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Slide-forms in concrete bridge column construction

Gleitschalungen für Betonsäulen bei Brückenbauten

Cofragens deslisantes para a construção de pilares de pontes

Coffrages glissants pour la construction de piliers de ponts

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For high bridge columns of concrete the costs for forms and scaffolding for shuttering and casting in situ are rather high compared with the costs for the reinforcing steel and the concrete which are the main components of the construction. The support-columns on concrete arches with large spans have to be made as slender as possible which makes the use of concrete of a high quality necessary. A great deal is expected also in regard to the look of the columns. Previously used, conventional timber or steel shuttering for columns hamper the handling of the concrete in the narrow form and for the erection of the shuttering a comparatively large number of skilled hands is needed.

Through the simplified method for slide-form concreting — the Concretor System — developed in Sweden during the last decade, large savings in material and labour costs can be made, and at the same time the concrete will be easily accessible for handling, whereby the possibilities of making high quality concrete probably are better than by any other method. A profitable use of this new method, however, is subject to a suitable design of the construction and a comparatively large height of the columns.

The first bridge building in Sweden at which slide-forms were used would be the railway bridge over the river Vindelälven up north, constructed in the years 1950 to 1952 by Nya Asfalt AB for the Royal Board of Swedish State Railways. This bridge comprises an arch span, 112 metres of length (fig. 1) and approach viaducts, supported by pairs of columns with circular cross section, spaced 14.35 metres (fig. 6). The height of the columns varies from 9.7 to 22.8 metres. The total length of the bridge is 242 metres

When in late autumn 1952 the work was started, heavy increases in prices, caused by the war in Korea, prevailed. It was, therefore, to the advantage of the client as well as of the contractor to keep the quantity of material to be used for temporary constructions as low as possible. The contractor, together with AB Byggförbättringar of Stockholm who originated the Concretor Method, made out a working programme for the use of slide-forms. The programme was approved by the client and all the bridge columns, except the shortest ones at both sides of the crown of the arch span, were constructed by the Concretor Method. The forms were of sheet steel and of a height of 1.2 metres (fig. 3). The jacking equipment consists of a number of hydraulic jacks, here four, on which the form equipment is suspended. These jacks are connected through oil pipes with a small electric powered oil pump. When the pump is started oil is pressed to the jacks which all raise simultaneously. When needed the jacks may be operated individually, thus allowing for adjustment in case of deviation from the vertical line.

