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Formwork Launching Girders

Cintres autolanceurs
Vorschubbrüstungen

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SUMMARY

A survey is made of the state of the art in bridge construction with formwork launching girders, available products on the market, their characteristics, capacities and applications. Girders for the placing of precast segments in free cantilevering bridge are not considered in this survey.

RÉSUMÉ

L'article présente l'état actuel de la conception de construction des tabliers de pont avec cintres autolanceurs. Il donne une description des cintres existant sur le marché, leurs caractéristiques, capacités et applications. Les cintres pour la mise en place des voussoirs préfabriqués de ponts en encorbellement ne sont pas traités dans l'article.

ZUSAMMENFASSUNG

Der vorliegende Artikel gibt einen kurzen Überblick über die Möglichkeiten des Einsatzes von Vorschubbrüstungen im Brückenbau. Vorhandene Rüstungstypen, ihre Leistungsfähigkeit und Anwendung werden vorgestellt. Versetzgeräte für vorfabrizierte Elemente im Freivorbau werden in diesem Artikel nicht behandelt.



INTRODUCTION

With the development of prestressed concrete, a large number of new erection methods were introduced in bridge construction.

Among them was the span by span in situ erection of the bridge deck. At first, conventional scaffolding was used. However, as a result of highway construction (also in the Alps), bridges became longer and the site conditions more and more difficult, so that conventional scaffolding was no longer economical. The use of formwork launching girders was suggested as one solution.

The push for the development came from the Fed. Rep. of Germany at the end of the fifties. Today the span by span erection of the bridge deck with formwork launching girders is in use worldwide. The formwork launching girders work absolutely independently of the ground. Thus the construction of the piers and usually pier diaphragms also has to be carried out in advance. These serve directly as supports for the girder, or they carry temporary works over which the girder moves.

One of the principle problems associated with these girders is their reuse. The support conditions of each bridge are often so different, that the costs of modifications are higher than for a new girder. In the Fed. Rep. of Germany, however, where contractors' alternatives are often winning in bridge construction, the reuse of the formwork launching girders is quite good (the cross-sections and piers are designed for an existing launching girder).

The most economical range of span for this method is from 30 to 60 m, and normal construction time is two weeks per span.

A special note should be made regarding the post-tensioning tendon layout. Not all tendons should be coupled at the construction joint. But, for lowering the formwork and moving the launching girders forward, all tendons must normally be stressed. A solution to the problem is to have overlapping tendons at the pier sections. This system was used successfully in the construction of the viaduct of Gruyère.

The extent of application of the method is quite large. In fact, 750'000 m² of concrete bridge deck have been produced worldwide (partly as licensee or consultant), using only the girders of Polensky & Zöllner, and Strabag.

Another erection method made possible in bridge construction by post-tensioning is the free cantilevering method. This can be done either with in situ casting or with precast segments. To eliminate the transport of travellers in the former, formwork launching girders are successfully in use. Hence, the geometry of the bridge deck and the post-tensioning tendon layout is quite different from the span by span erection method. Therefore the two girder systems are treated separately.

The design of formwork launching girders is quite complex. There should be close teamwork between the designer of the bridge and the designer of the launching girder. Mechanical parts need special caution to guarantee factory like production, i.e. to reach the envisaged construction cycle.

SPAN BY SPAN ERECTION OF THE BRIDGE DECK

1. WORKING METHOD AND LAYOUT OF THE GIRDER SYSTEM

The method is suitable for the construction of continuous bridges. The cross-section can be of a box girder or web-slab girder type. It allows for a segmental construction of the superstructure with the length of each segment corresponding to the span length. The construction joints are at the points of zero moment. The cross-section is poured complete or in stages. For the latter, an additional travelling formwork is necessary. The formwork launching girder could be referred

to as a moving fabrication plant, as it consists of both a bearing structure and the formwork. It has to carry the weight of the span until the concrete has reached the strength required for stressing the tendons. The launching girder is then moved to the next span. Thus, step by step the whole superstructure takes shape, becoming finally one continuous girder.

The launching girder consists of the following principle elements:

- a supporting structure
- supports for concreting and launching stages
- launching devices and
- the formwork with regulating devices.

2. CONCEPTION OF THE GIRDER

The supporting structure can be placed above or below the bridge deck. In the former, the formwork must be borne by hangers, with a special support system being necessary during the launching stages. As shown in Fig. 1, all bearing structures are positioned above the deck.

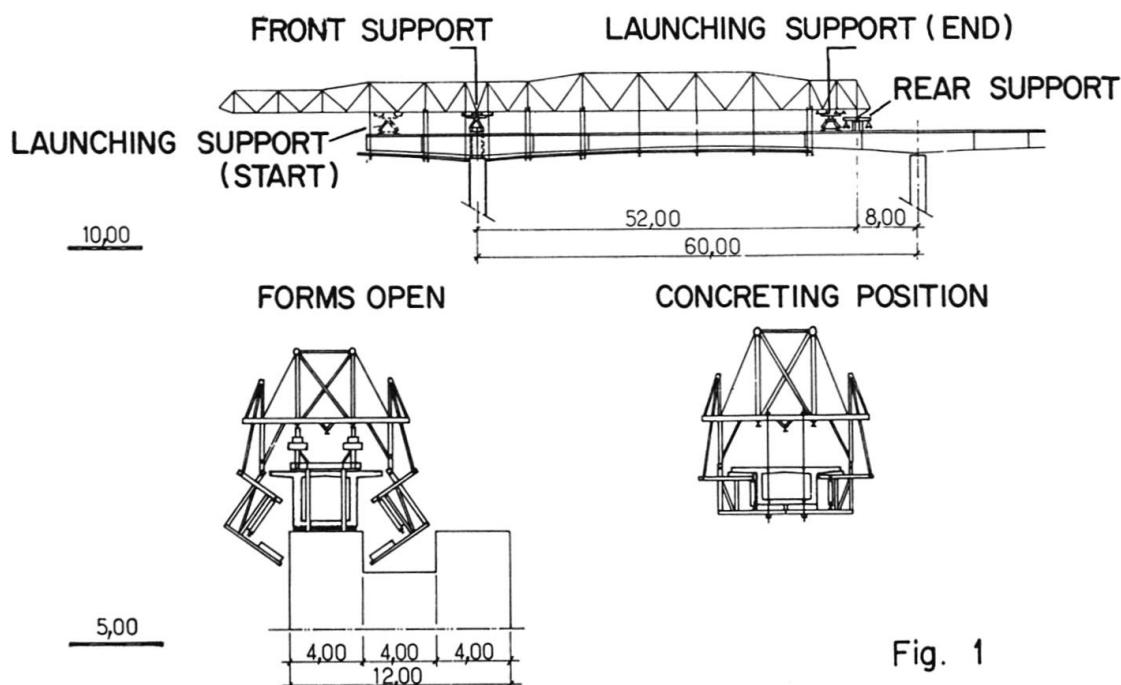


Fig. 1

In the second case, the formwork is borne directly by the supporting structure. For launching at piers, special devices are necessary as shown in Fig. 2.

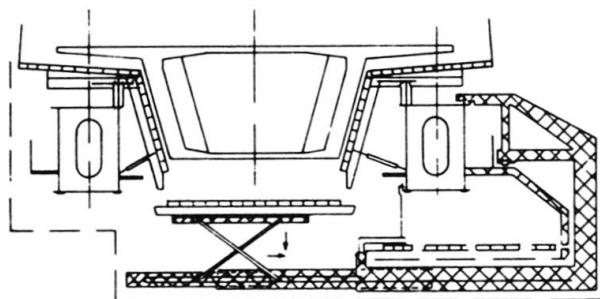


Fig. 2

In both cases, the supporting structure itself is composed of either steel box girders or trusses. Formwork surface material is either steel or wood.

Recently, a solution between the "above and below" types was quite successfully



introduced combining the advantages of both. See Fig. 3.

