considerable energy absorbing ability could be observed.

Based on the results of strength tests, as well as on basis of the analysis of the concrete structure we propose to use glass metal reinforced concretes with a grain size of D_{max} = 8 mm instead of the maximal grain size of D_{max} = 16 mm. Characteristic results of strength tests are summarized in Table 1-2.

Batch of fibres vol.%	Strength measured at the age of					
	7 days MPa		28 days MPa		90 days MPa	
	bending	compr.	bending	compr.	bending	compr.
0	10,5	70,9	12,4	87,0	12,7	89,5
0,25	11,3	79,3	13,4	86,5	13,3	85,9
0,50	12,5	76,1	14,2	73,5	14,6	87,3
1,00	17,4	72,8	18,8	72,4	19,6	81,0

Table 1 Strength data of concretes with D_{max} = 6 mm

Batch of fibres vol.%	Strength measured at the age of					
	7 days MPa		28 days MPa		90 days MPa	
	bending	compr.	bending	compr.	bending	compr.
0	8,5	51,4	8,7	59,0	9,2	81,2
0,12	8,6	57,3	9,8	55,6	9,9	85,1
0,25	9,4	54,3	10,0	64,2	10,3	75,0
0,50	10,7	55,5	10,8	60,0	11,4	72,2

Table 2 Strength data of concretes with D_{max} = 16 mm.

3.2 Repeated loads

We tested the effect of frequently repeated pulsating pressing loads on fibre-reinforced specimens and specimens without fibre reinforcement of the size 40x40x160 with D_{max} = 8 mm. Lowest stress level amounted uniformly to 5 MPa, at a frequency of 250 Hz. Compressive load was applied onto the 40x40 mm surface of the specimens. Limit value of fatigue belonging to 2 millions repetitions for the specimen without fibre reinforcement amounted to 35 MPa, while for the specimen containing 0,5 vol.% glass metal fibre the value amounted to 50 MPa. Tests were begun with the specimens at the age of 90 days, with 6 specimens each.

The effect of few repetitions was measured for compressive loads on specimens 70,7x70,7x250 mm, with D_{max} = 16 mm, containing 0,25 vol.% glass metal fibre. As loading stages 10 loadings downwards and 10 loadings upwards were performed and we measured the stress-strain datas. Characteristic curve of deformation is shown in Fig.2.

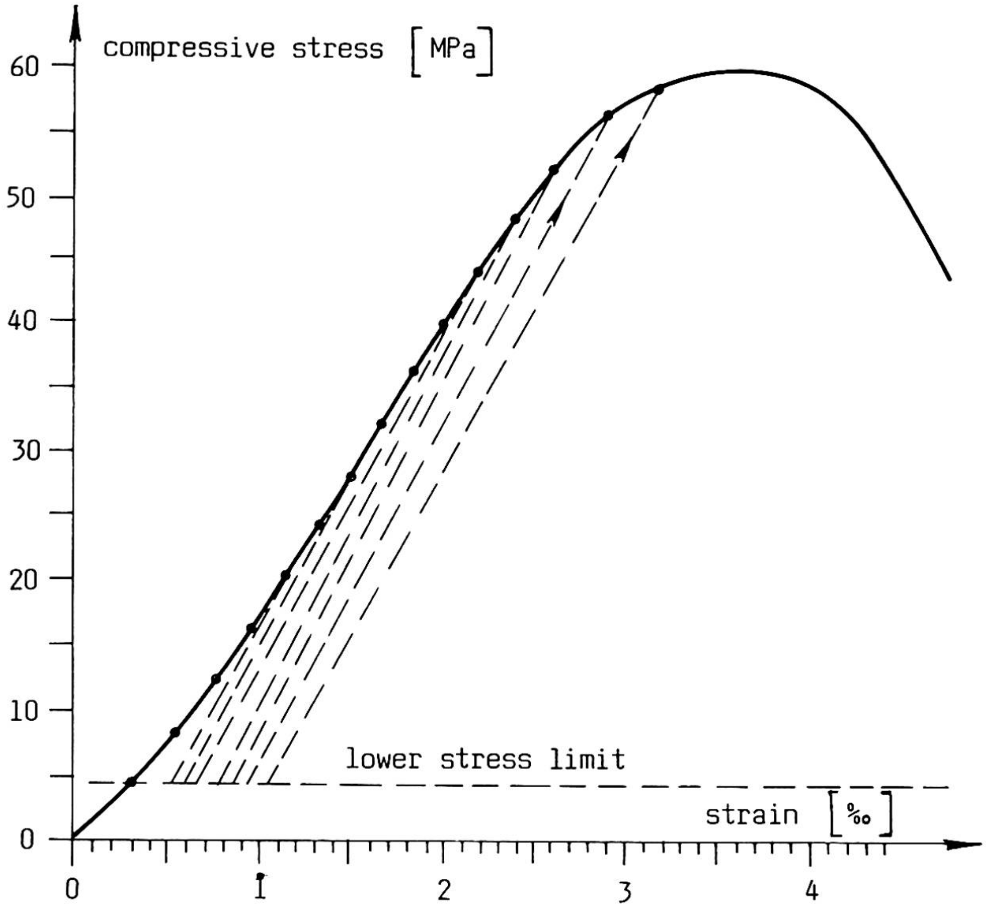
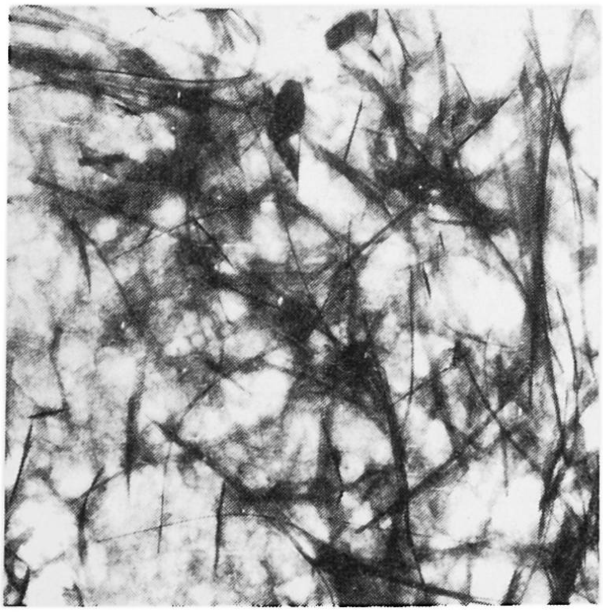