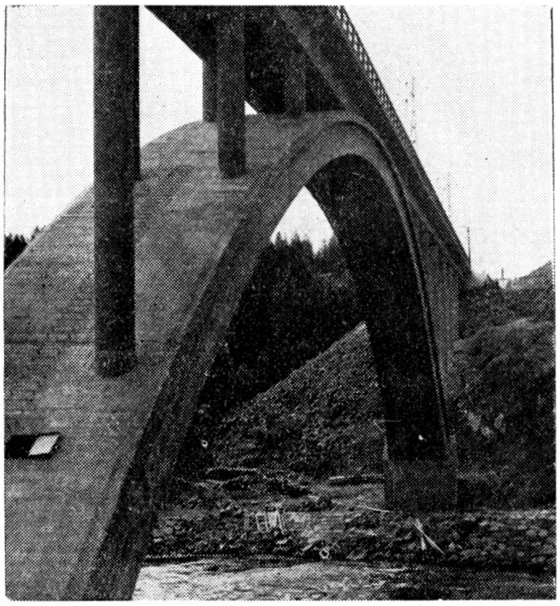

FIG. 1. Railway bridge over the river Vindelälven in North Sweden

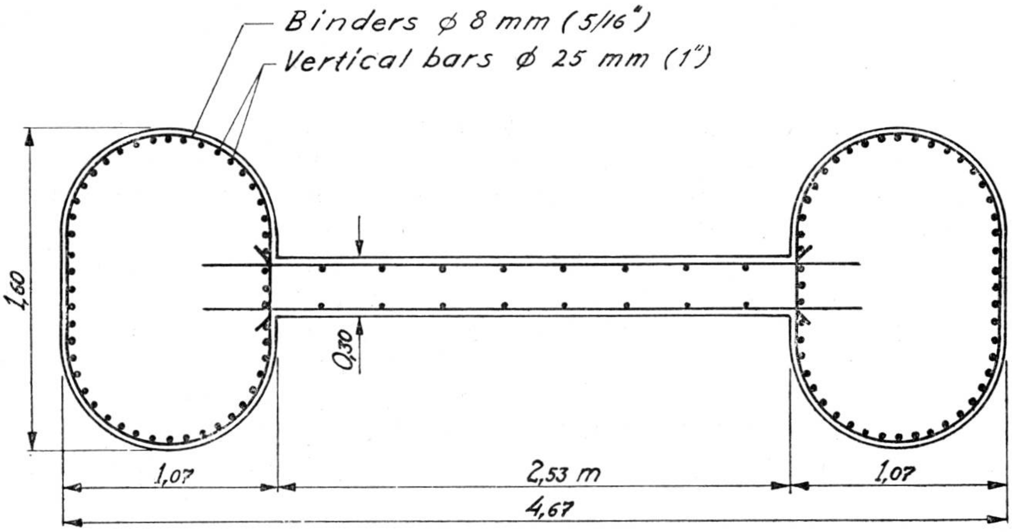

FIG. 2. Cross section of an abutment column

Each jack «climbs» on a smooth steel rod 25 millimetres of diameter and each raise is 25 millimetres.

The lifting speed depends amongst others on the growing strength of the concrete, and was in this case 3 to 4 metres per 24 hours. The quality of the concrete used for columns and all other parts of the concrete construction, with the exception of foundations and abutments was K 400 (min. ultimate strength 400 kg/cm² or 5700 lb/in² after 28 days). The reinforcing steel consists of deformed bars of the quality Ks 40 with a yield ratio of 40 kg/mm² (57000 lb/in²).

The columns on the arch abutments (fig. 2) are heavier than the rest of the columns. On account of the new method the sharp angles between the columns proper and the connecting wall have to be rounded, which merely adds to the structural strength. Furthermore, the binders, being placed in the course of the pouring, need have two splices, making each unit consist of two U-shaped parts instead of one oval.

For constructive reasons the vertical reinforcement of the columns has to be made using as long bars and as few splices as possible. The maximum length of the bars is 10 metres. It was therefore, necessary to build, at the side of a column to be constructed, an auxiliary scaffold fitted with extending fixtures for keeping the reinforcing bars in position. The steel scaffolding used will be seen from fig. 4 and 5. If it is possible to limit the length of the reinforcing bars to 5 to 6 metres they may be kept in position by fitting similar fixtures to vertical masts, attached to the slideform. The reinforcing bar positioning fixtures will then follow the upward movement of the slide form, and no scaffolding will be needed at the side of the column.