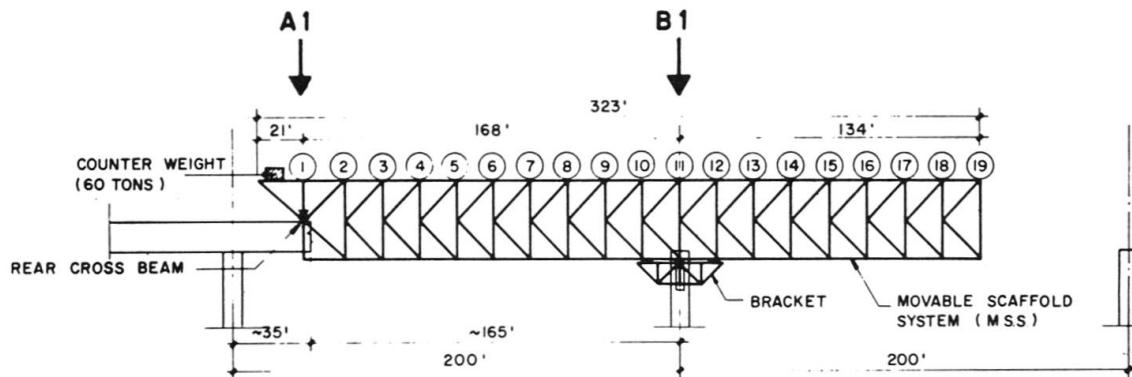


Fig. 3

3. COMPARISON OF THE TWO POSSIBILITIES

3.1 Girder "above"

Advantages:

- Construction height is unlimited.
- Supply of material to the segment being built, can be integrated into the supporting structure.
- Relatively sharp curving is possible.
- Support reactions are transmitted directly into the pier.
- Weatherprotection can be implemented.

Disadvantages:

- Suspension rods going through superstructure.
- Formwork not used statically longitudinally \rightarrow more material.
- Large wind affected surface.
- Young concrete is loaded at an early age during launching.
- High bearing devices over pier head.
- Relatively large side clearance required.

3.2 Girder "below"

Advantages:

- Surface of superstructure remains clear.
- Formwork can be used statically with the supporting structure \rightarrow less material.
- No suspension rods to be removed.
- Smaller wind affected surface
- Young concrete is less loaded during launching.
- Side clearance is not affected.

Disadvantages:

- Ground clearance may limit construction height of the girder.
- Temporary brackets are needed at piers.
- Sharp curving requires special measures.

The listed advantages and disadvantages do not obviously make one or the other of the systems more preferable. Only for web-slab bridges are the formwork launching girders "below" more suitable since they are able to carry the formwork directly.

Thus, it is very important to check all factors of a bridge construction to come to the right choice of system. Probably the solution "between" is the best.

3.3 Weight of Girders

Typically, 300 to 600 kg of girder weight (including mechanical and hydraulic equipment) is necessary for each tonne of bridge concrete weight. With this range of values it is possible to check quickly whether a formwork launching girder is economically feasible. Shown in Fig. 4 is the weight of structural steel per tonne of concrete carried as a function of the span for some bridges. A specific relationship is not evident, and although it is obvious that the weight increases with the span, exactly how remains unclear.

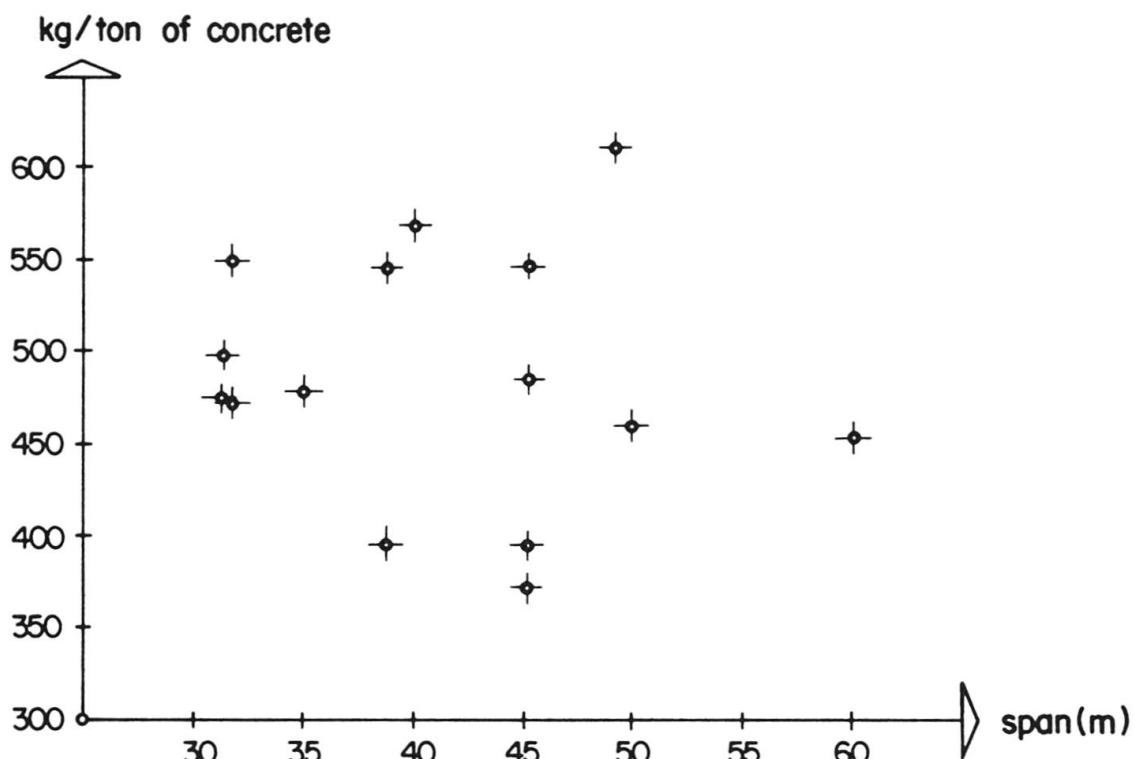


Fig. 4

4. GIRDERS CURRENTLY AVAILABLE ON THE MARKET

4.1 Girders "above"

MSU 60/900

Owner : AG Heinr. Hatt-Haller, Zürich
Designer : Dipl. Ing. Dr. K. Koss, Wien

Concept (see Figs. 5 and 6)

The launching girder consists of unit composed sections and is adaptable to any type of cross-section. The main girder and nose are hollow box girders. I-section transverse girders are fixed with stays.

No additional devices for the bridge deck construction are necessary. Concrete pouring and material transport is done by means of a moveable hydraulic 45 mt crane or by an electric, steered overhead trolley. With the latter, a roof can be provided, so that a factory likely construction of the bridge deck is possible.

Moving forward is done automatically hydraulically from pier to pier. During concrete pouring the system is supported on the two piers and on the rear bridge deck cantilever. No special constructions for these supports are necessary.



Leveling and positioning in all directions is possible. During launching, the forming system is lowered on the platform and moved transversally to pass by the piers. Construction cycle is three weeks.

Technical details

- Overall length: 114 m
height: 13 m
- Max. possible bending moment of main girder: 8'000 mt
- Gross weight: 1'000 t

Capacity

- Max. span: 60 m (can be increased to 80 m, providing the main girder is stayed)
- Max. width of bridge deck: 25 m
- Max. height of section: 4 m (can be increased with extensions)
- Max. transverse slope: 6% (compensated with forming hangers)
- Max. longitudinal slope: 6%
- Min. horizontal radius: 200 m

Application

4 times until now:

- Weihermatt Bridge, Sissach, CH, 1968/70, 2 x 360 m
- Sihl fly-over, Zürich, CH, 1970/73, 1'255 m
- Saane Viaducr, Gümmenen, CH, 1973/76, 849 m
- Railway-bridge Galgentobel, near St. Gallen, CH, 1979/81, 521 m

At present in use for the Ruina Viaduct, Leventina, CH.

