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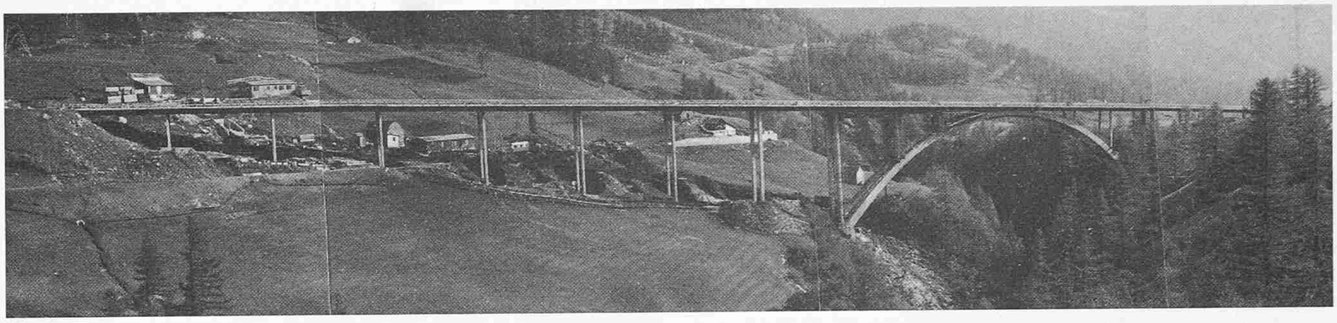

Bild 12. Krummbachbrücke

Ursprünglich war dazu ein konventionelles Bogenlehrgerüst vorgesehen, das aber im Vergleich zu den Gesamtkosten recht teuer gewesen wäre. Man hat daher *erstmals in der Schweiz den Bogen im Freivorbau mit Schrägabspannungen* erstellt (siehe Umschlagbild und Bild 11). Obwohl der Bogen an sich primär ein Druckelement ist, hat man ihn leicht vorgespannt. Dies brachte einerseits den Vorteil, die Arbeitsfugen während des Vorbaus zu überbrücken und die Kontinuität der Längsbewehrung durch Kuppeln der Spannglieder sicherzustellen, was sich im Blick auf die Rissesicherheit und die Verformungen als sehr zweckmässig erwiesen hat. Vor allem war es dadurch auch möglich, längere Vorbauetappen zu wählen und auf der einen Seite auf einen Abspannpylon zu verzichten.

Die hier verwirklichte Baumethode hat sich in jeder Beziehung bestens bewährt und das inzwischen fertiggestellte Bauwerk darf sicher auch als ästhetisch sehr gelungen bezeichnet werden (Bild 12).

Outstanding bridges in prestressed concrete

During the construction of the *Swiss national highway network*, a good number of bridges have been designed or built during the last two years, and as is the case in other countries, *prestressed concrete* has taken there a *preponderant* position.

These structures are mostly prestressed by means of concentrated cables with allowable prestress forces of 250 to 450 tons, and even up to 750 tons in the extreme cases. *Prestressing systems with high capacities* have been developed *quite early in Switzerland.* Though the progress in the prestressing technic does not necessarily lie in the quest for bigger and bigger tendons, it is worth stating that this development specific to Switzerland has undoubtedly helped the evolution of the construction of great bridges. This influence has also spread widely to foreign countries (in particular in the construction of *nuclear reactors* where cables still bigger are necessary).

Given that the transportation and installation of such cables becomes somewhat difficult on account of their weight, successful methods of *placing later on by pushing or by pulling* through of entire cables, individual wires or strands have been developed. This technic has been successfully utilized for the majority of bridges built by the cantilever style method.

Partial prestressing

As a *further particularity of Switzerland,* one should mention above all *partial prestressing*, introduced by the Swiss Standard SIA of 1968 already and whose application is still broadened by the recent introduction of the directive 34 of this Standard in 1976. In what follows, we will briefly present this subject.

At present, *Switzerland could probably be the only country where, at least in principle, all degrees of prestress between the ordinary reinforced concrete (no prestress) and the full prestress are allowed.*

With regard to the *principal direction of spanning of long-span bridges*, partial prestressing does not practically give any advantage. The criteria of concentration and continuity of tensile forces, as well as the limitation imposed on deformations, force in this case the choice of a high degree of prestress.

The situation is however different in the *transverse* direction. As in this case a high degree of prestress is often uneconomical and also constructionally inadequate, the idea of prestressing in the lateral direction was generally given up. On the other hand, partial prestressing allows to select cross-sections with large lateral overhangs, which produces functional, economical and aesthetical advantages. For this reason, in Switzerland, several bridges, even those very wide, are often built with a single cell box girder (see examples in Fig. 1).