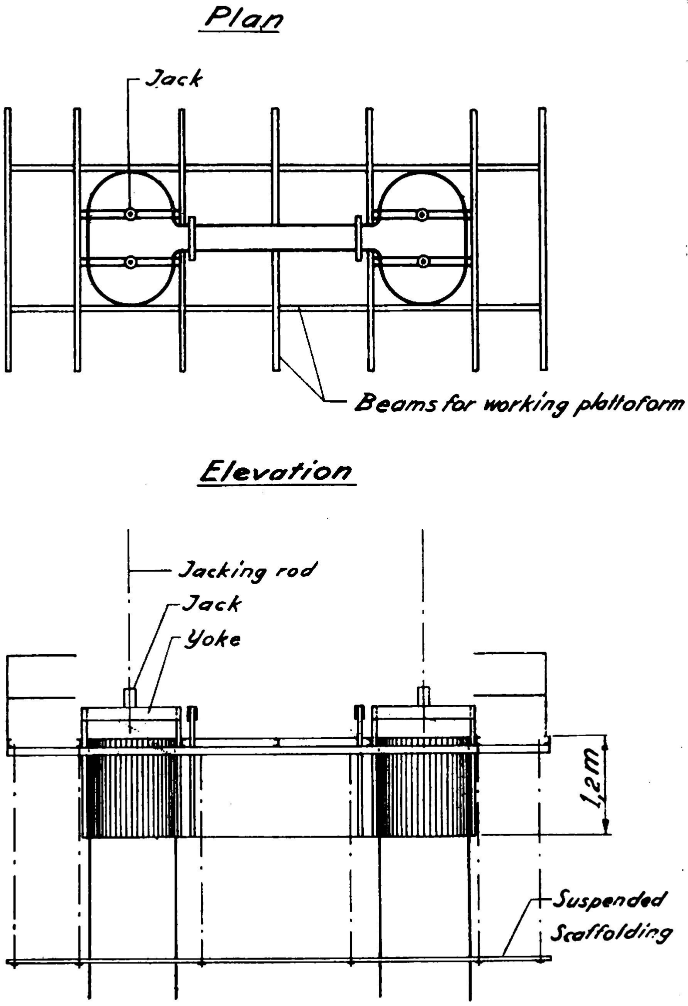

FIG. 3. Slide-form for abutment column

When the first column was cast the night temperature was rather low and calcium chloride was added to the concrete so that the lifting speed would not have to be reduced too much. When the slideform had been raised somewhat above the position shown on fig. 6 a suspended scaffolding was attached as indicated on fig. 3 to make possible inspection of the slide-form itself and of the consistency of the concrete underneath the slide-form. The suspended scaffolding is used also for finishing the concrete surface. Great demands are made on the appearance of the

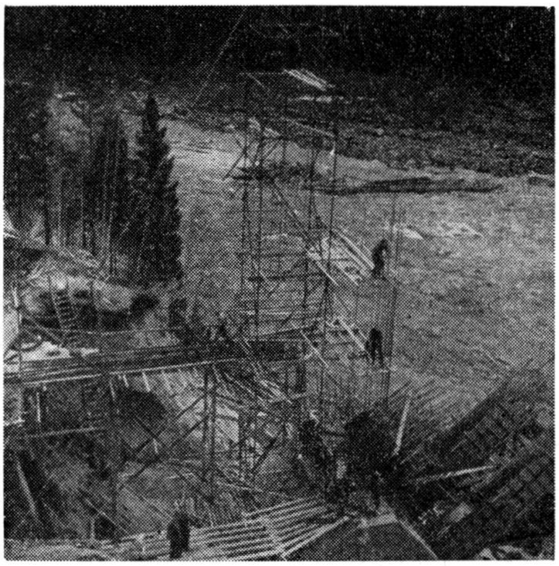

FIG. 4. Auxiliary steel tubular scaffolding at an abutment column. The assembly of the sliding form is in progress

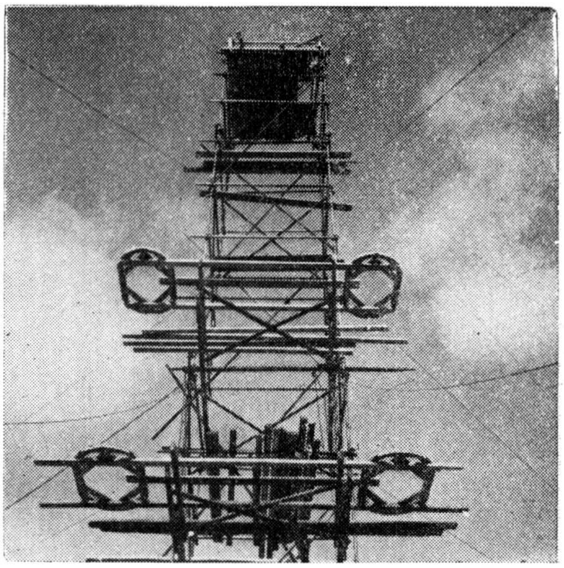

FIG. 5. Auxiliary scaffolding with fixtures for the reinforcement, seen from below

concrete surfaces of bridges and therefore the aftercasting treatment is of main importance. During the period following the casting all slide-formed surfaces are getting flamy or striped depending upon the age and the humidity of the concrete. If the after-casting treatment is properly done by skilled workmen these flaws normally will disappear when the concrete has dried up. A slight rubbing of the surface with a broom should be sufficient, whereas the rubbing with felt is not recommended. The after-casting treatment of course includes water spraying and protection of fresh concrete surfaces, amongst others, against insolation.

