CHAPTER 7 – REFERENCES

7.1 – Referenced standards and reports

Bunke, N.: Prüfung von Beton: Empfehlungen und Hinweise als Ergänzung zu DIN 1048. Berlin: Beuth - Schriftenreihe des Deutschen Ausschusses für Stahlbeton (1991), No. 422

DIN 18555-2:1982-09; Prüfung von Mörteln mit mineralischen Bindemitteln; Teil 2: Frischmörtel mit dichten Zuschlägen, Bestimmung der Konsistenz, der Rohdichte und des Luftgehalts (German Standard)

DIN 18555-3:1982-09; Prüfung von Mörteln mit mineralischen Bindemitteln; Teil 3: Festmörtel, Bestimmung der Biegezugfestigkeit, Druckfestigkeit und Rohdichte (German Standard)

DIN 1048-5:1981-06; Prüfverfahren für Beton; Teil 5: Festbeton, gesondert hergestellte Probekörper (German Standard)

7.2 – Cited references

Brameshuber, W.; Brockmann, T.; Hegger, J. and Molter, M., 2002, "Untersuchungen zum textilbewehrten Beton", *Beton 52*, No. 9, pp. 424-426, 428-429

Brameshuber, W., 2003, "Textil bewehrter Beton – Grundlagen und Anwendungsbeispiele", *Betonwerk International BWI 6*, No. 5, pp. 82-84, 86-88

Hegger, J.; Brameshuber, W.; Bruckermann, O.; Voss, S.; and Brockmann, T., 2003, "Kleinkläranlagen aus textilbewehrtem Beton", Institut für Massivbau, Institut für Bauforschung, Aachen, 2003, Forschungsbericht No. 84/2003

Hinzen, M.; Brockmann, T.; and Brameshuber, W., 2006, "Subsequent Sealing of Basements with a Waterproofing TRC (Textile Reinforced Concrete) Construction", *Ferrocement and Thin Reinforced Cement Composites: Proceedings of the 8th Symposium and Workshop, Bangkok, Thailand, February, 6-8, 2006,* ed. by Nymityongskul, P. et al (Eds.)), pp. 339-353

Hinzen, M., and Brameshuber, W., 2006, "Hybrid Short Fibres in Fine Grained Concrete", *Proceedings of the 1st International Conference on Textile Reinforced Concrete (ICTRC), Aachen, Germany, September 6-7, 2006*, ed. by J. Hegger, W. Brameshuber and N. Will, RILEM Publications S.A.R.L., pp 35-44

Mott, R., and Brameshuber, W., 2007, "Laminating and Spraying Techniques for the Production of Textile Reinforced Concrete", *Proceedings of the 8th International Symposium on Fiber-Reinforced Polymer Reinforcement for Concrete Structures, Patras, Greece, July 16-18, 2007*, ed. T. C. Triantafillou, FRPRCS-8

RILEM Technical Committee 201-TRC, 2006, *Textile Reinforced Concrete. State-of-the-Art Report of RILEM Technical Committee 201-TRC,* RILEM - Report 36, Bagneux, ed. W. Brameshuber, RILEM

Tables

Table 4.1 – Composition of fine-grained concrete mixture

Materials	Unit	Content
CEM I 42.5 R HS (c)	kg/m³†	520
Fly ash (f)		250
Silica fume (s)		50
Limestone sand 0-0.8 mm		1049
Superplasticizer	% by mass of binder	0.79
AR-glass fibers	% by vol.	1.5
Methyl cellulose	% by mass of solids	0.044
w/c	-	0.60
*w/b**		0.49

* w/b = w / (c+0.4·f+s)
† 1 kg/m³ = 6.2426 x 10^{-2} lb/ft^3

Table 4.2 – Fresh fine-grained concrete properties

Properties	Unit	Value	
		sprayed	compacted with usual compacting equipment
Density	kg/m³*	2129	1987
Spread	mm†	155	

* 1 kg/m³ = 6.2426 x 10^{-2} lb/ft^3
† 1 mm = 3.937 x 10^{-2} in.

