LONG-TERM BEHAVIOUR OF COMPOSITE CONCRETE SPECIMENS BONDED TOGETHER WITH EPOXY RESIN

LANGZEITVERHALTEN VON MIT EPOXIDHARZ VERKLEBTEN BETONPROBEN

ÉSSAIS À LONGTERME SUR DES PRISMES EN BÉTON COLLÉS AVEC DE LA RÉSINE ÉPOXY

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Summary

This paper reports about the results of long-term tests upon bonded conrete prisms. Even after a 16 years-storage under different conditions such as temperatures of 23°C and 40°C, water or open air weathering time had no definite effects upon the shear strength of bonded cement mortar prisms. Thus, durable bonding of concrete may be produced with special epoxy mortars and suitable working conditions.

Zusammenfassung

In diesem Beitrag wird über die Ergebnisse von Langzeitversuchen an verklebten Betonproben berichtet. Auch nach 16 Jahren Lagerung unter verschiedenen Bedingungen wie Luft von 23°C und 40°C, Wasser oder Freibewitterung zeigten die Scherfestigkeiten der verklebten Zementmörtelprismen keinen eindeutigen Zeiteinfluß. Mit ausgewählten Epoxidharz-Klebemörteln und richtigen Verarbeitungsbedingungen lassen sich demnach dauerhafte Betonverklebungen herstellen.

Résumé

Un rapport est donné sur les résultats d'essais à long terme réalisés sur des prismes en béton collés. Même aprês une durée de stockage de 16 années sous des conditions differentes comme des températures de 23°C et 40°C, stockage dans l'eau ou à l'extérieur la résistance au cisaillement des prismes en mortier de ciment n'était pas influencée par le temps. Ainsi il est possible de réaliser des collage de béton durables à la base de mortiers de résine époxy spéciaux et des conditions de travail appropriées.

key-words: bonded concrete, epoxy-resin-mortar, long-term-test, shear-strength

1. PREFACE

About 20 years ago, long-term tests on the bonding of concrete were initiated with the financial support of the German Concrete Association and the Bundesminister für Raumordnung, Bauwesen und Städtebau. The results of these tests, which have now been completed, are summarized in the following text. An exact description of the materials used and of the preparation of the specimens can be found in [1].

2. GENERAL DESCRIPTION OF THE TESTS

Instead of the usual concrete specimens, cement mortar prisms of relatively high strength were cast, cut into several pieces and then butt-jointed together with epoxy resin mortar. The bonded prisms were kept in different environments or media (air 23 and 40 °C, water, weathering exposure) for periods of up to 16 years duration. A number of the prisms were subjected to continuous stress equivalent to 25 % of the short-term shear strength. At various times,these prisms were tested in shear tests up to breaking point.

3. MATERIALS USED

The following materials were used:

- Cement mortar prisms, 4 cm x 4 cm x 16 cm, consisting of:
  Cement PZ 35 F
  Water-cement ratio W/C: 0.45
  Aggregate: Standard sand according to DIN 1164
- Epoxy resin adhesive mortar, consisting of:

Basic resin:	Ruetapox 0164	100 parts by weight
Hardener:	TETA	15 parts by weight
Thixotropy material:	Sylodex 24	1.2 parts by weight
Aggregate:	Standard sand I (O up to 0.2 mm)	228 parts by weight

The adhesive mortar had a plastic to flowing consistency and wetted the concrete surfaces in a satisfactory manner when applied with a spatula.
Hardened prisms of cement mortar and adhesive mortar, of size 4 cm x 4 cm x 16 cm, developed the following average strengths:

		Cement mortar	Adhesive mortar
Bending resistance	N/mm²	8.5	28.0
Compressive strength	N/mm²	55.0	92.8

4. PREPARATION OF THE TEST SPECIMENS (BONDING)

At an age of 28 days, the wet cement mortar prisms were cut into pieces and, after re-drying, were bonded together into prisms by means of 1.5 mm thick epoxy resin joints as shown in Figure 1.

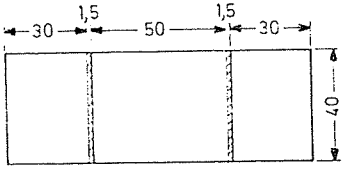

Figure 1: Side view of the bonded cement mortar prisms

Following hardening, the bonded prisms were ground plane-parallel, using a wet procedure, in order to ensure level bearing surfaces for the shear strength tests described in the following section.

5. STRENGTH TESTS

The strength tests for the bonded prisms were made as shear-tests,with the device shown diagrammatically in Figure 2, compare with [2], [3].

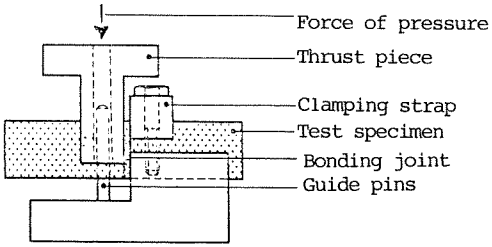

Figure 2: Shear testing device

In the test, the specimen was fixed to the lower part of the device with a clamping strap in such a manner, that the bonding joint projected immediately over the edge of the clamping surface. Guided by two pins, the thrust piece transferred the test load into the centre of the bonding joint.

For determination of the shearing resistance, the shear testing device was installed in a hydraulic pressure testing machine. The thrust piece was then placed under stress, up to the point where the part specimen sheared-off (in approx. 2 minutes).

The distribution of stress in the described test arrangement is not absolutely defined because, without doubt, a certain degree of bending moment was also induced in the test specimen. The arrangement has, however, been shown to be satisfactory for comparative tests. With this test arrangement, the direct influence of external factors on the bonding joint, however, can only be determined when the strength of

the joint is less than that of the cement mortar.