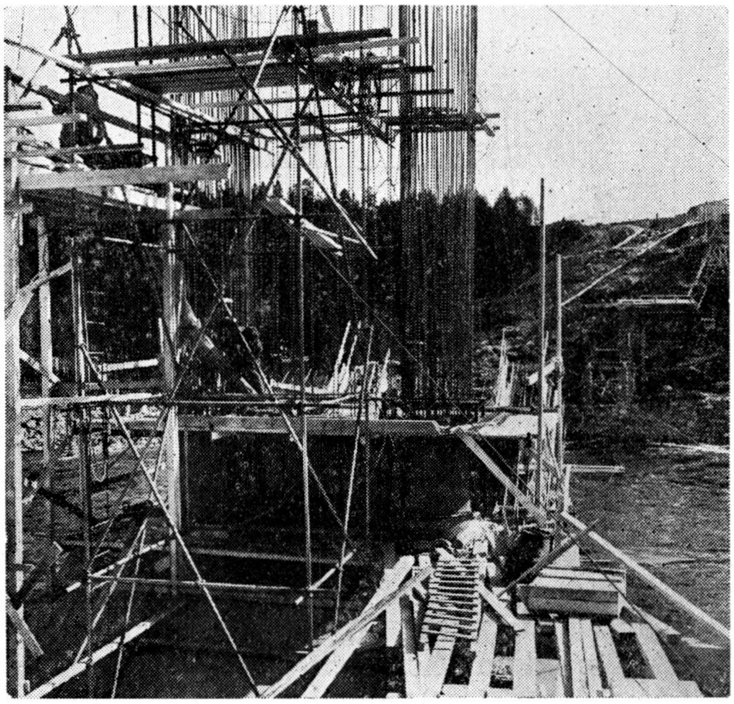

FIG. 6. Concreting of an abutment column by means of a sliding form. The raising of the form has recently begun. Photo. Eric Rosenberg

The rest of the columns are circular and placed in pairs. The viaduct columns are 1.0 metre and the columns on the arch are 0.9 metres of diameter. Slide-forms and working platform used for these columns were similar to the equipment used for the abutment columns. Consequently the slide-forms for a pair of columns were connected through the working platform. In these columns too the binders were made in halves.