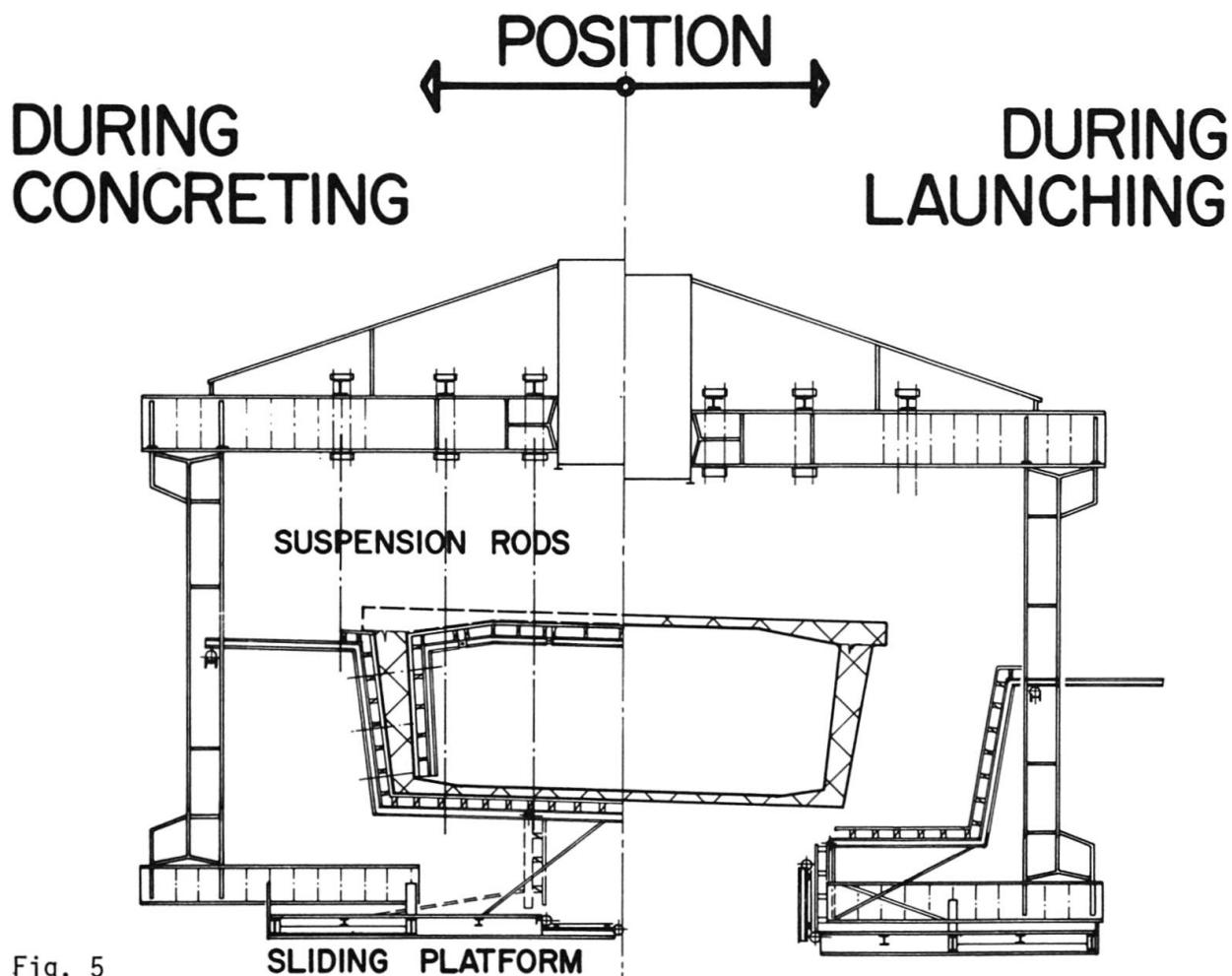


Fig. 5

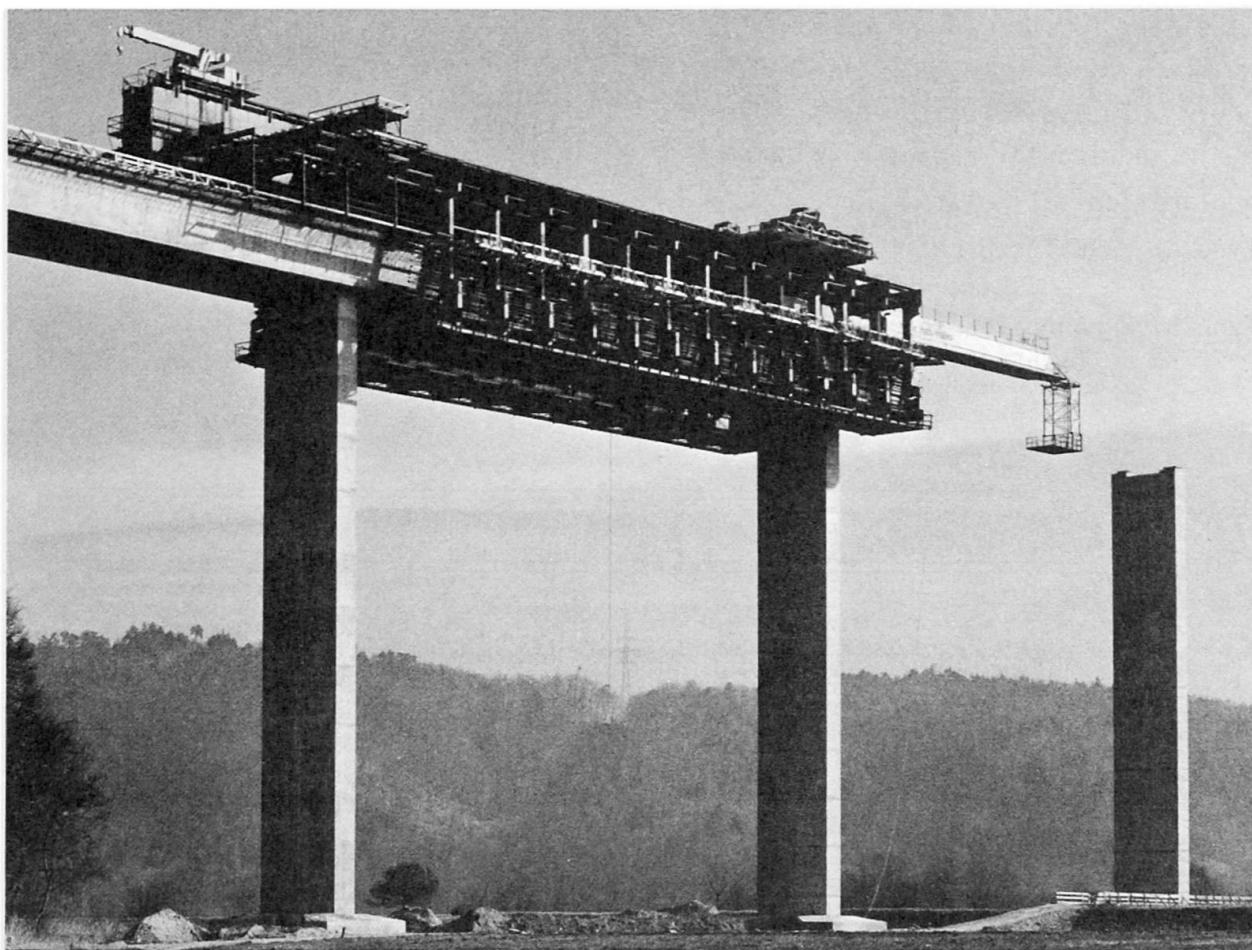


Fig. 6

"Type Welda"

Owner: Type A: Heilit & Woerner Bau AG, München

Type B: Julius Berger-Bauboag AG

Manufacturer: Stahlbau, F. Maurer Söhne, München

Concept (see Figs. 7 and 8)

Concreting stage:

The main girder is supported on a slide chair on the already concreted diaphragm of the next pier and at its rear on a slide chair on the cantilever portion of the previously cast deck. The shuttering flaps are closed and the formwork scaffolding hangs from the main transverse girder.