6. TESTING STANDS FOR THE CONTINUOUS STRESSING OF BONDED PRISMS

As mentioned in Section 2, a number of bonded prisms were to be stressed with a continuous stress equivalent to 25 % of the short-term shear strength. Under the assumption that no test specimen would break during the 16 years test duration, testing stands were constructed in which 2 test specimens as shown could be placed under stress at the same time.
Figure 3 shows a stand for continuous testing with built-in bonded test specimens.

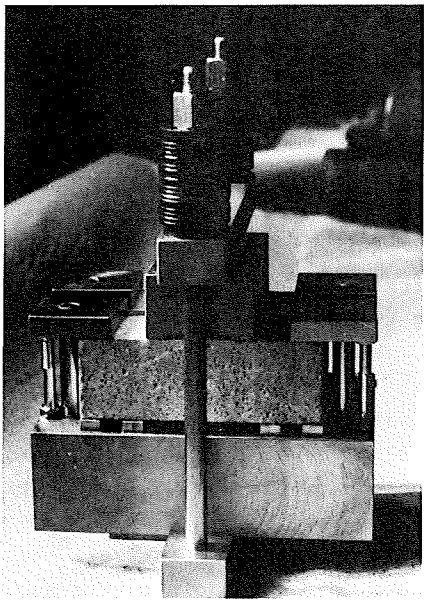

Figure 3: Stand for continuous testing with built-in test specimens

The test specimens were stressed, through a ball situated below the traverse, by means of tensioning rods and bundles of disc springs located on both sides of the testingstand.
Each of the tensioning rods contains 2 measuring lengths of 100mm, staggered at 180°, for extension measurements by means of extension meter. Before the tensioning rods were installed in the testing stand, their linear deformation diagram was determined in a tensile test, so that the effective force in the testing stands, produced by the compression of the disc spring bundles, could be exactly adjusted and controlled by means of the change in the measured lengths on the tension rods.

A total of 50 continuous test stands were produced for the stressing of 200 bonded joints. As a rule, 8 joints were tested, with respect to type and duration, for each exposure condition.

7. EXPOSURE OF THE BONDED CEMENT MORTAR PRISMS AND DETERMINATION OF THE RESIDUAL STRENGTH

The designated number of bonded prisms and testing stands with prisms under continuous stress, were subjected to the following 4 different exposure conditions:

- Standard climate 23/50-2 DIN 50014
- Air at a temperature of 40 °C (heating cabinet)
- Water bath at 23°C (renewal of water at 14 days intervals)
- Weathering exposure on the roof of our institute building

After expiration of the respective test period, the appropriate number of bonded joints were subjected to shear tests in accordance with Section 3. The specimens from the water bath were tested in the wet condition, those from the heating cabinet and those under weathering exposure

were tested after at least 14 days exposure to standard climate 23/50-2 DIN 50014.

8. TEST RESULTS

Firstly, it must be stated that none of the bonded joints, including those under continuous stress, had fallen apart during the 16 years.

The result of the shear tests are listed in Table 1. This table shows, that the average values of tests with identical storage and stress conditions, show no definite dependance on the duration of the test and lie always between 10 and 16 N/mm^2. The differences between the average values were essentially due to the relatively large dispersion of the individual shear strength values, which varied up to a maximum of 25% from the respective average arithmetical value. The cause of this dispersion can be found possibly in the non-unified shear strength of the cement mortar prisms originating from various different production series and the not fully clarified stress distribution factors in the test arrangement (see Section 5).

The fractures occured mainly and sometimes completely at the boundary between the cement mortar and the bonding joint. The proportion of fracture occuring at this boundary was, as a rule, somewhat larger for the test specimens immersed in water or subjected to weathering exposure than for those which were exposed to standard climate or air at 40 °C.

9. CONCLUSION

The results gained, over a period of 16 years, from test-specimens stored under different storage and stress conditions, confirm that with the use of selected epoxy resins and their correct application, the permanent bonding of

Table 1 Results of the shear tests

Age of the bonded joints at the time of testing	Shear strength in N/mm² [1]) after exposure to: Standard climate		40 °C Air		23 °C Water		Weathering exposure	
	without continuous stress	with continuous stress	without continuous stress	with continuous stress	without continuous stress	with continuous stress	without continuous stress	with continuous stress
7 days	11,8 (0)	10,0 (5)	--	--	--	--	--	--
3 months	--	--	--	--	10,6 (10)	--	--	--
6 months	--	--	--	--	10,4 (10)	10,1 (20)	--	--
1 year	10,7 (0)	9,5 (0)	10,8 (5)	11,0 (0)	14,3 (20)	11,1 (5)	10,5 (10)	13,3 (15)
2 years	10,7 (0)	12,7 (5)	10,2 (0)	12,5 (0)	10,5 (15)	13,7 (10)	11,3 (10)	11,5 (15)
4 years	11,6 (5)	13,7 (5)	13,5 (15)	12,5 (0)	13,4 (20)	12,9 (5)	16,1 (25)	14,7 (10)
8 years	11,4 (20)	14,5 (5)	10,7 (10)	12,8 (5)	11,5 (35)	13,7 (10)	13,9 (15)	16,3 (10)
16 years	10,4 (0)	13,5 (0)	10,7 (0)	12,7 (0)	11,5 (25)	13,0 (15)	11,9 (20)	13,4 (5)

[1]) Values in () give the percentage of the average adhesive share of the bonding mortar at the surface of fracture, the remaining share of the fracture ran always in the cement mortar.

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LITERATURE

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