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Autor: Wästlund, G.

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Practice of reinforced and prestressed concrete

Praxis des Eisenbetons und des vorgespannten Betons

Prática do betão armado e preesforçado

Pratique du béton armé et du béton précontraint

General Report – Generalreferat – Relatório Geral – Rapport Général

PROF. DR. G. WÄSTLUND
Stockholm

This subject covers various questions relating to the execution of concrete work, and includes site work, as well as factory work, reinforced concrete as well as prestressed concrete. The papers falling under this head are enumerated below in the order which may be regarded as their logical sequence. Those papers which deal with more or less basic problems are therefore placed at the beginning.

Three authors, Mr. GOSCHY, Mr. CARDOSO, and Mr. BERGFELT, thus study those internal stresses and deformations in concrete structures which are in a high degree influenced by the procedure used in the execution of the structure. Mr. BATE and Mr. PLOWMAN then express in their papers their views on the manufacture of prefabricated concrete members. Mr. ENSKOG describes a method of facilitating and rationalising the design and construction of high reinforced concrete bridge piers by means of sliding forms. Finally, Mr. COURBON presents two prestressed concrete systems and their applications on bridges. — These papers are examined in what follows in the same order as above.

Mr. GOSCHY has made a theoretical study of the redistribution of stresses in a composite system in which one part consists of older concrete (Fertigbetonteil), whereas another part is made of more recently placed concrete (Ortbeton) cast so as to be integrated with the former part. Internal stresses are set up in his case on account of the difference in shrinkage between the older part and the more recent part. Furthermore, when the external load is constant, the internal stresses are redistributed owing to the difference in creep between these two parts of the structures.

Completely analogous condiions are met with in composite systems made up of steel and concrete (e. g. composite beams). Moreover, a closely similar redistribution of stresses takes place in prestressed concrete structures as a consequence of creep and shrinkage of concrete. The problem dealt with by Mr. GOSCHY can be applied to concrete structures of two types, viz. first, those structures which consist of several parts cast in different stages, e. g. the top and bottom of hollow box sections of bridge arches, cf. Mr. CARDOSO'S paper below, and second, those structures which are made up of prefabricated units integrated into monolithic systems.

The redistribution of stresses is chiefly of importance under the normal load conditions, whereas the ultimate loads are less or not at all influenced. Mr. GOSCHY also deals with this problem, where he calculates the ultimate loads on the assumption that the material is perfectly plastic, cf. Fig. 4, so that he can apply the law of addition. Factors of safety in this connection are discussed.

The problems studied by Mr. GOSCHY have previously been treated in the literature. A good review of the European publications dealing with this subject is to be found, together with the autor's own contributions, in a paper by H. RÜHLE (1). He refers, for instance, to earlier papers by FREYSSINET (1936), DISCHINGER (1937), CRAEMER, SATTLER, and RÜSCH, cited in chronological order.

American researchers have taken a different line, and two authors represented in «Preliminary Publications» have referred to these works. BÄCKSTRÖM thus refers to a work by MCHENRY (1943), while BERGFELT refers to works by ROY CARLSON (1937) and PICKETT (1946).

It is of interest to compare the European and American works. DISCHINGER and others take as a starting-point the creep function

$$\varphi_t = \varphi_\infty \, (1 - e^{-t})$$

which implies that the elongation or the contraction after the time t is

$$\left(\frac{\Delta l}{l}\right)_t = \frac{\sigma}{E} \, (1 + \varphi_t)$$

where E is the modulus of elasticity, which can also be a function of the time, and φ_∞ is the asymptotic value of the creep (order of magnitude 2 to 3).

Furthermore, in the European publications, the shrinkage function ε_t is usually supposed to be affine to the creep function, that is to say,

$$\varepsilon_t = \frac{\varepsilon_\infty}{\varphi_\infty} \cdot \varphi_t$$

MCHENRY'S creep function is much more intricate, see BÄCKSTRÖM'S paper, while BERGFELT gives a creep function which is somewhat between DISCHINGER'S and MCHENRY'S functions. MCHENRY'S creep func-

(1) RÜHLE, H.: «Die Ermittlung der zeitabhängigen Eigenspannungen in Verbundkonstruktionen aus Stahlbetonfertigteilen mit Ortbeton». Bauplanung und Bautechnik, No. 10, 1954.

tion comprises a time function which is dependent on several variables, e. g. the dimensions of the concrete body and the composition of the concrete at the time of load application. Moreover, there is one term, the first, which is independent of the age of the concrete. It is highly desirable that these relations, which have been but little studied up to now, should be elucidated as far as possible in further researches.