Fig.2 Curve of deformation of concretes with glass metal fibre content



3.3 Structure tests

Parallel with mechanic tests slices were cut from every specimen for macroscopic and microscopic analysis of the structure and the radiograph. Fig.3 shows a characteristic radiograph.

Experiences having been gained in course of structure analyses were fed back to the planning of the composition. In such a manner it succeeded that glass metal fibres should be embedded into the cement paste with their entire surface.

Fig.3 Radiograph of concrete, of 8 mm grain size

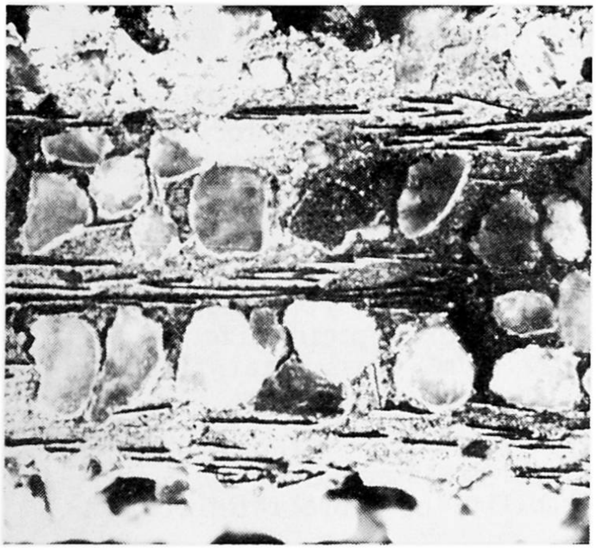


Fig.4 Section of fibre-reinforced slab

4. MODEL TESTS

In order to study the phenomens taking place in the reinforced fine mortar part of concretes, special plates with lamination of the size 70x250x10 mm were prepared, tested as two-support beams with concentraded force, with a span of 80 mm. In the slabs fibre reinforcement was arranged irregularly in the plane Fig.4 . Tests were performed at the age of 7, 28 and 90 days, in addition to glass metal fibre (b) - polypropylene fibre (c), glass - (d), steel fibre (e) and reference specimens (a) were also used. Stress-deflection diagrams are shown in Fig.5 - fibre length amounted uniformly to 40 mm. Batch of fibres 1 vol.%