Moving stage:

A hydraulic rope winch moves the launching girder forward on Teflon bearings. The launching girder is lowered and the slide chairs must be shifted during moving. At pier passing, the shuttering flaps are opened.

The slide chairs are moved by winches on the bottom chord of the main girder.

Technical details

	Type A	Type B
--	--------	--------

- Length:	90 m	175 m
- Height: (over Bridge deck)	10.2 m	15.2 m
- Weight:	620 t	2'000 t



Capacity

	Type A	Type B
- Max. span	60 m	106 m
- Max. width of section	20 m	15 m
- Min. horizontal radius	1'000 m	

Application

Type A: - Kaltenbachtal Viaduct, Fed. Rep. of Germany, 2 x 470 m, 1969/71
 - Bengen Viaduct, Fed. Rep. of Germany, 2 x 970 m, 1972/75

Type B: - Ahrtal Bridge, Fed. Rep. of Germany, 2 x 1'520 m, 1975/76
 (stored and ready for possible reuse)

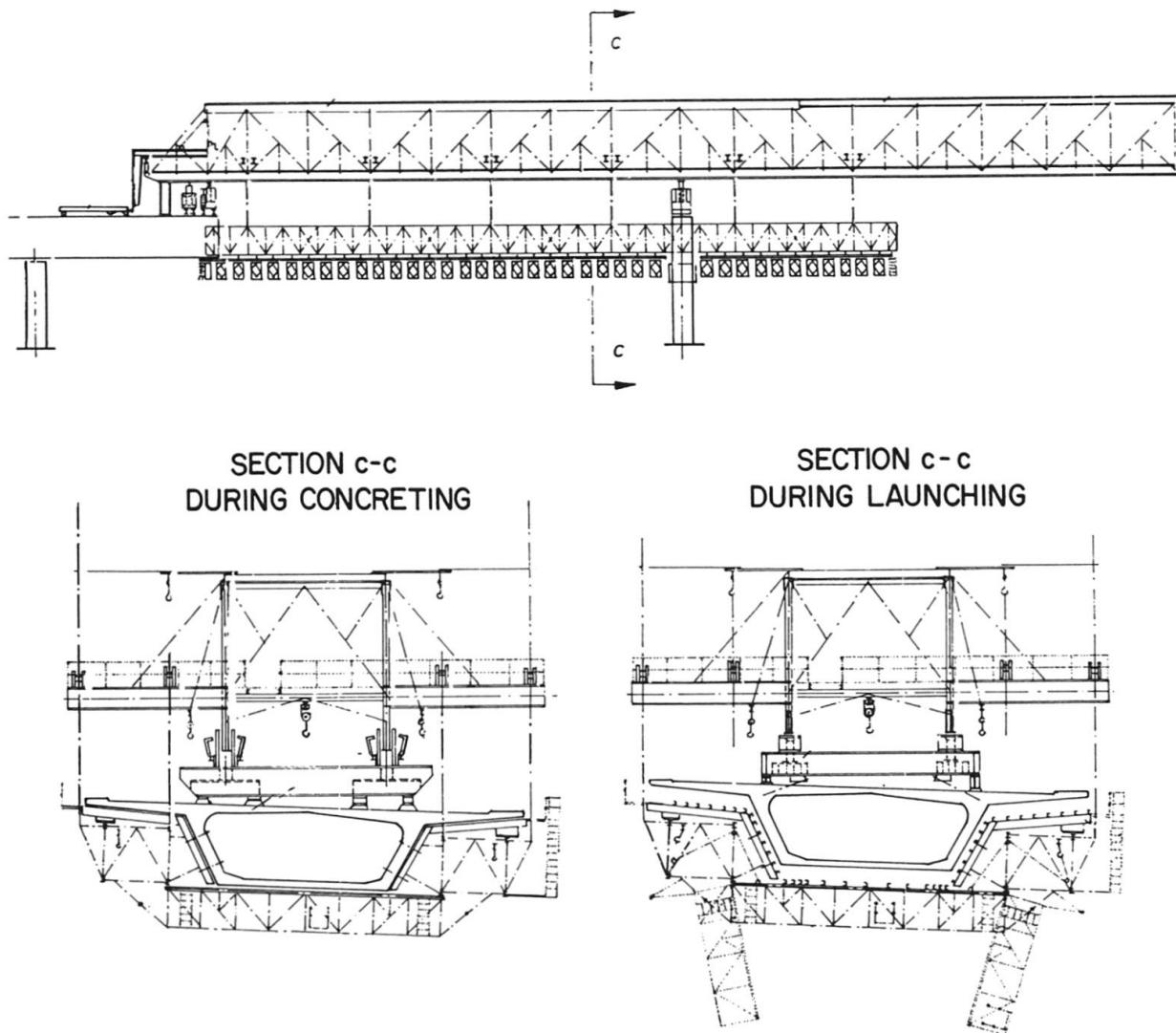


Fig. 7

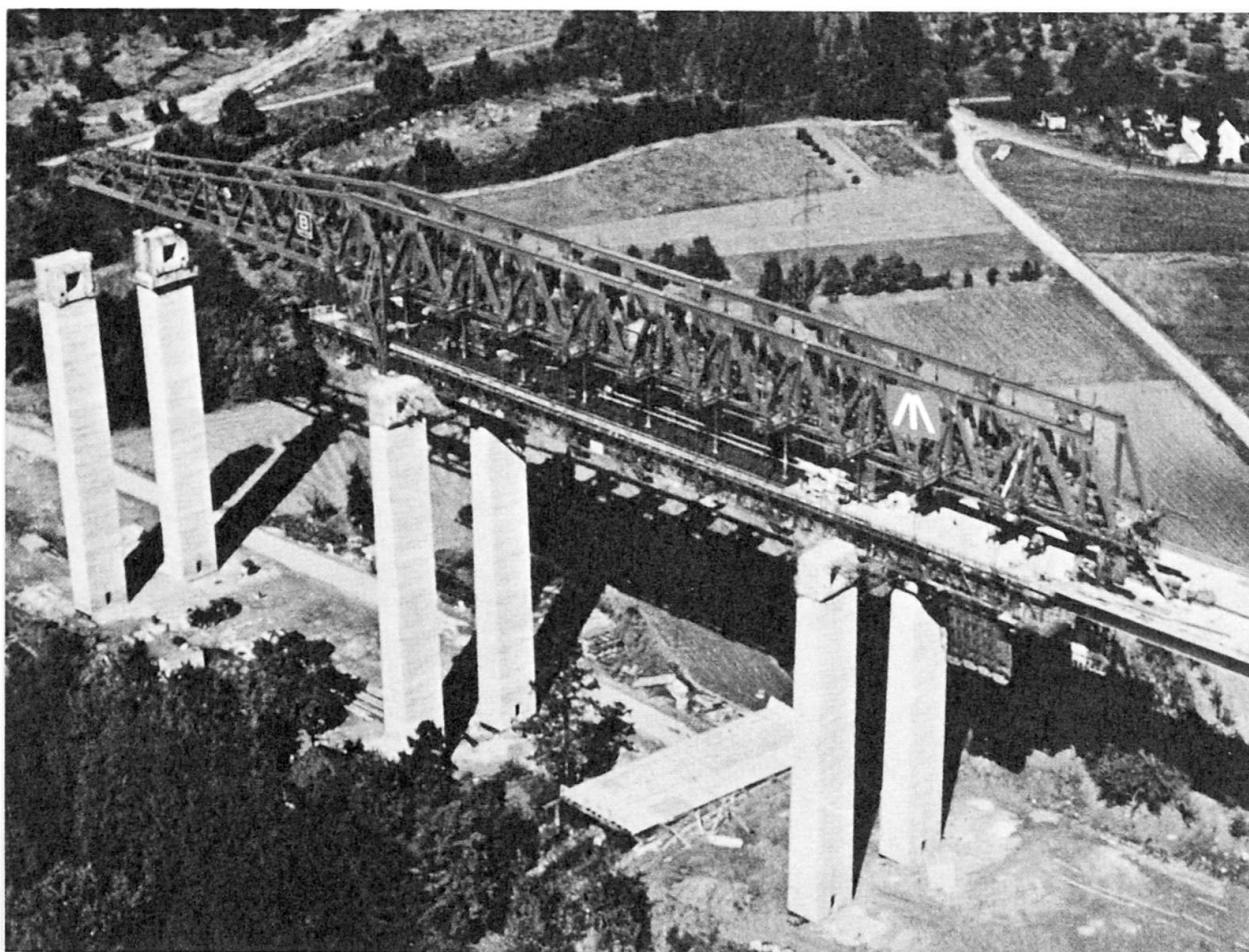


Fig. 8

4.2 Girders "below"

One phase type ("Krahnenberg")

This launching system was originally designed by Polensky & Zöllner. Over the years, various changes were made, and there are now about four different types in use. The principle difference is the number of main beams.