The *advantage* of this option for the cross-section lies in the fact that it is possible to realize in a first stage only the cell or even its trough. This reduces in a decisive manner the erection loads of the scaffolding or the launching girder. Subsequent concreting of the lateral overhangs is possible without great difficulty, with the help of a relatively light movable scaffolding.

For *slab bridges or framed bridges*, generally encountered as overbridges or underpasses, partial prestressing turns out often to be an appropriate and economical solution. The degree of prestress adopted could be relatively low in this case.

After these general remarks, we will describe some noteworthy bridges recently built in prestressed concrete.

Ganterbrücke

(National highway N9, Simplon)

Consulting engineers: Prof. Dr. Chr. Menn, Zürich.
Schneller, Schmidhalter & Ritz, Brigue.
Blötzer + Pfamatter, Brigue.
H. Rigendinger, Coir.

Total length: 678 m.

Main spans: 127 m, 174 m, 127 m.

This bridge in prestessed concrete with the *longest span* in Switzerland (central span of 174 m) is actually under construction on the layout of the national highway to Simplon, in the deep valley of Ganter above Brigue. The authors of the project have adopted a new, original construction (Fig. 2) consisting of a *combination of the traditional method of cantilevering out and of cable staying* in which the cables are not left free, but are subsequently concreted in a thin wall.

As the bridge has a relatively narrow deck width of 9.6 m, it was possible to select a box section with single cell without lateral cantilevers, which facilitates the layout of the anchorages of the stays (Fig. 3). As the piers on the left bank are situated in a *slow slip zone* (Fig. 4), they have to be *constructed in wells*, so that the creep movements of the bank could be ultimately compensated by a displacement of the foot of the pier. For this reason, the piers are supported, without fixity, on big Neotopf supports. During construction by cantilevering out, it is however necessary to fix the piers with the help of short cables, as well as packing pieces of concrete blocks incorporated in the pier bearings. According to the construction schedule, this interesting and daring structure should be finished in 1980.

Lehnenviadukt Beckenried

(National highway N2, Höfe—Tunnel of Seelisberg

Consulting engineers: D.J. Bänziger, Zurich.
K. Aeberli, Buochs.
Werffeli & Winkler, Effretikon.
Total length: 3150 m.
Spans: 55 spans of 55 m plus 2 end spans.

Construction of this structure, which with its overall length of 3150 m, represents the *longest bridge* in Switzerland, has given rise to some *difficult foundation problems*. This bridge situated on a hill slope extends in effect *for a long distance in a slip zone* having a creep movement of a few centimeters per year, according to the measurements taken. The situation is further complicated due to the fact that the slip layers are quite thick in some places. For this reason, the spread foundations founded on the rock, have to be arranged in *flexible wells whose maximum depth attain 76 m.*

It looks that these conditions dictated the choice of a single central pile, as the construction of twin wells under each intermediate support would have been much too costly.

The unusual design that won the bidding nevertheless provides for two separate box girder bridges, the two piers being however connected together at the ground level by a transverse beam, and then founded in a single central well (Fig. 5). The well and the central pier are separated in the transverse plane by a gap of about 1.5 m to insure sufficient room for the creep movements to take place freely, till such a time that these latter movements are reduced by the drainage measures taken in the hill slope.

Viaduc du Lac de la Gruyère

(National highway N12, Vevey–Berne)

Consulting engineers: E.&A. Schmidt, Basle.
B. Bernardi, Zurich.
I.C.A. SA, Fribourg.
Overall length: 2043.75 m.
32 spans of 60.5 m plus 2 end spans.

This bridge, remarkable from aesthetic and constructional point of view, extends over more than 2 km crossing the two deep creeks in the Gruyère Lake. With the exception of the two end spans, the intermediate spans are of constant length of 60.48 m.

The cross-section selected consists of a relatively narrow box girder 6 m wide, with two large ribbed cantilever overhangs 8.85 m wide, concreted with the help of a travelling scaffolding (Fig. 10). These cantilevers bestow to the structure a special elegance and also contribute to make the structure economical thanks to the partial prestressing.

The construction procedure, by stages of one span at a time, appears remarkable. For this purpose, the consulting engineers have developed a *highly mechanized launching beam* having a total weight of 666 tons (Fig. 6). The design and construction of such a launching beam satisfying the strict requirements, represents without doubt a big undertaking demanding great qualities of engineering. Certain innovations have been successfully applied in the realization of this structure. For example, the ever difficult problem of transferring the shuttering of the bottom slab across the piers during the advancement of the launching beam, has been by-passed in an elegant manner by realizing this slab with the *prefabricated elements*. This way, no scaffolding is necessary, which avoids the usual dismantling or pulling down.

Some of the piers have to be constructed on piles going down to a depth of 20 m below the water table, which resulted in considerable difficulties.