Table 4.3 – Mechanical properties of fine grained concrete at a testing age of 28 days

Mechanical properties	Unit	Value
Compressive strength f_c	N/mm²*	88.0
Flexural strength $f_{ct,fl}$		7.8
Dynamic Young's modulus E_c		31,500
Density	kg/m³†	2164

* 1 N/mm² = 0.14504 ksi
† 1 kg/m³ = 6.2426 x 10^{-2} lb/ft^3

Figures

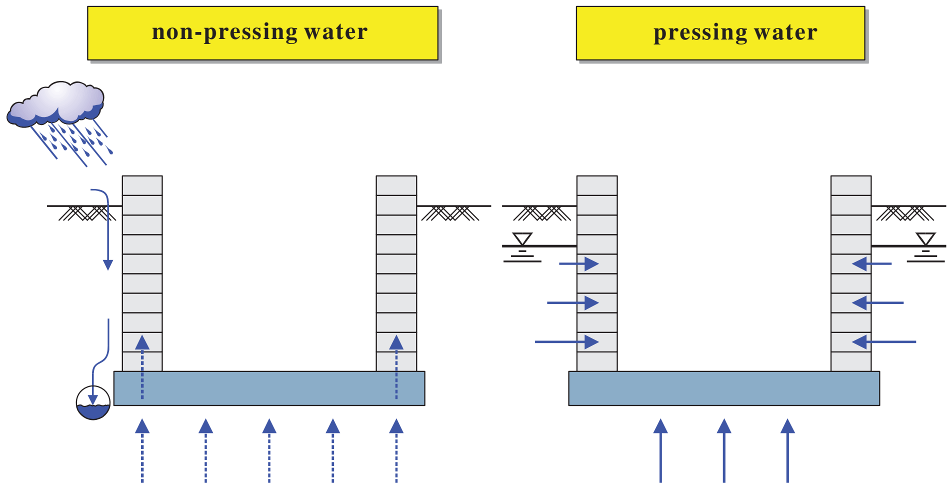

Fig. 1.1 – Non-pressing and pressing water

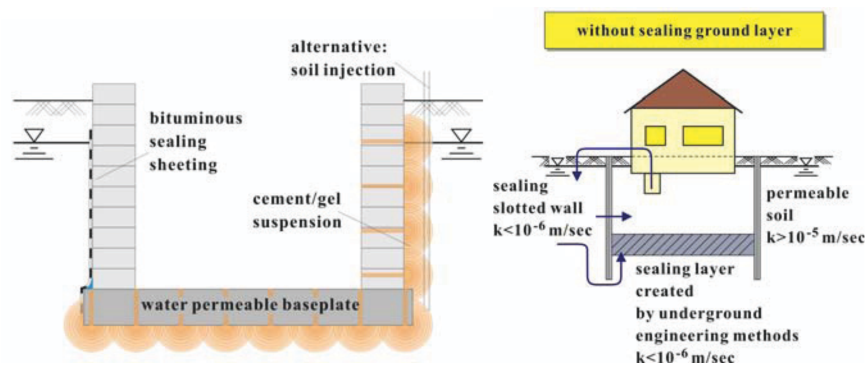

Fig. 2.1 – Sealing methods for outer walls in case of pressing groundwater (1 m = 3.2808 ft)

