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New Methods in the Rehabilitation of Prestressed Concrete Structures

Nouvelles méthodes pour l'assainissement des ouvrages en béton précontraint

Neue Verfahren bei der Instandsetzung von Spannbetonbauwerken

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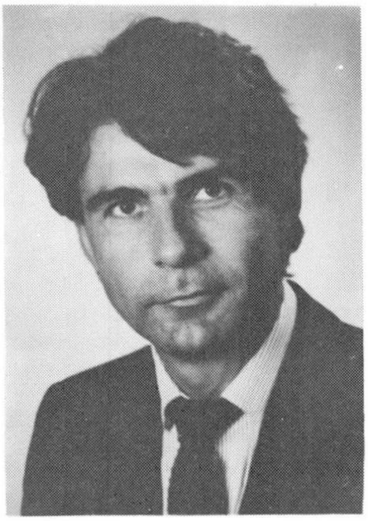

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SUMMARY

There are two major requirements when repairing prestressed concrete structures: effective analysis methods must be available and one has to be well acquainted with the technology to be used. The present paper deals with the following recent methods:

— locating of steel tendons covered by conventional reinforcement by applying the method of radar technology
— opening of prestressing ducts without any danger of damage being caused to the steel tendons
— measuring and grouting of cavities in ungrouted prestressing ducts
— reprofiling of repaired sections by using a new, high-quality wet shotcrete-method.

RÉSUMÉ

L'assainissement des ouvrages en béton précontraint demande avant tout des méthodes d'analyse efficaces et en parfaite adéquation avec la technologie utilisée. Les succès récents sont les suivants:

— recherche des câbles de précontrainte situés sous les fers à béton passifs, par l'emploi de la technologie du radar
— ouverture des gaines en tôle d'acier sans risque d'endommager les câbles de précontrainte
— mesure de volume et injection des cavités des gaines mal injectées
— fermeture des sections réparées des ouvrages avec un nouveau béton projeté à malaxage de haute qualité.

ZUSAMMENFASSUNG

Für die Instandsetzung eines Spannbetonbauwerks sind vor allem leistungsfähige Analyseverfahren und beherrschte Instandsetzungstechniken gefordert. Jüngste Erfolge, über die das Referat berichtet, sind:

— das Orten von Spanngliedern, die von schlaffer Bewehrung überdeckt sind, mit der Radartechnik
— das Öffnen von Hüllrohren ohne Verletzungsgefahr für Spannglieder
— das Messen und Verpressen von Hohlräumen in unverpressten Hüllrohren
— das Verschliessen instandgesetzter Bauwerksabschnitte mit einem neuartigen, qualitativ hochwertigen Nasspritzbeton.

1. Introduction

Post-injection of uninjected sheathings in a prestressed concrete structure may effect prolongation of its lifespan or bring about its complete destruction.

A drill point hitting a tendon under tension may possibly cause its bursting with the effect of an explosion. This would not only endanger the structure but those doing the job, too. Execution of rehabilitation work must be quality-assured. Subcontractors must prove, prior to contract award, that they are organizationally and technically in a position to fulfill the specified quality requirements. To this end, they must submit a detailed description of how they intend to solve the problem. This is what quality assurance means in control.

Easy accessabilitiy to critical points, simplicity of structural design, testability of conditions and rapid detectability of errors are criteria that mean safety and economy in the rehabilitation of existing structures. The designer of new constructions must recognize the above mentioned features as a quality criterion.

The realization of construction projects always encompasses different domains. They cannot be carried out by individual domains alone, such as structural design or production or development or analysis techniques. Technically outstanding rehabilitations require in-house organizational support for planning and testing. This strategic task involves decision-making on the company's management level.

In addition, changes in works-techniques - and changing requirements as to the knowledge of employees require selective training. The mentioned quality-assured rehabilitation measures refer essentially to the organization of planning and of job sequence.
Relevant advances in the techniques of analysis and execution are described in the following.

2. Radar technique

The radar detector developed for geological soil investigations can be used to locate the reinforcement in reinforced concrete and prestressed concrete structures. Within structural components radar detects material interfaces at which the dielectric characteristics of the material change. Such changes occur for instance with density differences. The radar technique competes with other non-destructive test methods allowing insight into the concrete. It stands out for the rapidity of its functioning, is easy to handle, yields safe localization results and is economical.

The radar equipment consists of the antenna, control unit and recording unit. A monitor, computer and data logger can be added for the purpose of documenting and evaluating the radar signals. The size of the control and recording units correspond approximately to a DIN A 3 plotter. The antenna used to detect prestressed reinforcement can be held in one hand and weighs about 2 kgs.