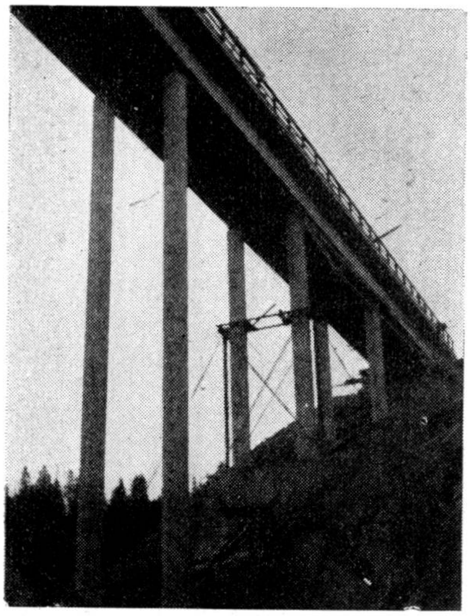

FIG. 7. Guying of a column

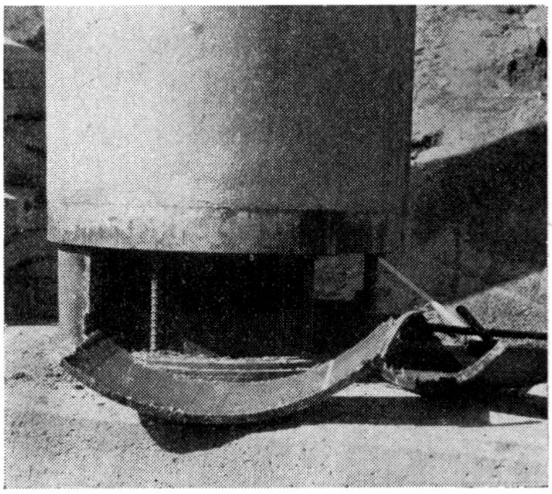

FIG. 8. Provisional arrangement used for a row of columns

During the construction work the columns are fixed only in the foundation, and the longer columns therefore are exposed to buckling until they are fixed in the bridge deck. Until the concrete is strong enough the columns are even susceptible to wind stress. Several columns, therefore, had to be guyed during the casting and the guying had to remain until the bridge deck was concreted. Before the critical height of the columns was reached a guy bridge as shown on fig. 7, was mounted right below the suspended scaffolding. The guy bridge consists of rings around the columns connected by a steel frame. The guy bridge was supported by guys resting on the foundation and braced by steel rods with tightening nuts at the end brackets.

To make possible adjustments made necessary by eventual future sinking, columns not having foundations on rock were supported on the foundation by bearings of steel.

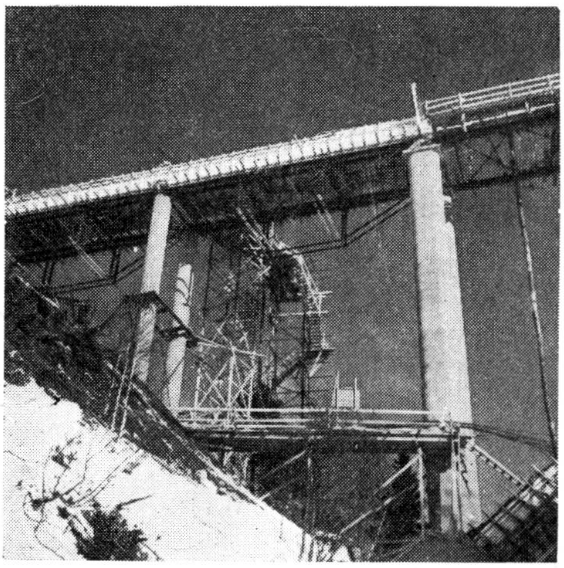

FIG. 9. Steel trusses between columns, concreted by means of slide-forms. The hoist and tower at the concrete mixing plant is seen in the background

When casting these columns the foundation and the columns were provisionally connected by means of reinforcing irons passing through holes in the plates of the bearing, and a supporting ring of steel was inserted between the plates. After concreting the bridge deck the provisional parts were removed (fig. 8).

In order to fully utilize the rationalization implied in the use of slide forms, conventional scaffolding close to, or between, the columns

