

UPON THE NECESSITY TO DEFINE BOUNDERY CONDITIONS IN TESTING NEAR TO PRACTICE.

ZUR NOTWENDIGKEIT, PRAXISNAHE VERSUCHSRANDBEDINGUNGEN FESTZULEGEN.

SUR LA NECESSITE DE PRECISER LES CONDITIONS D'ESSAI PROCHES A LA PRATIQUE.

Bernhard Kipp

ABSTRACT

Upon the example of the crack bridging test according to the "Bau- und Prüfgrundsätze für den Gewässerschutz" (BPG) it has been shown how the improvement of the testing material - in this case water protection systems - may influence the boundary conditions of a test and, thus, its effectiveness.

ZUSAMMENFASSUNG

Am Beispiel des Rißüberbrückungsversuchs nach den "Bau- und Prüfgrundsätzen für den Gewässerschutz" (BPG) wird aufgezeigt, wie die Weiterentwicklung des Prüfgutes - hier von Gewässerschutzsystemen - die Randbedingungen eines Versuches -und damit seine Aussagekraft- nachhaltig beeinflussen kann.

RESUMEE

Par l'exemple du test surmonter-fissures d'après les "Bau- und Prüfgrundsätze für den Gewässerschutz" (BPG) il est montré, comment l'évolution d'un produit puisse influencer les conditions du test et les résultats.

Key words: Crack-bridging, shrinking, boundery conditions.

1. General

Normally the developments of products occur gradually without realizing at the beginning if and how the desired aim is reached. The tests required for describing the material qualities and the practical application are equally submitted to a development, whereas the testing procedures may lag behind the development of the product. It is therefore necessary to examine critically, at least from time to time, if the practical-technical problems are still effectively answered by the investigation methods.

The example of a crack bridging test according to the "Bau- und Prüfgrundsätzen für den Gewässerschutz" (Construction and testing principles for water protection) BPG, part 1 of the IfBt, Berlin, Nov. 91, shall show that the testing procedures have to be adapted to the development - and in this case - to the water protection systems.

2. The beginning

2.2 Systems and areas of application

At the beginning it was the main objective to protect the soil and groundwater against the in the beginning 70ties quickly spreading stocks of heating and diesel fuels in private households, agriculture and industry. The collecting reservoirs used for this purpose built either of concrete or bricks and rendered afterwards, were covered with a 2 or 3-layer coating out of vinyl-resin-based dispersions which might not yet merit the designation "coating system".

2.3 Crack bridging test

The most important conditions for a protection and sealing

cover is the absence of cracks and the capability to bridge, in certain limits, even cracks in the support. For proving this capability a test has been conceived in the course of which a reinforced concrete beam with the dimensions $L \times W \times H = 70 \text{ cm} \times 20 \text{ cm} \times 8 \text{ cm}$ has been thus bent that in the coated surface (bending-tensile area $70 \times 20 \text{ cm}^2$) as much cracks as possible have appeared within at least 10 minutes and at most 15 minutes, with a width of about 0,2 mm.

By such a test it was possible to cover shrinkage or creep cracks moving very quickly but which already existed in the concrete at the moment of coating. But the cracks which spontaneously appeared in the concrete after coating were not covered: The cracks widths of such "static" cracks may be limited by a corresponding distribution of reinforcement; up to now the dynamic of a spontaneous crack development has not yet been taken into consideration.

3. The further development

3.1 Fields of application

Already in 1973, besides of heating and diesel fuels further water polluting materials (frequently used solvents such as chlorinated hydrocarbons etc.) were taken into the testing program. As far as the industry is concerned until 1983 -with one exception in 1977- no need has been recognized so that the approval demands and tests were furtheron limited to coatings resistant to heating and diesel fuels.

Only with the approval demand of a known chemical company in 1986 for a crack-bridging chemical-resistant coating system a very violent development started which more or

less has overburdened the testing instituts as well as the approval authorities. This is all the more true that owing to the huge expansion of the field of application additional criteria had to be taken into consideration which hardly comply wiht the requirements valid hitherto.

3.2 Crack bridging test

On behalf of the above described different problems with the reinforced concrete beams in view of handling and reproduceability of the test results stated with these beams -every testing laboratory has produced its own beams- in 1979 the fabrication of the test specimens was given to one central testing laboratory. In the mean time the beam was "reduced" to a more easily handable reinforced concrete slab with the dimensions L x W x H = 30 cm x 20 cm x 4 cm, which was completely sufficient for testing the dispersion-based coatings used at that time. The crack bridging test remained the same as described in 2.2.

4. The actual situation

4.1 Systems and fields of application

As already indicated in chapt. 3.1 the multilayer dispersion-based coatings resistant to heating- and diesel fuels have been more and more replaced since 1986 by high-strength coating systems covering in the mean time a variety of at least 12 of the water pollutant liquids listed in the BPG. Such systems are essentially composed of the following layers:

- primer
- intermediate or floating layer

- laminate (glass fleece or fabric impregnated with reaction resin)
- cover layer (resistant to chemicals)

The priming - normally on the basis of epoxy resin - shall deliver a good, overall and durable adhesion of the coating system to the prepared (sandblasted) support.

