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Autor: Ivány, György / Buschmeyer, Wilhelm

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Strengthening Techniques Using Additional Reinforcement

Techniques de renforcement par armature secondaire

Verstärken durch zusätzliche Bewehrung

György IVÁNYI
Professor
Essen University
Essen, Germany

György Iványi received his engineering degree from Budapest Univ. in 1962, and his Ph.D. from Braunschweig Univ. in 1967. Since 1978 he has been Prof. for Structural Concrete at Essen University. He authored several papers on prestressed concrete and strengthening of structures.

Wilhelm BUSCHMEYER
Dr.-Ing.
Essen University
Essen, Germany

Wilhelm Buschmeyer received his eng. degree from Braunschweig University in 1976, and his Ph.D. in 1983, from Essen University. His research interests include partially prestressed concrete with and without bond and strengthening of concrete structures.

SUMMARY

A new technique for strengthening reinforced or prestressed concrete structural elements, using additional reinforcement in grooves, embedded into shotcrete or high slump con-crete with fine coarse aggregate, was developed. In this paper, details of design and construction of the new technique are compared with other strengthening methods. Several applications to bridge superstructures are presented.

RÉSUMÉ

Une nouvelle technique pour le renforcement de structures en béton, ayant pour principe le renforcement de la zone de traction, a été développé. À cette fin, des fentes ou des rainures sont faites dans le matériau et, après y avoir mis l'armature secondaire, elles sont remplies de béton projeté ou, dans le cas de surfaces horizontales, de béton à grains fins de consistance fluide. Les critères d'utilisation ainsi que les applications de la nouvelle technique sont présentés et comparés avec les méthodes existantes. Plusieurs exemples pour le renforcement des structures de ponts sont également présentés.

ZUSAMMENFASSUNG

Für die Verstärkung von Betonbauteilen durch Ergänzung der Zugzone wurde eine neue Technik entwickelt, die es gestattet, die Zusatzbewehrung im tragenden Betonquerschnitt unterzubringen. Hierzu werden Schlitze oder Nuten durch Hochdruckwasserstrahl hergestellt und nach Einlegen der Zusatzbewehrung durch Spritzbeton bzw. bei waagerecht liegenden Flächen durch einen fliessfähigen Feinkornbeton gefüllt. Auslegungskriterien und Anwendungen der neuen Technik werden vorgestellt, mit den bekannten verglichen und Beispiele für Brückenverstärkungen gezeigt.

1. INTRODUCTION

The performance of concrete structures with respect to load bearing capacity, serviceability and durability conditions or fatigue safety level can be improved by strengthening them. In general, the following methods are available for this purpose: increase of the cross sectional resistance by additional concrete parts, reinforcement or prestressing, change of the existing structural system to a more favourable one and finally by textural injections using fine cement grouts. A systematic presentation of various strengthening methods was given elsewhere [1]. In this paper special aspects of strengthening techniques using additional reinforcement are reported and a new technique shown.

2. BASIC REQUIREMENTS FOR ADDITIONAL REINFORCEMENT

In order to obtain an efficient strengthening of a concrete structural element, the chosen technique must guarantee a high quality bond of the additional reinforcement to the existing concrete.In particular, an effective bond is necessary in order to ensure the following criteria:

- the load bearing capacity can be calculated as the sum of those of the existing and the additional reinforcement (Fig. 1);
- the cracking behavior of the strengthened concrete member shows no differencies to that of the usual one (Fig. 2);
- the necessary anchorage lengths are as usual.