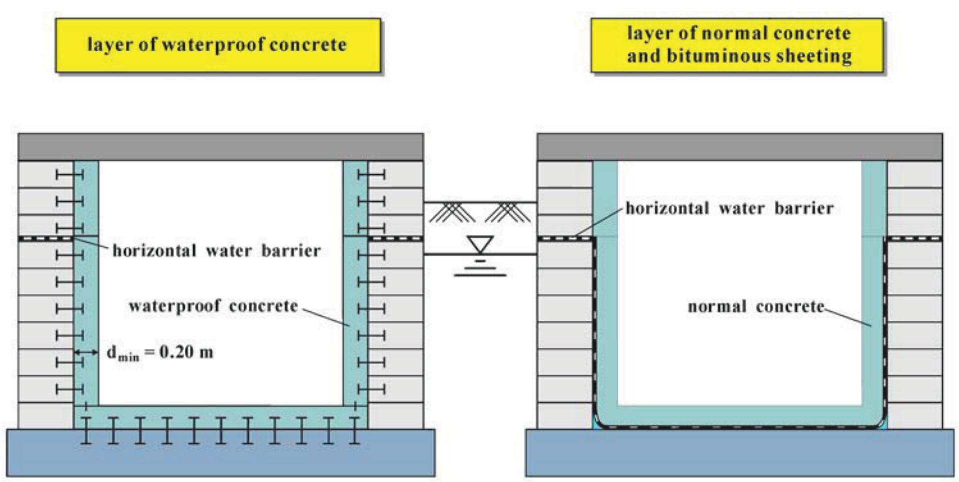

Fig. 2.2 – Sealing methods from inside in case of pressing groundwater (1 m = 3.2808 ft)

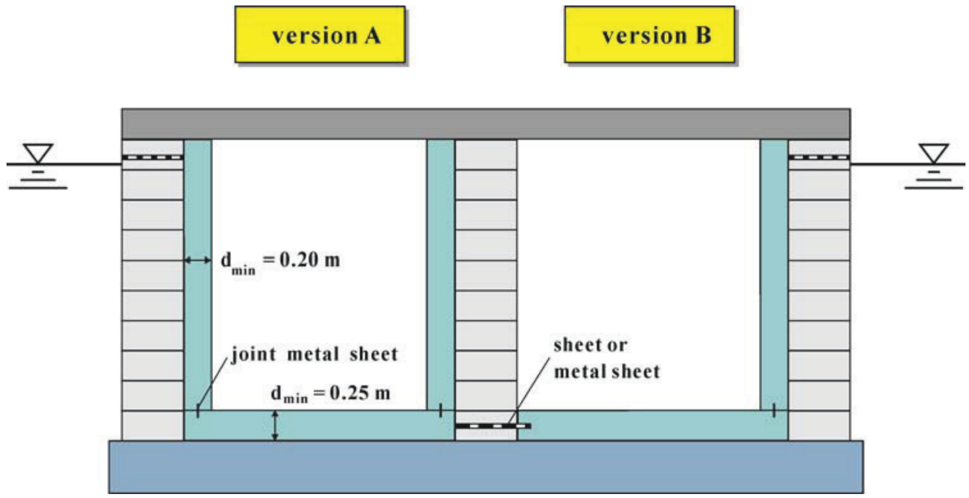

Fig. 2.3 – Two versions using water-impermeable concrete as a sealing method
(1 m = 3.2808 ft)

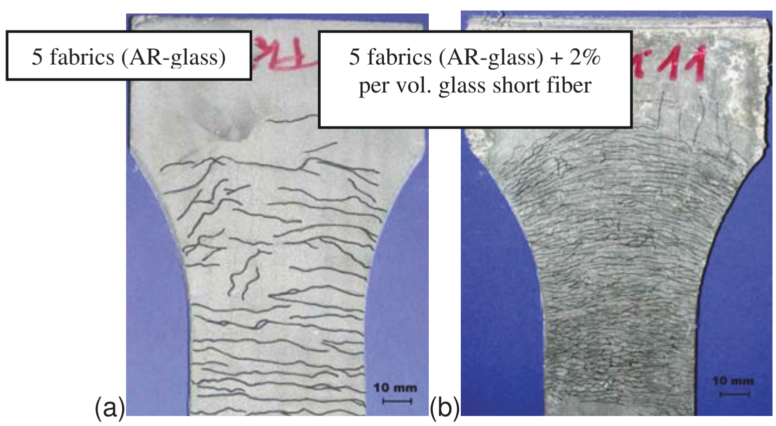

Fig. 3.1 – (a) Upper part of tensile test specimens with fabrics and (b) a combination of fabrics and short fibers
(1 mm = 3.937 x 10^{-2} in.)