When handling the antenna for detection, it should sweep over the surface of the test piece at possibly constant speed. The depth and spread of a fault area or an embedded reinforcing bar are determined through calculation, the wave velocity of the radar impulse and the relative dielectric constant of the material entering into the calculation. The impulse timing is taken from the graphic radar signal recording. This shows a characteristic graph of printer lines as shown in Fig. 1. With a motionless antenna the printer lines run parallel and straight. As soon as the antenna is moved when sweeping over the surface of the test piece, the blackened ribbons produce more or less accentuated oscillations indicating the detection result to the expert.

Formerly, the radar technique could only be used for the detection of reinforcement near the concrete surface. Meanwhile, the measuring technique has advanced to a point where it is possible to detect in bridges the transverse prestressed reinforcement beneath the non-prestressed reinforcement through the bridge cap as well as through the asphalt surfacing layer.

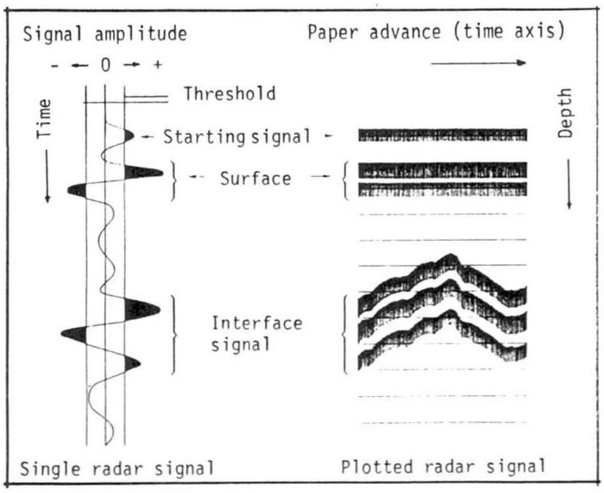


Fig.1 Graphic recording of a radar signal.

Fig.2 Guiding the radar antenna for the detection of transverse prestressed reinforcement

Latest references on radar detection of prestressed reinforcement within bridges in Germany pertain to the Köhlbrand bridge and the Kattwykdamm bridge in Hamburg as well as the Neuenkamper bridge in Remscheid.

3. Opening of sheathings

Safe and non-destructive hitting of a sheathing may just be regarded as a routine procedure. In wet drilling, a reduced electrical resistance shortly before the sheathing is reached, ensures that the drilling machine is automatically switched off. In dry drilling, an automatic switch-off device is inserted into the low-voltage circuit between drill hammer and the reinforcement. At the least contact between drill hammer bit and metal the drill hammer is switched off.

Fig.3 Drill hammer with automatic switch-off

Fig.4 The opened tendon seen through the borescope. The cavity is proof of insufficient injection.

The far greater risk of damage lies not in drilling but in the opening of the sheathing itself. Therefore the opening must be carefully surveyed. This is done by means of the borescope. This accessory, too, is meanwhile considered as belonging to the state of the art in rehabilitation works.

What is seen through the borescope can be recorded photographically and so be documented. This is a new development with opening the sheathings, because it allows everyone involved to check that the tendon was not damaged when opening the sheathing.

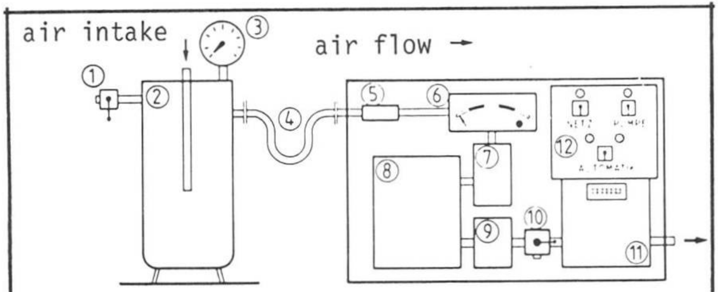
After opening of the sheathing, first the found situation as to voids must be described. Subsequently the bores are closed with injection hoses and sealing caps as protection against humidity.

4. Vacuum injection of un-grouted prestressed concrete sheathings

The patented vacuum injection procedure described below serves to fill a cavity which is accessible only through one opening with injection material.
The equipment used sucks the air out of the cavity and subsequently, via a relay valve, presses the injection material into the evacuated cavity.

The efficiency of the injection is examined by the following procedure.