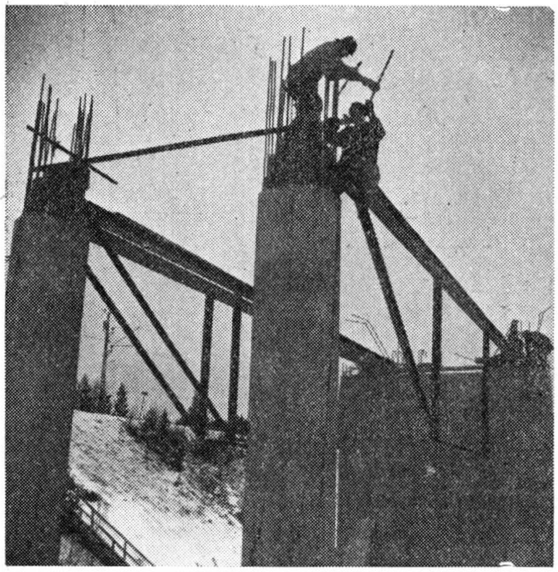

FIG. 10. Mounting of steel trusses on the top of a column

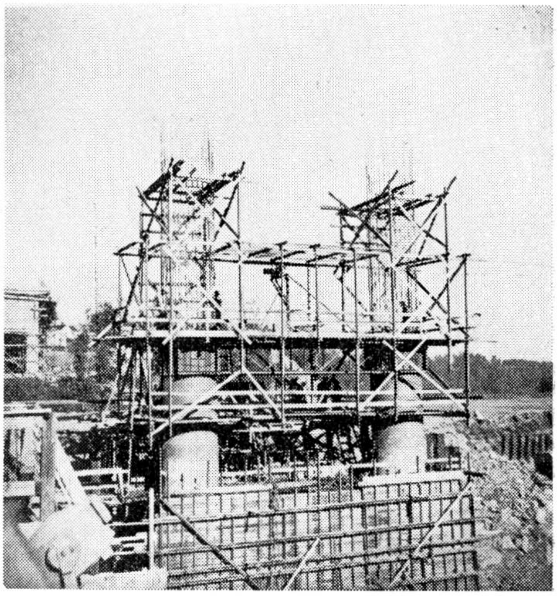

FIG. 11. Columns under construction for a highway bridge across the river Indalsäven at Bergeforsen, Sweden

for carrying the form work for the superstructure under construction should, if possible, be avoided. At the construction of the bridge here described, the space of 14.35 metres between the viaduct columns was overbridged by steel trusses (fig. 9). The steel trusses were placed on sand boxes, located in cupels at the top of the columns (fig. 10). The area of the remaining part of the cross section of the top of the column was sufficient for taking the full bridge deck and traffic load.

The cupels were filled out with concrete afterwards. Compared with conventional scaffolding a further advantage of these steel trusses will be that they make possible to compute deformations with a high grade of accuracy.

When this bridge building had been completed a new contract for a similar bridge over the river Indalsälven at Ragunda was placed with Nya Asfalt AB. With exception for the differences in regard to foundations and the length of the columns, the main difference between these bridges is that the Ragunda Bridge has one additional viaduct span at each side of the river. In view of the good result obtained in the construction of the Vindelälven Bridge the client, the Royal Board of Swedish State Railways, again agreed to the suggestion that slide-forms should be used for the casting of the columns and the slide-form equipment previously used was used once more.

Owing to delays one of the abutment columns had to be concreted in the winter. Before starting the casting a heating shelter was built around and to the full height of the column. Hot air was blown in at the base of the shelter. Because the extending reinforcing irons will cool down the concrete just poured it is, unfortunately, not possible to use

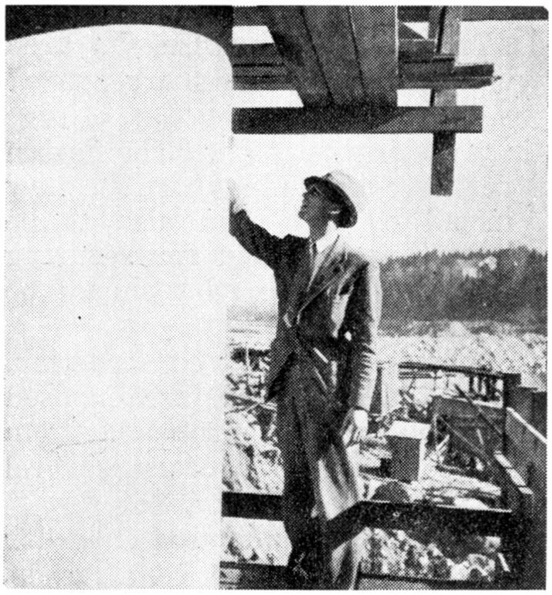

FIG. 12. Examination of the concrete surface of a column at Bergeforsen

FIG. 13. Concrete viaduct at Bergeforsen, Sweden

the simpler method of hanging tarpaulins from the working platform of the slide-form equipment. Great attention and foresight is called for at such a casting in wintertime.