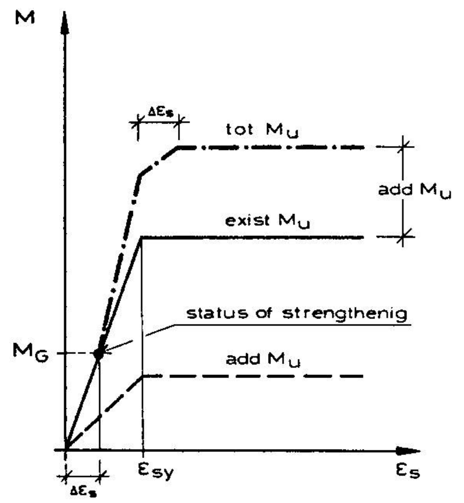

Fig.1 Ultimate of the strengthened concrete member

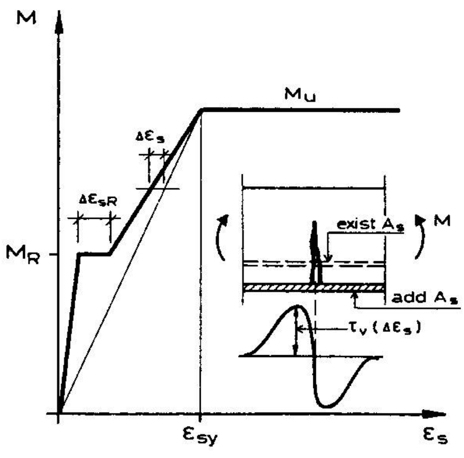

Fig.2 Changes in steel strains during cracking

Therefore, bond strength and bond stiffness of the additional reinforcement should be comparable with the existing one.

3. ADDITIONAL REINFORCEMENT AT THE BOUNDARY LAYER

The well-known technique of strengthening of concrete structures by additional reinforcement using the shotcrete technique was extended for quite some time with a new one using epoxy-bonded glued steel or plastic sheats [2]. In both cases, the strengthening will be realised at the boundary layers of the structural elements, in the concrete cover zone (Fig. 3). Therefore, intensive surface preparation works are necessary, in order to ensure the sufficient bond properties between both parts of the cross section. Because of the fact that the boundary layers of any concrete structural element are generally not the best part of them, the usable shear capacity of the bond area is highly limited. Therefore, reinforcing bars embedded in shotcrete often have to be bonded to the cross section by additional dowels. Glued steel sheats can also be applied taking into consideration the limited shear capacity of the prepared surface, in particular at the anchorage zones on both sides of cracks formed after gluing and at the edges. Therefore, the maximum thickness of the sheats, which influences directly the possible strengthening ratio of a structural element, have to be oriented to these facts [2].

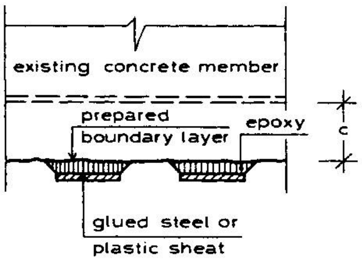

Fig.3 Additional reinforcement at the boundary layer

4. ADDITIONAL REINFORCEMENT IN GROOVES

4.1 Properties and construction

At the early ninties, a new strengthening technique was developed at Essen University in cooperation with a German construction company, using additional reinforcement in grooves, embedded into shotcrete or in case of non-existing shotcreting conditions into high slump concrete with fine coarse aggregate [3, 4].

The grooves are mechanically prepared by high pressure water jets allowing only minimum tolerances of the designed geometry. The additional reinforcement will be arranged in the sound part of concrete cross section (Fig. 4) and the bond characteristics of the existing concrete can fully be used. Moreover, the geometry of the grooves and the spacing of them can than be actually chosen taking into consideration the required bond characteristics for the designed bar diameters and construction aspects. These characteristics show very clearly that the new strengthening technique is highly advantageous in comparision with the known ones. The strengthening quality of rebars in grooves have been confirmed also experimentally. Test series at Essen University have shown, that strength, deformation and cracking behavior of concrete beams strengthened this way is the same as that of beams with identical reinforcement, constructed in one step.