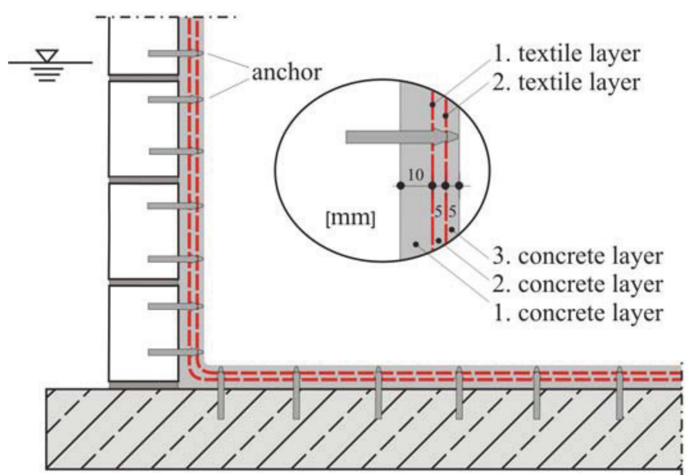

Fig. 4.1 – Principle of a subsequently applied sealing made of textile reinforced concrete
(1 mm = 3.937 x 10^{-2} in.)

(a) (b) (c)

Fig. 4.2 – Application of the fine-grained concrete (a, c) and inserted fabrics (b) applying the spraying method

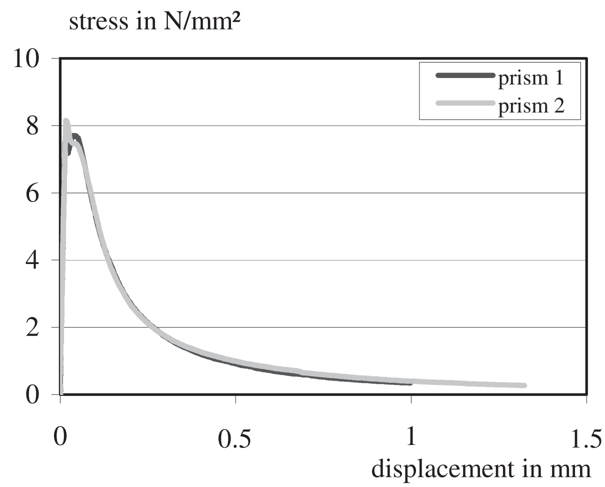

Fig. 4.3 – Test results of three-point bending tests of prisms
(1 N/mm² = 0.14504 ksi, 1 mm = 3.937 x 10^{-2} in.)

(a) (b)
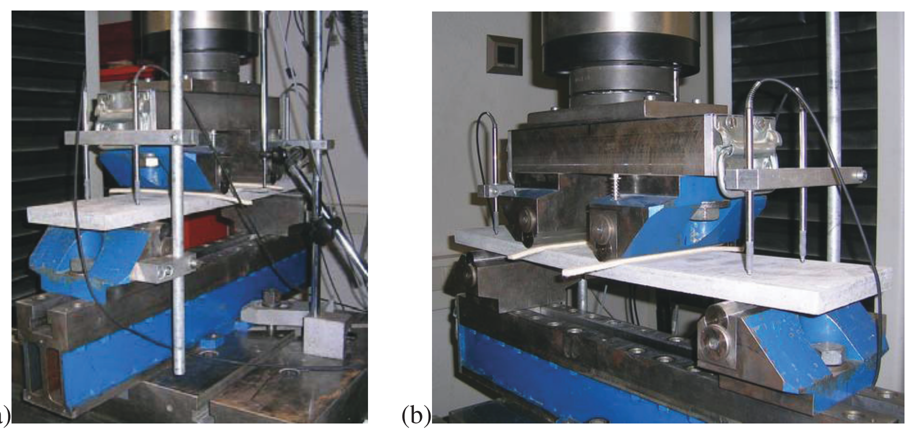
Fig. 4.4 – Test setup of four-point bending test with slab