Prior to the injection, the volume of the cavity is determined by measuring the pumped-off quantity of air down to a pressure of 400 mbar behind the vacuum pump. During an earlier check, the hose connections and the void were leakage-tested at 100 mbar. Leakages localized through hissing noises were sealed. In preparation of the injection, the underpressure is lowered to 50 mbar. Post pump injection assists the subsequent filling of the cavity.



1 air valve
2 dirt trap
3 precision manometer
4 connecting hose
5 quick-opening valve
6 low pressure switch
7 dust separator
8 vacuum pump
9 oil separator
10 deflation valve
11 air meter
12 switchboard

Figs. 5 + 6 The vacuum procedure.

After injection the quantity of grout introduced and the earlier determined volume of the cavity are to be compared to verify the degree of fill. Suitable injection materials are epoxy resin and grout.

5. Re-profiling with "synthetic-Silica" shotcrete

Shotcrete is particularly suited for reconstituting worn concrete courses and for rehabilitating plane concrete layers protecting the reinforcing steel against corrosion. Dry and wet mix shotcretes are suitable likewise.

Wet mix shotcrete has specific quality advantages in comparison with dry mix shotcrete:

- The water-cement ratio as the most important concrete quality parameter can be selectively adjusted and maintained constant.

- Wet mix concrete production renders a homogeneous fresh concrete mix.

- Conveyance of the wet mix shotcrete involves less material and wear-and-tear costs than of dry mix shotcrete.

- The high degree of homogeneity of wet mix shotcrete counteracts differential deformations and thus non-uniform conditions.

Wet mix shotcrete requires the admixture of an accelerating agent at the spray nozzle in order to produce adequately thick and well adhering layers and to reduce rebound. Water glass accelerates setting, but if incorrectly batched, the concrete may suffer a loss of quality.

A process is being developed under which the setting of wet mix shotcrete is accelerated by physical means, so avoiding chemically effective additives.
The effect is based on the addition of powdery synthetic precipitation silica which has an extremely large specific surface in the magnitude of almost 200 m^2/g. The large surface binds the surplus mixing water of the shotcrete and thus improves the cohesion of the concrete. The synthetic silica is added to the wet mix shotcrete together with the compressed air only in the spray nozzle.

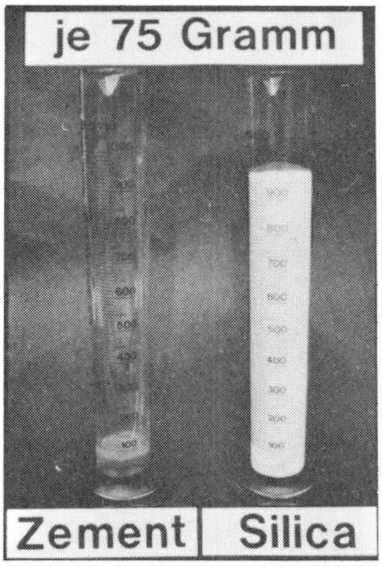


Fig.7 Comparison of volume

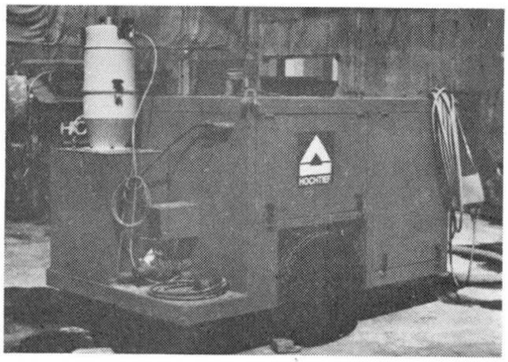


Fig.8 Batching device for loading the compressed air flow with synthetic silicic acid of 200 m^2/g fineness.

The following advantages of adding synthetic silica to wet mix shotcrete are particularly important.
- No loss of concrete strength
- Extremely small rebound (less than 5 %).
- High early and final strength.
- Due to the additional silica reactions within the micro range of the hardened cement paste high resistance against chemical attack.
- Denser concrete matrix through additional formation of CSH (calcium silicate hydrates).
- Small carbonization due to high density (improves corrosion protection of reinforcing steel).

Since the silica reaction is substantially physical, the hardening acceleration does not depend upon the degree of cement used. Thus, particular requirements for applying specific cement types can be easily and safely conceded.

The silica quantities to be added to the concrete are small and amount to only appoximately 3 % of the mass of cement.
We use synthetic amorphous silica, with a degree of purity of more than 98 %.