Concept

Launching is done in one step without a functional coupling of the main beams. Several support constructions are in use. These are shifted while the girder is in the neutral position.

As a typical example, the newest type, used at Beckenried Viaduct, Switzerland, is described briefly.

In principle, this girder consists of the following elements (see Figs. 9 and 10):

- 2 main beams (steel box girders)
- Front and rear noses (trusses)
- Trough shaped formwork, supported at inner web of main beam and with integrated rigid bottom slab forming elements (releasable for passing by piers)
- Rear hanging support at the coupling joint
- Support construction at piers (placed with the help of the launching girder from the bottom).

Table 1 lists the technical details, capacity, applications and owners of each of the four types.

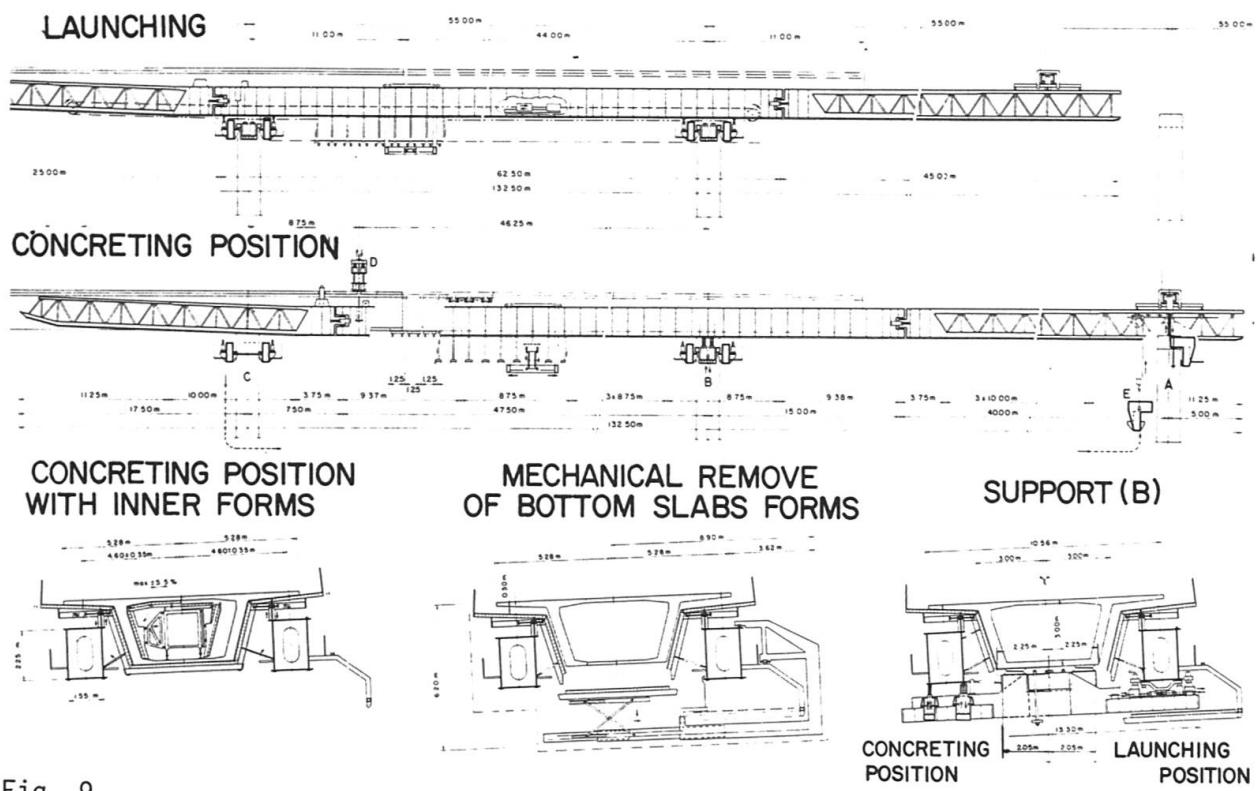


Fig. 9

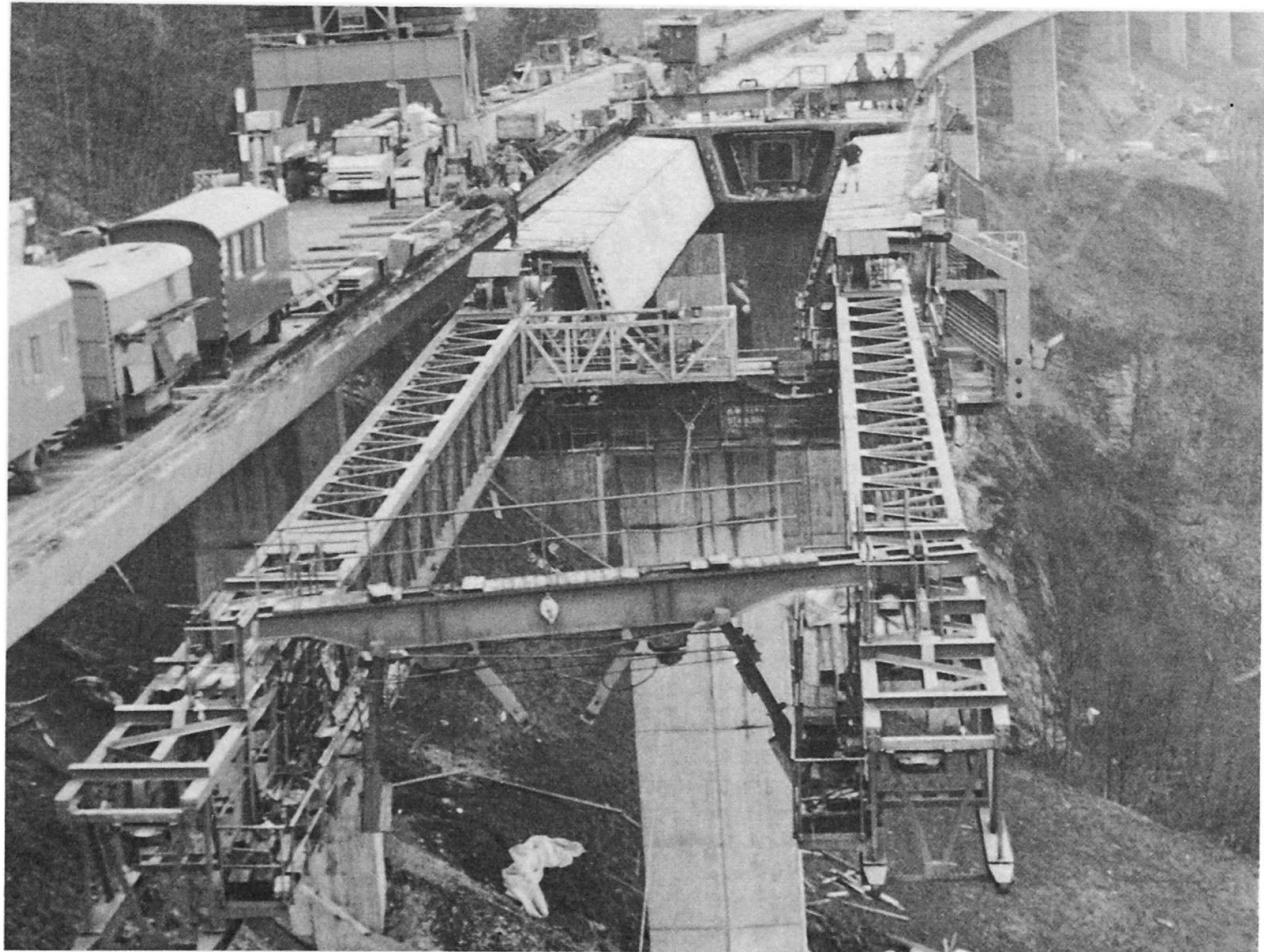


Fig. 10

Type	Technical details			Capacity			application	No. of reuses	owner			
	No of main beams	overall length (m)	weight (t)	max.span (m)	max.width (m)	min.radius (m)						
A	2	75,00	200	44,0	10,4	600	Volmetalstr., FRG, 1973 Eiderbridge, FRG, 1971 Krahnenberg, Münchholzh., Neumünster (FRG) Weserbridge, 1969-71	6	Polensky & Zöllner			
	3		350	51,4	14,5	475						
	4		350	34,0	20,7							
	5		480	44,0	24,0							
B	2	85,40	250	42,0	8,30	300	Flyover Amsinck, FRG, 1969 Mainz, FRG, 1966-68 Blasbachbr., Köhlbrandramp Volmetalstr., FRG Jadiriayahbridge, Iraq	6	Polensky & Zöllner			
	4		500	40,0	21,0	300						
	5		760	50,0	20,5							
			830	44,0	22,8							
			980	46,0	25,5	600						
C	2		650	47,0	12,3		-Viaducto de Somonte, Spain, 1974-76 -Rio Paraguay, Paraguay, 1976-78	2	unknown			