The intermediate or floating layer is normally about 2 mm thick and is composed of a shear-resistant material which delivers a crack-bridging capacity. In most cases this layer is formulated upon polyurethans or at least upon co-polymers.

The laminate layer shall deliver the tensile strength which is necessary for a sufficient crack-bridging capacity and constitute a sufficiently stiff support for the chemical-resistant cover layer.

As the chemical-resistant cover layers the lamination resins were formulated on the basis of epoxy resins, phenol resins, polyester resins or furan resins, so that in some cases, no proper separate cover layer is needed: the reinforcement by a glass fleece or fabric is intergrated into the cover layer so that laminate and cover layer constitute a functional unit.

All highly-chemical-resistant cover layer materials have one thing in common: they all were extremely cross-linked and, thus, have brittle elastic qualities. Besides of a certain weakness after aging (later hardening or embrittlement) another very detrimental property has to be mentioned, the partly important shrinkage tendency during hardening. For polyester resins, especially vinyl-ester-

resins, shrinkage may reach more than 10 vol.% and may be bigger than the multiaxial rupture strain of resin. The consequence in practice is, that an unreinforced resin layer cracks by itself during hardening at restraint shrinkage, that is to say without external influence.

4.2 Crack bridging test

Besides some unessential modifications the crack bridging test has not been modified since 1979 (see chapt. 3.3). Upon one section of the 30 cm x 20 cm big surface of the reinforced concrete testing slab (see fig. 1) the system to be tested is applied whereas its borders were "free ends".

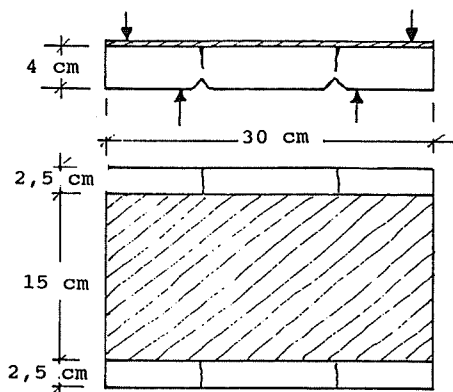


Fig. 1:
Reinforced concrete testing slab with a coated surface (shaded areas) and the expected cracks in concrete (bending-tensile-stress)

While testing heating- and diesel fuel-resistant coatings this matter doesn't play any role because in the bridging test only very small tensile forces may be produced in the thin coating film which, in the immediate environment of the crack, may be introduced in form of bond stresses into the support (concrete slab): only very small anchorage lengths are needed; the testing slab with its dimensions $L \times W \times H = 30 \text{ cm} \times 20 \text{ cm} \times 4 \text{ cm}$ may be regarded as

"infinitely big"; the tests correspond to practice.

This is different for highly-resistant and, thus, highly-tensile sealing systems, especially if there are effective floating layers. In this case the free ends have a fatal reaction in a double way:

- a) Contrary to the application in practice the system upon the small slabs may shrink, without restraint, into all directions, with the result that the tensile stresses, which appear after a restraint shrinkage, will get lost. The crack bridging test is then carried out upon a specimen without stresses, thus, a favourable loading case is created which never happens in practice.
- b) For the same reason the crack bridging test is worthless. Because of the free ends - and according to the tensile strength and the effectiveness of the floating layer - the system to be tested may escape more or less to the (bending-) tensile stress, the free ends follow. This means nothing else than each system creates its own "boundary conditions" why the testing results were not comparable among each others.

Within the frame of a research work with the subject "Sealing of collecting reservoirs upon which one may walk and drive" terminated at the end of 1991, it has been proved that at least 75% of a random choice of already approved systems do not pass an appropriately modified crack bridging test.

The modification consisted only in applying the systems around the (broken) borders up to the 20 cm x 4 cm big front surfaces of the testing slabs and anchoring it in a

shear-resistant way (without floating layer) (see fig. 2).

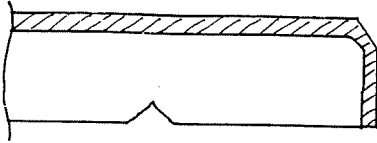


Fig. 2:
Coating system
(without floating
layer) placed around
the broken borders up
to the front side of
the slabs

This measure may surely not be considered as the best solution of the problem, all the more that the attainable fixing degree of the borders depends essentially upon the skill of the craftsman. In spite of this imperfection an impressive result has been reached which shows clearly the disadvantages of the actual testing procedure.

5. Summary

Upon the example of the crack bridging test according to the BPG it has been shown how the improvement of the testing material - in this case water protection systems - may influence the boundary conditions of a test and, thus, its effectiveness.

The essential properties of more recent systems - for instance the partly very big shrinkage tendency of several layers - have not been investigated in this test and, thus, lead to results far from practice.

This is all more important as a calculation of the behaviour of the system is not possible at the moment because of lacking appropriate material characteristics.

It is therefore necessary to examine established testing methods in view of their relation to practice and their effectiveness and to analyze them critically in order to avoid that the test is degraded to a simple execution of the standard and does no longer fulfill its task to simulate reality.