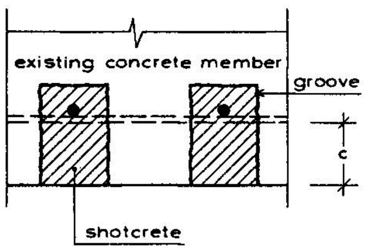

Fig.4 Additional reinforcement in grooves

Practically, the groove geometry is to be defined decisively from the constructional point of view (Fig. 5). For an embedding of good quality, a minimum distance should be chosen between rebar and groove surface of the magnitude of 20 to 30 mm. The tolerances of the groove geometry result from the grading of the coarse aggregate of the existing concrete. Therefore, approximately one half of the mean size of coarse aggregate has to be taken into consideration as a realistic measure of tolerance. Between two grooves, a minimum distance of 60 to 80 mm should exist. Following the geometric requirements, it is clear that the new method cannot be used for the strengthening of 'filigree' structures.

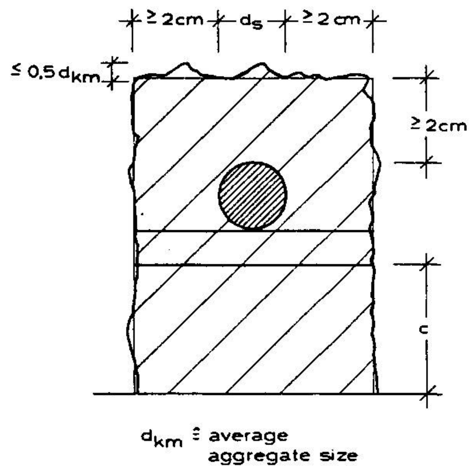

Fig.5 Groove geometry

For the embedding it should be used a concrete-mix with a maximum size of coarse aggregate of 8 to 16 mm. The optimum quality of embedding can only be guaranteed, if the curing conditions are carefully carried out. This means, chemical compounds are not acceptable for this purpose.

4.2 Applications

Until now, three bridge superstructures have been strengthened with the new technique. The first case was a hollow slab pedestrian bridge, strongly cracked in the transition zone between the hollow and solid parts of the superstructure at the bottom side. After the crack injection with fine-cement grout, a completely new longitudinal reinforcement was applied in grooves and embedded into shotcrete (Fig. 6). The second use was the partial strengthening of a deck slab. Because of local defects in the insulation, a great number of the transverse prestressing tendons were heavily corroded and in many cases also failed. The function of these tendons was replaced always by two additional rebars of ∅ 28 mm. A high slump concrete with fine coarse aggregate was used for the embedding of the rebars. The third use was the local strengthening of a prestressed bridge superstructure to remove the resistance of spliced tendons to fatigue fracture in the working zone. The additional longitudinal reinforcement of each joint consisted of two up to eight rebars of ∅ 20 to ∅ 28 mm (Fig. 7).

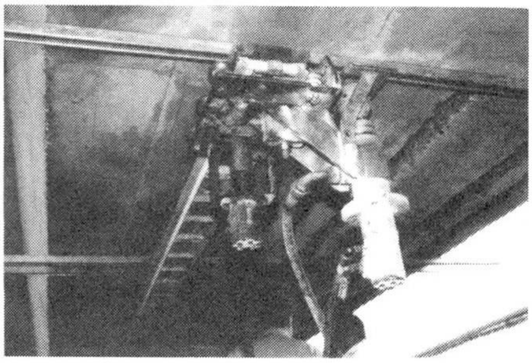

Fig.6 Construction phase of groove preparing

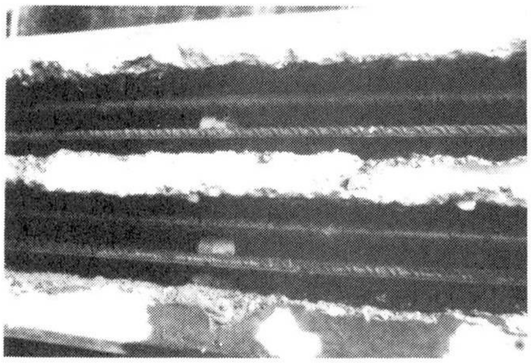

Fig.7 New longitudinal reinforcement

5. CONCLUSIONS

In three applications to date, the advantages of the new strengthening technique could be shown very impressively. The equipment for the cutting procedure of grooves is very efficient and costs for the additional reinforcement per ton are less than by other methods. Numerous further applications are in the design phase.

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