The variation in the shrinkage function with the time must also be conditioned by the dimensions of the concrete body, but this circumstance has not been taken into account in the above-mentioned shrinkage function.

It is possible that the final states ($t = \infty$) after redistribution of internal stresses are not influenced to any large extent by certain factors, e. g. the dimensions of the concrete body, and that the simpler expressions can therefore be used to calculate the final states, whereas it seems that these expressions can scarcely be employed to compute the variations with the time themselves.

Mr. CARDOSO deals with the secondary stresses which are caused in reinforced concrete bridge arches by the execution of concrete work in several stages, by deformations of formwork, and by shrinkage of of concrete. Furthermore, the author describes various methods of counteracting the occurrence of such secondary stresses. In addition, several concrete practical cases are discussed from this point of view. (Unfortunately, since I am not familiar with the language used in this paper, I am not in a position to make any detailed comments on its contents).

Mr. BERGFELT begins his paper with an enumeration of the various factors which cause losses of stress in the steel cables used in prestressed concrete. The author examines the theory of friction losses along a curved cable. After that, he presents the results of measurements which were made on two prestressed concrete bridges designed according to Freyssinet. In this connection, the losses are resolved into the following components:

Losses in the jacks and at the thread angle for attachment to the jacks. (NOTE. The losses are here denoted by C, but the real loss in stress is $1 - C$).

Friction losses due to the intentional curved line of the cable.

Losses due to the unintentional wave form of the cable and to adhesion along the cable.

Losses after anchoring; influences of creep, shrinkage, and tempeture.

The results are reproduced in the author's summary.

It is of special interest to note that the author has attempted to calculate the plastic deformations of one of the bridges under investigation and to compute the deformations due to shrinkage, cf. Fig. 7. For this purpose he used the creep and shrinkage functions given in the formulae (10a, 11a) and (12, 13). The author states that these formulae have formerly been used in a successful manner for the calculation of long-time deformations of the Sandö Bridge, Sweden, but are now at variance with the values observed so far. The measurements are continued.

Mr. BATE has studied the variation in cracking moments and failing moments of small prefabricated prestressed concrete beams, and has investigated the causes of this variation. He found that the variation in question is to be attributed to many causes, viz. first, the same causes that give rise to variations in cube strength, second, the heterogeneous vibration of long beams (thorough in the neighbourhood of the vibrators, but inadequate midway between them), third, the variations in the dimensions of the beams, and finally, some factors of minor importance. Accurate supervision of concrete quality has proved to be essential but it is at least as important to keep the dimensions exact. Accordingly, the author recommends the use of steel moulds, and considers that consolidation of the concrete on the vibration table in the individual mould system is superior to the use of fixed shutter-vibrators on the «long-line» system.

Mr. PLOWMAN deals with the question of how prefabricated concrete structural components for post-tensioned bridge members should be cast so as to ensure high concrete quality. In particular, he examines two properties which high-quality concrete must possess, viz., high strength and homogeneousness, cf. BATE'S paper. According to the author, concrete is usually consolidated by vibration. The author lays special stress on the fact that the vibration must be so intense as to produce in every point of the concrete mass a sufficiently high acceleration, usually at least 2,5g to 3g, depending on the frequency of the vibration and the workability of the mix. Furthermore, the author points out that the vibrations are propagated through the surface layers of the concrete mass without being damped to any appreciable degree, while the damping increases towards the interior. Therefore, we should not be led to believe that the whole concrete mass has been thoroughly vibrated solely for the reason that the concrete surface appears to be compacted. The author then touches on the effect of overvibration, and states that the troubles of overvibration and segregation only result from a badly designed mix. This might be true within some limits. BERGSTRÖM (2) considers that a concrete mix is stable under vibration only for a certain definite time. Fig. 5 in the paper by BERGSTRÖM also shows that the effect of comparatively small variations in the grading is remarkable.

Mr. ENSKOG describes the construction of a large railway bridge in North Sweden. The piers of this bridge were the first in Sweden to be built by means of a special method using sliding forms (the «Concretor System»). The lengths of the piers ranged from about 10 to 23 m, and their cross sections were either circular or more intricate, see Fig. 2. A distinguishing characteristic of this sliding form system is the fact that the forms are raised by several hydraulic jacks, and that all jacks can be controlled from a central point. Each jack can also be operated individually, if required. The amount of manual labour needed for raising the forms is reduced to a minimum. It was found that this concreting method saved materials used for temporary auxiliarys, and that the quality, the accuracy of dimensions, and the appearance of the

(2) BERGSTRÖM, SVEN G.: «An Experimental Study of the Relation between the Properties of Fresh and Hardened Concrete». I. A. B. S. E., Vol. XIII.

finished structure were good. This method was therefore soon employed again in the construction of other bridges.