D	2	132,50	750	56,0	11,3	700	-Beckenried Viaduct, CH 1970-80	1	Spaltenstein			

Table 1



One phase type "Küppers"

This formwork launching girder was developed by the contractor Theodor Küppers, Fed. Rep. of Germany. Two similar types are in existence: type Lemptal and type Achenbach.

Concept

The main girders are hollow box sections, 3 m in height with rear and front noses. During concreting, the main girder is supported at the rear on the cantilever portion of the already concreted bridge deck by means of a suspension truss as shown in Fig. 11. The front supports are pier brackets, fixed by means of pre-stressed bars.

During launching, rear and front support reactions are taken by the pier brackets. At the first and last span, auxiliary towers are necessary for bearing. The launching is done with hydraulic jacks. The brackets and the suspension truss are moved forward with a cable crane or a travelling crane on the bridge deck. The bridge deck is poured in one stage. The outer forming trestles are fixed to the main girder while the inner form consists of moveable blocks. Supply of material is done by a cable crane or by a travelling crane on the bridge deck. Construction time is three to four weeks per span.

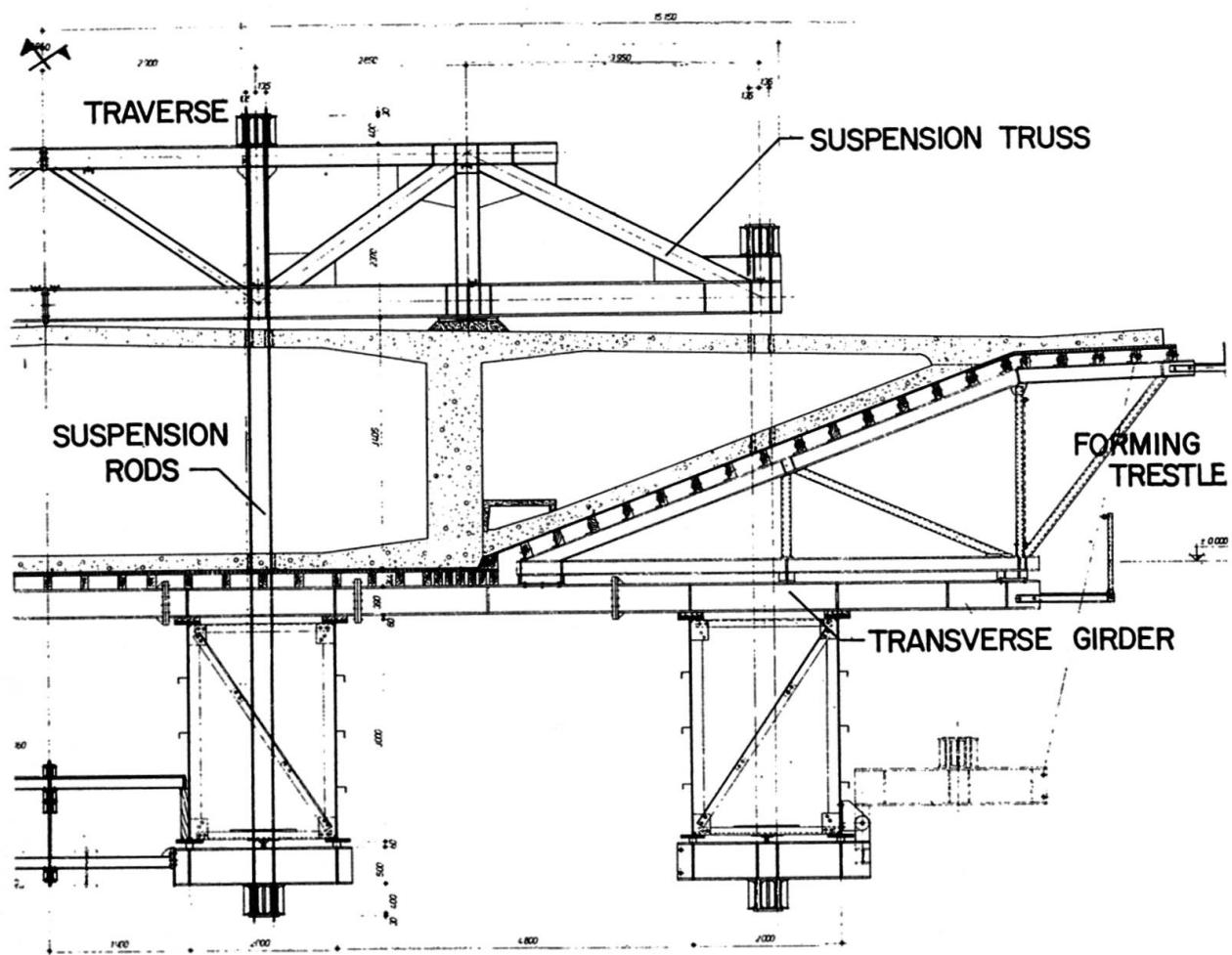


Fig. 11

Technical details

- Overall length: 98 m
- Gross weight : 600 t (for two main beams)

Capacity

- Max. span: 48 m
- Max. width of bridge deck: adaptable, using more than 2 beams, as done at Lösterbach Viaduct (4 main beams, see Fig. 12)

Application

Type Lemptal used 4 times until now, type Achenbach 2 times. All bridges were box girders with an inclined web. All sites in the Fed. Rep. of Germany.