Saaneviadukt Gümmenen

(National highway N1, Lausanne–Berne)

Consulting engineers: Ingenieurgemeinschaft Walder AG, Bern.
Prof. Dr. H. von Gunten, Zurich.
Overall length: 849 m.
11 spans of 60 m plus 4 end spans.

The structure also is of a *single cell box girder section with large cantilever overhangs*, but *without ribs*, however (Fig. 1A). In order to make use of an existing launching girder, which however was not foreseen for spans of this magnitude, nor to such sections, the bridge was built in stages: first of all, only the trough of the span under consideration is concreted. It is then prestressed in such a manner that the weight of the top slab of the box girder placed subsequently does not induce any additional stresses in the launching beam. The lateral cantilever slabs are concreted later with the help of a travelling scaffolding relatively light (Fig. 7). Use of partial prestressing for transverse stresses also turned out to be interesting and economical for this structure.

As this example shows, bridges with a single box section have a harmonious and pleasing appearance, due to the marked contrast between the lighted and shaded zones and due to the relatively slender piers. Such structures integrate perfectly in the landscape. Finally, they revealed to be quite competitive from the economic point of view.

Pont sur le Talent

(National highway N1, Lausanne–Berne)

Consulting engineers: Carroz & Küng, Lausanne.
Gianada & Guglielmetti, Martigny.
B. Bernardi, Zurich.
Overall length: 374.17 m.
6 spans of 49.3 m plus 2 end spans.
384.20 m.
5 spans of of 46.9 m plus 4 end spans.

The tendency to *reduce to the maximum extent the launching weight of the main girders* to be able to use a light scaffolding is *achieved in a rational way* in this bridge actually under construction. The cross-section selected (Fig. 1F) with a relatively narrow box girder and very massive lateral cantilever overhangs could appear somewhat disproportionate at first sight. In effect, in the transverse direction the deck slab is essentially stressed by the large negative bending moments, which requires a high degree of transverse prestress. This is however compensated from the economical point of view by the fact that, in spite of a grand span of 49 m, an unusually light and comparatively cheap steel truss falsework could be utilized (Fig. 8).

Pont de Cucloz

(National highway N12, St-Légier)

Consulting engineer: Piguet S.A., Lausanne.
Overall length: 479.7 m.
11 spans of 36.2 m plus 5 end spans.

This structure also was built by concreting initially only a single cell as the main load bearing structure on a conventional falsework centering. However, to avoid the large transverse bending moments and icing that appear with big cantilever overhangs, the section is subsequently completed with two lateral triangular cells (Fig. 1E). Such crosssections are less interesting with regard to the concrete volume, as they have a lower slab that extends over the entire width of the bridge serving only as an inclined prop for the deckslab in the lateral cells. On the other hand, the economy achieved in the transverse prestressing steel and ordinary reinforcement steel is considerable.

Viaduc d'Ependes

(National highway N1, Lausanne–Berne)

Consulting engineers: Bureau d'ingénieurs Perret-Gentil & Rey,
Yverdon and Lausanne.
Collaborator: J. Bize.
Overall length: 605 m (2 bridges).
17 spans of 31.00 m plus 3 special spans
(CFF, Swiss Federal Railways).

With a concrete volume of only 0.32 m^3 per square meter of bridge surface, this structure actually under construction is without doubt at the *limit of what could still be achieved, even with the method of prefabrication* adopted here. To achieve this result, some new concepts have been worked out. On the one hand, only two prefabricated, prestressed main girders per direction of circulation have been provided. This results in a relatively long transverse span for the deck slab, which in addition had to be provided with cantilever overhangs. On the other hand, prefabricated slab elements that are only 5 cm thick, stiffened by transverse prestressed ribs spaced at 1.4 m centers have been developed (Fig. 10). As shown in this figure, these slab elements are interrupted on the main girders, while the transverse ribs are continuous, so that once the cast-in-situ concrete of 15 to 30 cm thick is in place, a good connection is achieved between the main girders and the slab. Longitudinal, straight prestressing cables in the deck slab provided on intermediate piers along with cast-in-situ concrete diaphragms at this place provide continuity.

Krummbachbrücke

(National highway N9, Simplon)

Consulting engineers: De Kalbermatten, Burri, Missbauer, Sion.
Main span: 124 m (arch bridge).

Novel methods of construction and development of prestressed concrete have made it possible to bridge bigger and bigger spans with continuous beams. From economical considerations, these latter have gradually superseded the arch bridges, much to the regret of several people in view of their pleasing appearance and their good integration in hilly landscapes. As the present example shows, it is still possible, or better, it is once again possible to build economical arch bridges.