The same method, as described above, was used also in the construction of the highway bridge over the river Indalsälven at Bergeforsen, which was built in the years 1953-1954. The columns of this bridge are 2.0 metres of diameter, and the quality of concrete used was K 300. Fig. 11 shows a pair or columns under construction and fig. 12 a detail of the concrete surface. Even here a pair of columns had to be cast at a low temperature.

The columns of a concrete approach viaduct (fig. 13) placed in rows of three, were also constructed with the aid of slide-forms. The columns are 0.7 metres of diameter. All columns in one row were cast at the same time from a common working platform.

Here too, there were two lifting jacks in use on each column. Because of the small diameter the columns will be susceptible to eccentric loads on the working platform. When constructing similar groups of columns by the aid of slide-forms columns less than 0.65 – 0.70 metres of diameter, therefore, would not be recommended.

SUMMARY

For high bridge columns of concrete the costs for forms and scaffolding are rather high. Through slide-form concreting large savings in material and labour costs can be made and the concrete will be easily accessible to handling.

For a concrete railway bridge, constructed in North Sweden from 1950 to 1952, all support-columns were concreted by means of slide-forms in accordance with the Concretor method. The bridge comprises an arch span, 112 m in length and approach viaducts, whose piers are spaced 14.35 m.

A description of the sliding forms is given in the paper. The design of the abutment columns was modified so as to be adapted to the new method of construction. The binders in all columns had also to be modified. It was necessary to build an auxiliary scaffold for securing the vertical reinforcement bars in position, since these bars should be as long as possible.

The columns are fixed only in the foundations during construction. Therefore, the columns, which are of considerable length, are exposed to buckling in the course of construction, and are not protected from buckling until they are fixed to the bridge deck. For this reason, several columns had to be guyed during the slide casting.

An account is given of the provisional arrangements used in order to render possible the concreting of columns with steel bearings at the base.

Steel trusses resting on the tops of the columns carried the form for the superstructure. These trusses contributed to the utilisation of the possibilities of rationalising the construction produce, since conventional scaffolding was entirely dispensed with in this manner.

For another similar railway bridge, constructed from 1953 to 1955 the columns are concreted by means of slide-forms. One of the columns of this bridge was built in the winter, then the temperature was permanently below 0° C.

The same method has also been used for the columns of a highway bridge.

ZUSAMMENFASSUNG

Die Gerüst- und Schalungskosten bei längern Brückensäulen sind ausgesprochen hoch. Bei Anwendung der Gleitschalung lassen sich bedeutende Material- und Arbeitskosten einsparen; auch wird die Zugänglichkeit für die Betonbearbeitung verbessert.

Bei einer in Nordschweden in den Jahren 1950-52 gebauten Eisenbahnbrücke aus Stahlbeton wurden alle Stütz-Säulen mit Hilfe von Gleitschalungen nach dem Concretorsystem betoniert. Die von einem Bogen überspannte Mittelöffnung dieser Brücke ist 112 m lang, und die Stützen der seitlichen Anschlussviadukte liegen je 14,35 m auseinander.

Die Bemessung der Widerlager-Säulen wurde der neuen Betoniermethode angepasst. Auch die Bügel wurden entsprechend ausgebildet. Um die möglichst langen Vertikaleisen in ihrer richtigen Lage festzuhalten, musste ein besonderes Hilfsgerüst erstellt werden.

Während des Baues sind die ausgesprochen langen Säulen nur am untern Ende eingespannt; demnach sind sie dem Knicken ausgesetzt, bis sie mit der Fahrbahnplatte verbunden werden können. Aus diesem Grunde mussten verschiedene Säulen während des Betonierens seitlich abgestützt werden.

Es folgt eine Beschreibung über die Einrichtungen, die das Betonieren von Säulen mit Stahllagern am untern Säulenende ermöglichten.

Ueber den Säulenköpfen aufliegende Stahltragwerke dienten zur Unterstützung der Fahrbahnschalung und hatten wesentlichen Anteil an der Verwirklichung dieser rationelleren Bauweise.