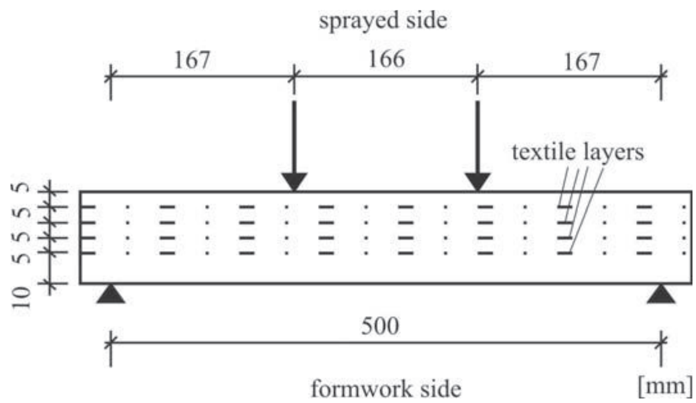

Fig. 4.5 – Distribution of textile layers within the cross section of version 1 (1 mm = 3.937 x 10^{-2} in.)

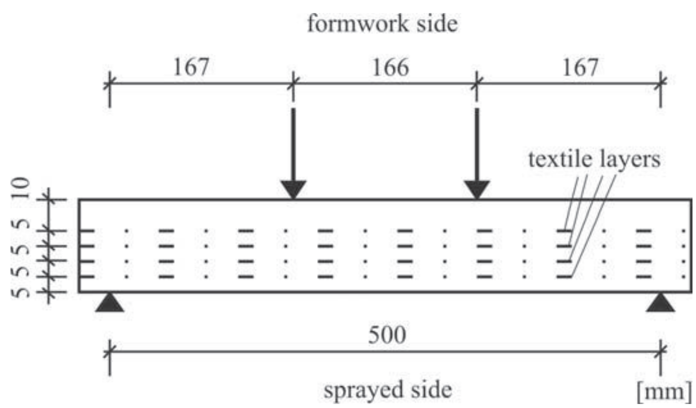

Fig. 4.6 – Distribution of textile layers within the cross section of version 2 (1 mm = 3.937 x 10^{-2} in.)

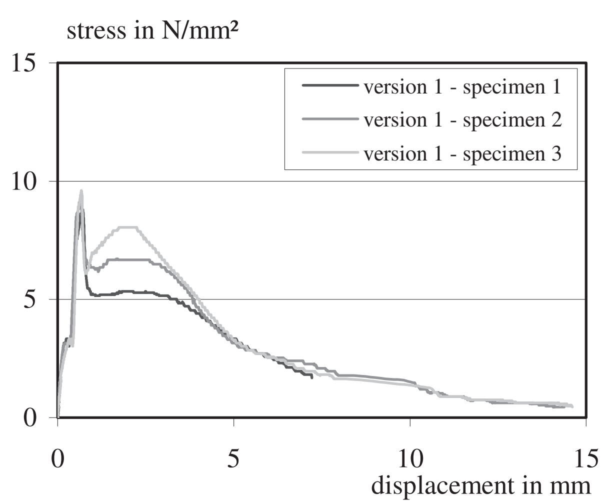

Fig. 4.7 – Test results of four-point bending tests of sprayed slabs, version 1 (1 N/mm² = 0.14504 ksi, 1 mm = 3.937 x 10^{-2} in.)

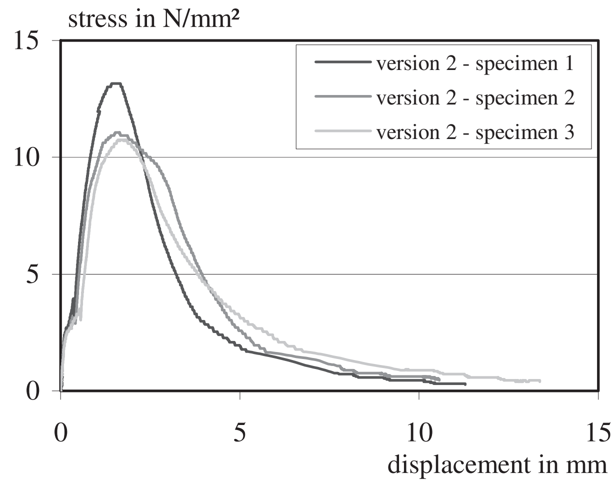

Fig. 4.8 – Test results of four-point bending tests of sprayed slabs, version 2
(1 N/mm² = 0.14504 ksi, 1 mm = 3.937 x 10^{-2} in.)