Lemptal: Lemptal Viaduct, 2 x 579 m, 1969/70
Rüblingshausen Viaduct, 2 x 300 m, 1970/71
Karweiler Viaduct, 2 x 500 m, 1971/72
Lösterbach Viaduct, 1 x 645 m, 1973/74

Achenbach: Achenbach Viaduct, 1 x 560 m, 1969/70
Wintersohl Viaduct, 2 x 264 m, 1970/71

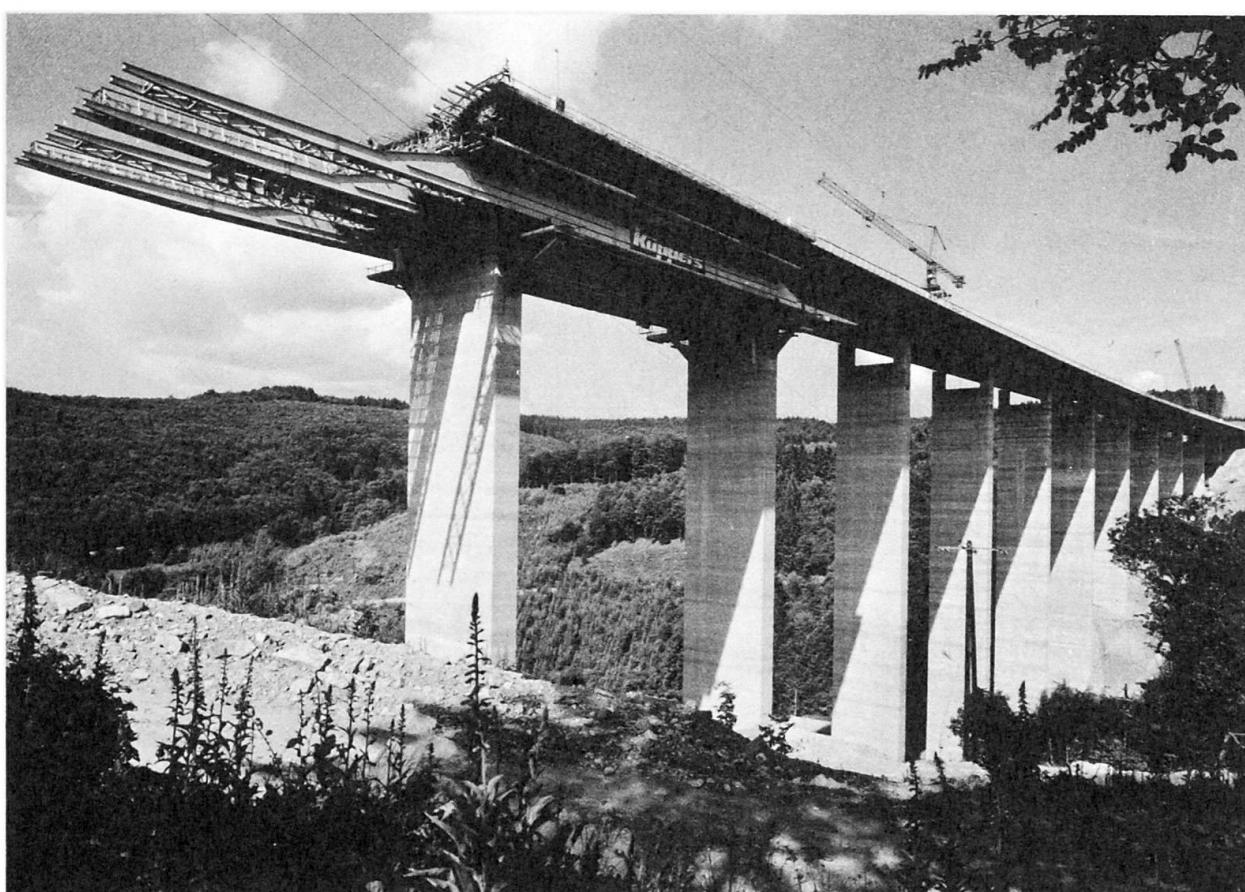


Fig. 12

One phase type "Thyssen"

Two types of launching girder from Thyssen are available: HV and T50. The steel construction company Thyssen hires the girders.

Concept

Both types consist of individual sections and are adaptable to any cross-section.



The main beams of the HV type are hollow box girders and truss girders for the T50 type. For the support arrangements during the concreting and launching stages, see Fig. 13. The brackets for the HV type are moved forward on the lower chord of the main beam by means of travelling gears. For the T50 type, the brackets are shifted with cranes. The brackets are equipped with roller blocks, hydraulic lowering devices and driving machinery. Forming trestles are not integrated into the main girder as shown in Fig. 14. The forming trestles are movable in the transverse direction for pier passing. Pouring of the cross-section in stages might be advantageous (placing of main beam beside the web). Construction cycle is two weeks.

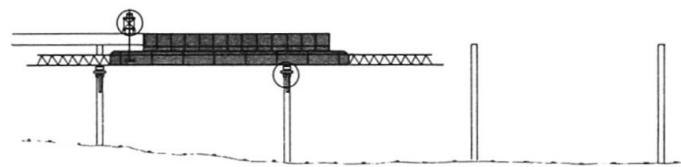
Technical details

	HV	T50
- Overall length:	slightly more than 2 spans	
- Main beam height:	0.80 to 3.20 m	2.34 m
- Max. bending moment:	3600 mt/box	252 mt/girder

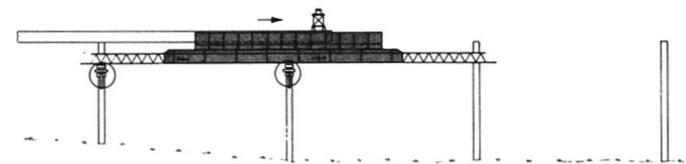
Capacity

	HV	T50
- Max. span:	55 m	39 m
- Min. horizontal radius:	900 m	500 m
- Longitudinal slope:	as required	
- Transverse slope:	as required	

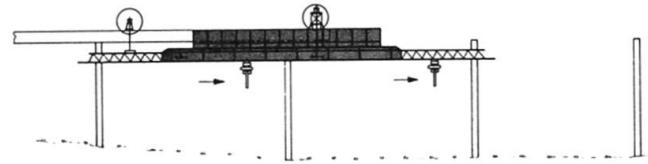
Concreting position supported on front bracket and at the suspension beam



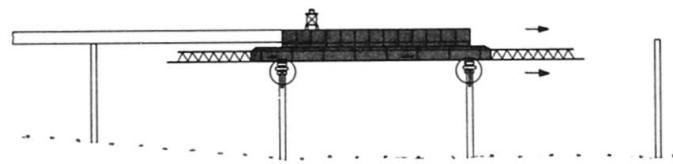
Lowering and launching until centre of gravity of launching girder is over the pier support



Launching of the brackets.
Launching girder suspended at the two suspension beams