Initially, a conventional scaffolding has been foreseen, which however turned out to be very expensive compared to the total cost of the structure. For this reason, for the *first time in Switzerland, the arch was built by cantilevering with the aid of tie-back cables* (see the cover page and Fig. 11). Though the arch by itself is an element under compression, it has been lightly prestressed. On the one hand, this has the advantage that the construction joints could be kept under compression during the construction and also insure the continuity of longitudinal reinforcement by coupling the prestressing cables. This turned out to be an appropriate step for the security against cracks and deformations. On the other hand, it became possible this way to select bigger stages of construction and to omit one of the guy towers.

The method of construction adopted here revealed to be advantageous from all points of view and the structure recently finished could be qualified as a fine aesthetical success (Fig. 12).

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Spannbeton im Hochbau

Von **Hugo Bachmann**, Zürich

Im folgenden Aufsatz werden Anwendungen der Vorspannung bei Hochbauten in der Schweiz während der letzten paar Jahre beschrieben. Obschon – mitbedingt durch die Rezession – kaum auffällige Neuentwicklungen im Gange sind, so kann doch auf einige bemerkenswerte Objekte hingewiesen werden.

Allgemein ist festzustellen, dass im Hochbau fast ausschliesslich die *teilweise Vorspannung* angewendet wird. Die volle Vorspannung kommt nur noch in Ausnahmefällen vor. Bei der teilweisen Vorspannung von Biegequerschnitten werden die Spannglieder meist so bemessen, dass für den Lastfall «ständige Last» am ungerissenen Querschnitt rechnerische Zugspannungen von im Maximum 10 bis 20 kg/cm² auftreten. Für den Lastfall «Vollast», d.h. «ständige Last und bewegliche Nutzlast» muss dann zusätzlich zur vorgespannten Armierung eine konventionelle schlaffe Armierung eingelegt werden. Der Spannungsnachweis für diesen Lastfall – der im Grunde genommen ein Rissnachweis ist – wird am gerissenen Querschnitt nach den Prinzipien des Stahlbetons (Biegung mit Normalkraft = Vorspannkraft) durchgeführt. Zudem ist – gleich wie bei voller Vorspannung – eine genügende Biegebruchsicherheit nachzuweisen.

Vorgespannte Flachdecken mit und ohne Verbund

Einen festen Platz hat sich die Vorspannung bei den Flachdecken erworben. Vorgespannte Flachdecken sind besonders wirtschaftlich bei Spannweiten von etwa 6 bis 12 m. Auch bei kleinen Deckenstärken treten unter ständiger Last nur geringe Verformungen auf. Daher sind auch kurze Ausschalfristen möglich.

Es können *drei verschiedene Arten der Spanngliedanordnung* unterschieden werden (Bild 1):

a) In beiden Richtungen auf Feld- und Gurtstreifen verteilte Spannglieder,

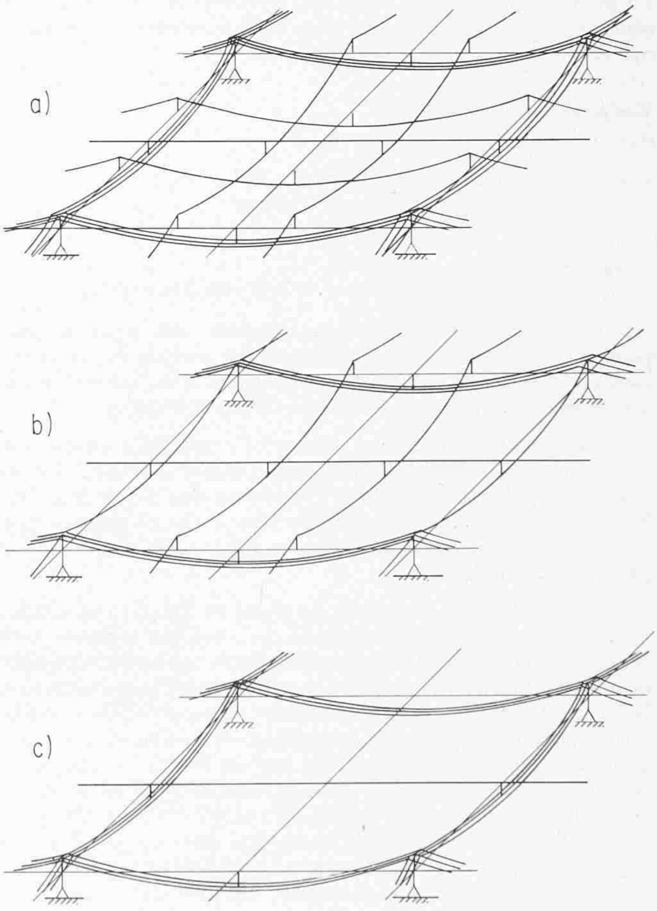

Bild 1. Verschiedene Möglichkeiten für die Anordnung der Spannglieder in Flachdecken
Different possibilities for the arrangement of prestressing steel in flat slabs