Fig. 5.1 – Cross section of the masonry wall with the layer of textile-reinforced concrete

Fig. 5.2 – Front and side view of the exhibit wall subjected to hydrostatic pressure

SP-251—5

Strength Degradation of AR-Glass Filaments Due to Cyclic Tensile Loading

by B.-G. Kang, J. Hannawald and W. Brameshuber

Synopsis: The tensile load carrying behavior under cyclic loading of filaments made of alkali-resistant glass, which is the basic component of the textile reinforcement used for textile reinforced concrete, has been analyzed. Therefore, tensile tests under cyclic loading at four different stress levels were carried out. A damage accumulation, which led in some cases to a failure of the specimens during the cyclic loading, could be observed. This motivated to introduce a strength degradation model. A calibration of the model parameters on the experimental data was performed using an optimization method. A statistical analysis was carried out beforehand, to estimate the initial tensile strengths of the specimens, which were needed for the calibration.

Keywords: cyclic loading; filament tensile test; hybrid optimization; inverse parameter determination; simulation; strength degradation model; textile-reinforced concrete

Bong-Gu Kang, Dipl.-Ing.: Research assistant at the Institute of Building Materials Research at RWTH Aachen University, Germany.

Joachim Hannawald, Dr.-Ing. Dipl.-Phys.: Head of the working group "Composite Materials and Modeling" at the Institute of Building Materials Research at RWTH Aachen University, Germany.

Wolfgang Brameshuber, Prof. Dr.-Ing.: Professor at the Department of Engineering and head of the Institute of Building Materials Research at RWTH Aachen University, Germany. Chairman of the RILEM committee "Textile reinforced concrete (TRC)". Former head of the international research laboratory of the construction company Bilfinger Berger.

1. INTRODUCTION

Textile reinforced concrete (TRC) is a new innovative composite material in structural engineering, which uses textile fabrics made of alkali-resistant glass yarns as reinforcement (cf. Fig. 1.1 on the left). A yarn itself consists of hundreds of individual filaments. Fig. 1.1 on the right shows a SEM image of a yarn embedded in concrete. Due to an incomplete penetration of the concrete into the yarn, filaments experience differently high loads during loading. Many investigations on the load carrying behavior of TRC under monotonically increasing loading have been carried out so far (Banholzer 2004, Curbach 2003, Brameshuber 2006, Hegger, Brameshuber and Will 2006). However, the design of structural elements made of TRC also needs knowledge on the long-term behavior as well as on the behavior under cyclic loading.
The recently carried out yarn pullout tests under cyclic loading (low cycle fatigue) by Kang and Brameshuber 2006 showed, that a successive filament rupture is significantly responsible for a failure of specimens. This fact showed the necessity, to analyze the damage mechanism of a filament under cyclic tensile loading.
A material model of the filament as well as a bond model was introduced for the finite element simulation of the yarn pullout test under cyclic loading by Konrad, Chudoba and Kang 2006. In the material model, the filament damage accumulation was supposed to be dependent only on the slip between filament and concrete. However, a filament damage accumulation, caused by initial imperfections of the material itself, is also expected in pure tensile cyclic loading. Therefore, a strength degradation model is introduced in chapter 4, which extends the existing material model of the filament. For a calibration of the model parameters simulations of the strength degradation have to be carried out, which need the knowledge of the initial tensile strengths of the specimens. However, a fundamental problem in tests with cyclic loading is that a damage accumulation can occur during the tests, so that consequently the original, un-damaged load carrying capacities (e.g. the initial tensile strengths) can not be determined and thus remain unknown. Therefore, a statistical method to estimate the initial tensile strengths dependent on the sample size of a test series is introduced in chapter 5.