Finally, Mr. COURBON describes two types of prestressed concrete and mentions some bridges in which these types were used. One of these types was invented by CHALOS, and its characteristic feature is the use of very thick, spiral-wound cables, which are provided with massive, but articulated steel cores before they are delivered to the site. The cables are stretched on these cores and fixed at the ends. The cables are embedded in concrete while they are in this stretched state. When the concrete has hardened, the core is detached and removed, with the result that the concrete is subjected to compression. This method has some advantages, namely, the tension in the cable is uniform throughout its length, and all losses involved in the application of the initial tension are eliminated.

Each of the reinforcing cables used in the other type of prestressed concrete consists of a number of separate, small, spiralloid wire ropes. In this case, the initial tension is applied to the cables in an ordinary way and the cables anchored by driving wedges between the cable and and the concrete after hardening. The cables can therefore be stretched successively, as the erection of the structure advances. The coefficient of friction is stated to be extremely low, 0.08.

SUMMARY

This subject covers various questions relating to the execution of concrete work, and includes site work as well as factory work, reinforced concrete as well as prestressed concrete. Long-time deformations of concrete, and in some measure those of steel, play an important part in this connection, and are dealt with in several papers. Secondary stresses or losses in stress due to other causes are also discussed. Various views on the manufacture of prefabricated concrete components are expressed with special reference to their quality characteristics. The use of a new sliding form method for the construction of a bridge is described in one of the papers. Finally, two types of prestressed concrete are presented together with their applications.

ZUSAMMENFASSUNG

Dieses Thema umfasst verschiedene Fragen, die sich auf die Ausführung der Betonarbeiten beziehen, wobei es sich um Blauplätze oder Fabriken, um Stahlbeton oder vorgespannten Beton handeln kann. In diesem Zusammenhang spielen die Dauerverformungen des Betons und in gewissem Masse auch diejenigen des Stahls eine wichtige Rolle. Dementsprechend werden sie in mehreren Berichten behandelt. Ausserdem werden sekundäre Spannungen oder durch andere Ursachen bedingte Spannungsverluste erörtert. Die Herstellung von Fertigteilen bildet den Gegenstand einiger Betrachtungen, wobei die Güteeigenschaften dieser Teile besonders berücksichtigt werden. In einem Bericht wird die Verwendung eines neuen Gleitschalungsverfahrens beim Bau einer Brücke dargestellt. Schliesslich werden zwei Arten von vorgespanntem Beton und ihre Anwendungen beschrieben.

RESUMO

Trata este tema de vários problemas relativos à execução de estruturas de betão armado e betão preesforçado, quer no local da obra quer em oficina. As deformações de grande duração do betão e, até certo ponto, as do aço têm um papel importante nestes problemas o que é posto em evidência em várias contribuições. Discutem-se igualmente os esforços secundários ou perdas de tracção devidos a outras causas. Alguns autores apresentam considerações acerca da produção de elementos de betão prefabricados, principalmente no que respeita às características que determinam a sua qualidade. Uma das contribuições descreve um novo processo de construção utilizando cofragens deslizantes, empregado na execução de uma ponte. Indicam-se, igualmente, dois tipos de betão preesforçado e suas aplicações.

RÉSUMÉ

Ce thème s'occupe de diverses questions relatives à l'exécution des travaux en béton. Il comprend les travaux sur chantiers de construction ainsi que les travaux effectués en atelier. Il se rapporte au béton armé aussi bien qu'au béton précontraint. Les déformations de longue durée du béton ainsi que, dans une certaine mesure, celles de l'acier jouent un rôle important dans cet ordre d'idées, ce qui ressort de plusieurs rapports. On discute également les efforts secondaires ou les pertes de tension dues à d'autres causes. Quelques auteurs présentent des considérations sur la production des éléments préfabriqués en béton, surtout en ce qui concerne les caractéristiques déterminant leur qualité. Un des rapports contient une description d'un procédé nouveau utilisant des coffrages glissants, procédé dont on a fait usage dans la construction d'un pont. Enfin, on signale deux types de béton précontraint et leurs applications.