Bei einer ähnlich gearteten, im 1955 fertiggestellten Eisenbahnbrücke werden die Säulen ebenfalls mit Hilfe der Gleitschalung betoniert. Eine dieser Säulen wurde im Winter erstellt, als die Temperatur ständig unter 0° C lag .

Das gleiche Verfahren kam auch bei Strassenbrücken-Säulen zur Anwendung.

RESUMO

O custo dos andaimes e das cofragens dos pilares de pontes de betão de grande altura é bastante elevado. O emprego de cofragens deslizantes não só permite realizar importantes economias de material e mão de obra como também facilita a manutenção do betão.

Na construção de uma ponte de caminho de ferro no Norte da Suécia, de 1950 a 1952, betonaram-se todos os pilares de apoio com o auxílio de cofragens deslizantes segundo o método «Concretor». A referida ponte compõe-se de um arco de 112 m. de vão e dois viadutos marginais cujos pilares têm uma espaçamento de 14,35 m.

O autor descreve as cofragens deslizantes. O projecto dos pilares dos encontros foi modificado de modo a adaptar-se ao referido método de construção. Os estribos também foram modificados em todos os pilares. Tornou-se ainda necessário construir um andaime auxiliar para suportar as armaduras verticais que deviam ser o mais compridas possível.

Durante a construção, os pilares só estavam ligados às fundações, ficando portanto, devido à sua grande altura, submetidos à encurvadura até ao momento de virem ligar ao tabuleiro. Por esta razão, alguns pilares tiveram de ser suportados durante a betonagem.

O autor relata as disposições provisórias adoptadas para tornar possível a betonagem dos pilares com articulações metálicas na base.

Vigas metálicas trianguladas, apoiadas no topo dos pilares, suportavam a cofragem da superestrutura. Essas vigas contribuiram para o aproveitamento das possibilidades de racionalização do método de construção, pois permitiram dispensar completamente os andaimes habituais.

Na construção de outra ponte semelhante executada de 1953 a 1955 foram os pilares também betonados com cofragens deslizantes. Um dos

pilares foi inteiramente betonado durante o inverno com temperaturas permanentemente negativas.

O mesmo método foi também utilizado para construir os pilares de uma ponte de estrada.

RÉSUMÉ

Le prix des échaffaudages et des coffrages des piliers de ponts en béton de grande hauteur est assez elevé. L'emploi de coffrages glissants permet non seulement une sérieuse économie de matériaux et de main d'oeuvre mais encore rend la manutention du béton plus aisée.

Lors de la construction d'un pont-rail dans le Nord de la Suède, de 1950 à 1952, tous les piliers d'appui ont été bétonnés à l'aide de coffrages glissants selon la méthode «Concretor». Ce pont comprend un arc de 112 m de portée et des viaducs d'approche dont les piliers sont espacés de 14.35 m.

L'auteur décrit les coffrages glissants. Le projet des piliers des naissances a été modifié afin de pouvoir les adapter à la nouvelle méthode de construction. Les étriers de tous les piliers ont également dû être modifiés. Il a été nécessaire de construire un échafaudage auxiliaire pour guider les armatures verticales qui devaient être aussi longues que possible.

Pendant la construction, les piliers n'étaient fixés qu'aux fondations, ce qui, du fait de leur grande hauteur, les soummettait au flambement jusqu'au moment de les relier au tablier. Pour cette raison, certains piliers ont dû être étayés pendant le bétonnage.

L'auteur décrit les dispositions provisoires adoptées pour rendre possible le bétonnage des piliers munis d'articulations métalliques à leur base.

Des poutres métalliques triangulées, appuyées sur le sommet des piliers, soutenaient les coffrages de la superstructure. Ces poutes ont contribué à l'utilisation des possibilités de rationalisation du mode de construction en permettant d'éviter entièrement les échafaudages conventionnels.

Des coffrages glissants ont été également utilisés dans la construction d'un autre pont-rail éxécuté de 1953 à 1955. L'un des piliers a été completement bétonné en plein hiver par des températures constamment en dessous de zéro.

La même méthode a également été employée pour la construction des piliers d'un pont-route.