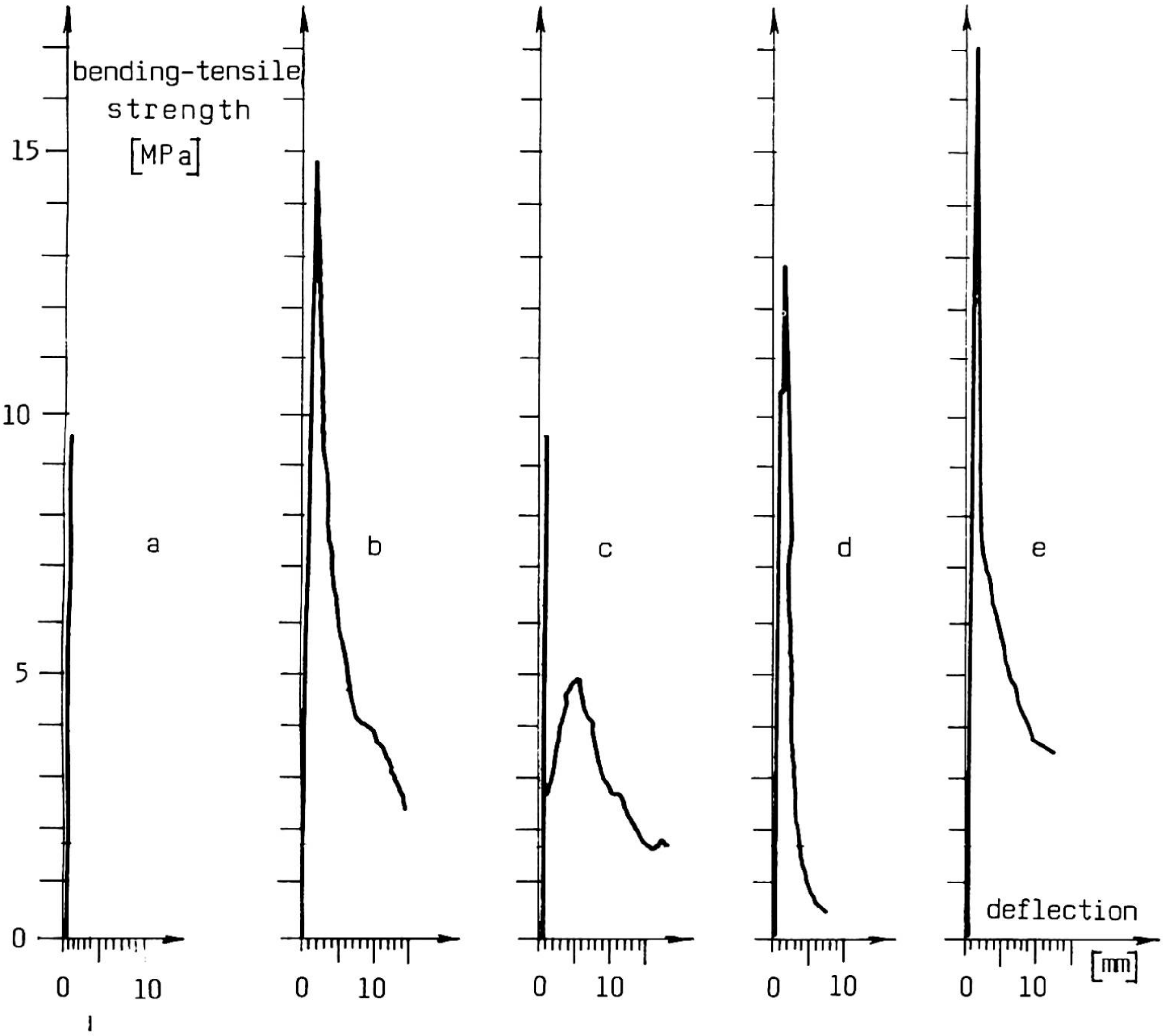


Fig.5 Bending test of fibre-reinforced slabs at the age of 28 days

5. EXPERIMENTAL PRODUCTION OF ELEMENT

As a result of intensive laboratory work the time has come for applying glass metal fibre in pactice, among others for a 30 mm thick shell structure, as it is to be seen in Fig.6.

Composition of the concrete applied: 600 kg/m^3 C 450 Portland Cement, aggregate with a grain size of max. 8 mm, 22 kg/m^3 glass metal fibre and 3 kg/m^3 polipropylene fibre.

Water/cement ratio equalled to 0,35. Structural tests confirmed applicability of fibre reinforcement.

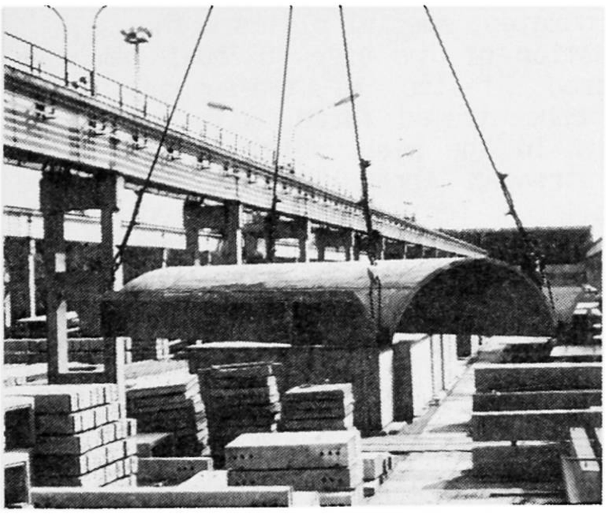


Fig.6 30 mm thick shell unit with glass metal fibre reinforcement

6. CONCLUSION

Composition of the mixture represents the fundamental matter in case of glass metal fibre reinforced concretes, where aggregate frame, cement quality and quantity, size of the glass metal fibre and the batch added play a special role. Model tests define well the effect of reinforcement, they refer also to the phenomene occuring in the reinforced concrete. In addition to favourable mechanic behaviour excellent resistance of the reinforced concrete to frequently repeated loading should be specially emphasized. In fibre-reinforcing microscopic shots and radiographs play an important role. After having finished the tests concerning glass metal, experimental production of elements was put in action.

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