Launching of the girder into the next concreting position



New concreting position

0 = support

Fig. 13

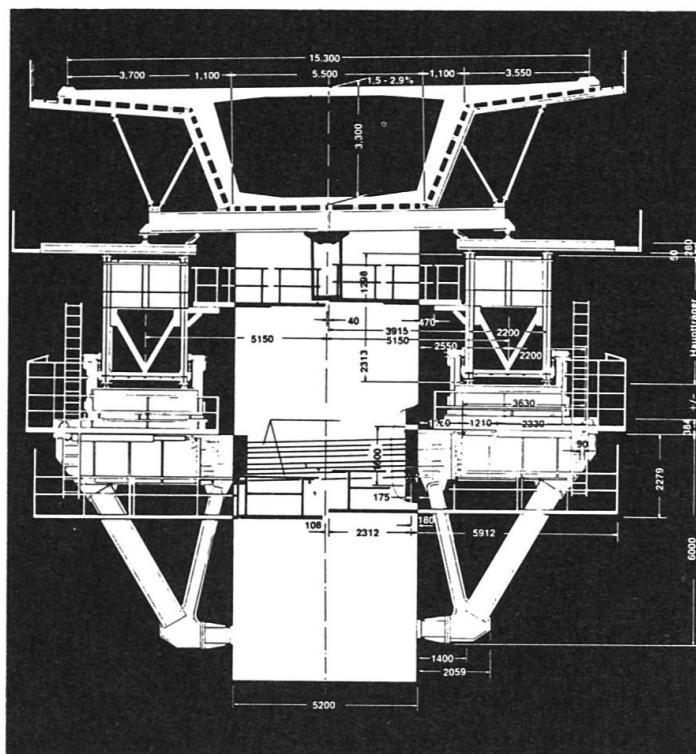


Fig. 14

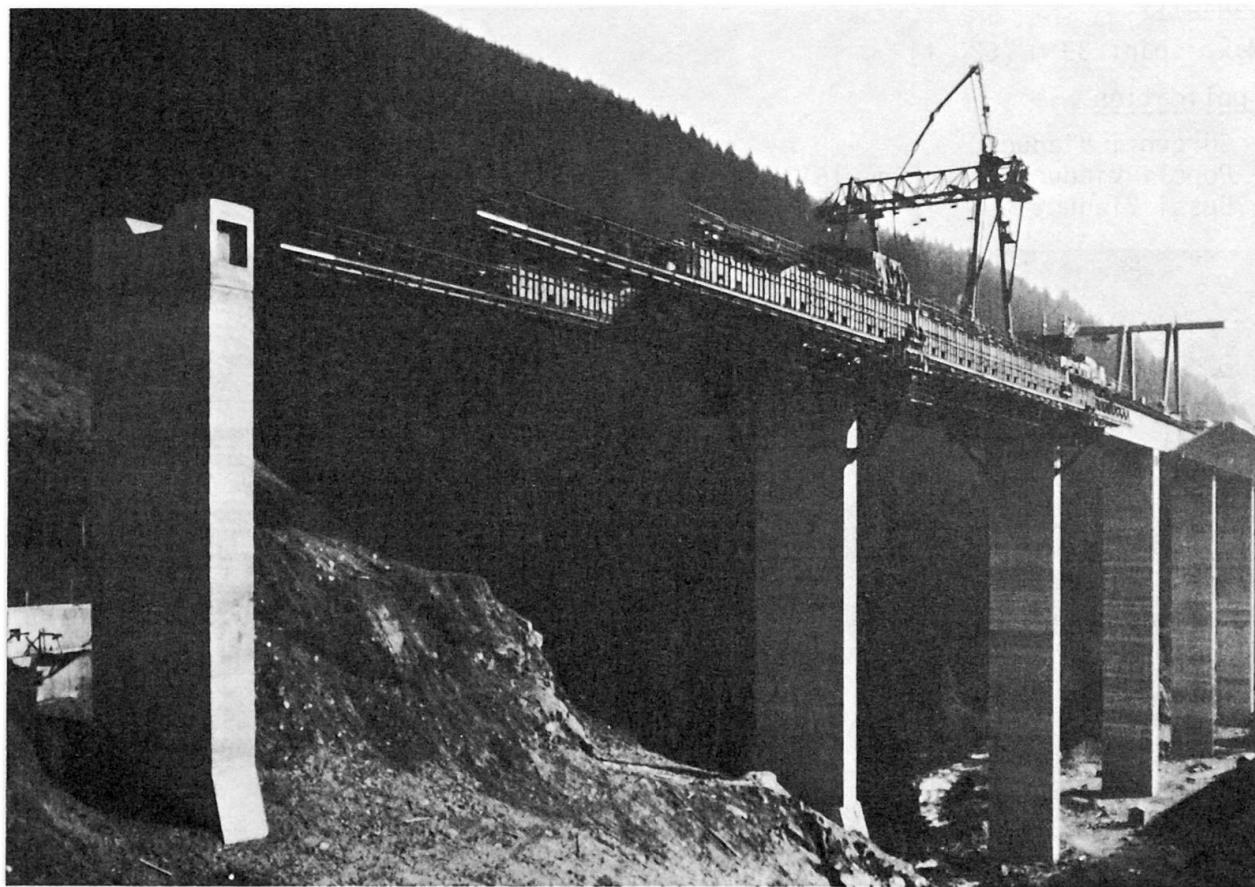


Fig. 15



Application

Type HV: - Pressingberg Bridge, Austria, 1 x 2300 m
 - Rauchenkatsch Bridge, Austria, 1 x 1600 m (see Fig. 15)
 - Steinau Viaduct, Austria, 1 x 370 m, 1 x 348 m
 - Meiselgraben Bridge
 - Larzenbachtal Bridge

Type T50: - Ofner Hansl Bridge, Austria, 1 x 665 m
 - Rachbach Bridge
 - Krebsbach Viaduct, Fed. Rep. of Germany (with intermediate towers)

One phase types from Italy

a) Type for Highways A25 (Torano-Pescara)

Owner: Cogefar

Manufacturer: Sicea

Concept

The main beam consists of two hollow box girders, while the rear and front noses are truss girders (front nose fixed). Supporting is done by auxilliary towers on the pier foundation at the front, with a suspension transverse at the rear (on the existing cantilever). Moving forward is done by hydraulic jacks.

Typically 2.5 to 3 spans can be erected per month, using steam curing. The site has a roof with an integrated crane trolley for the supply of material.

Technical details

Gross weight: 450 tons

Capacity

Max. span: 39 m (620 t)

Application

- Sorgenti Viaduct
- Popoli Viaduct (see Fig. 16)
- Bussi Viaduct

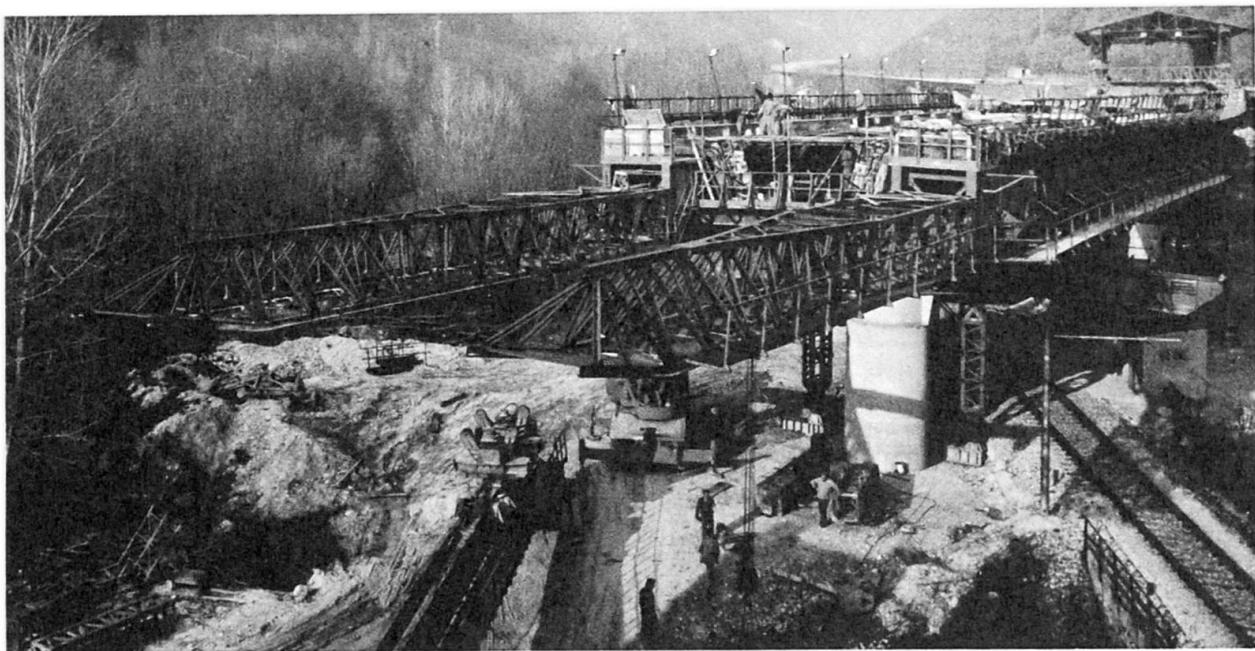


Fig. 16

b) Type for Highway Rome - L'Aquila

Owner: Generalvie

Manufacturer: Sicea

Concept

The main beams and noses consist of truss girders as shown in Fig. 17. The front nose is hinge connected. The girder is supported on pier brackets (also during concreting). Moving forward is done by hydraulic jacks. Using steam curing, 2.5 to 3 spans can be done monthly. Material supply is via a trolley crane (within the covering roof).

Technical details

Gross weight: 480 tons

Capacity

- Max. span: 42 m (700 tons), for single span bridges
- Min. horizontal radius: 600 m

Application

- Costa del Mulino Viaduct, 2 x 630 m
- Calderone Viaduct
- Biselli Viaduct

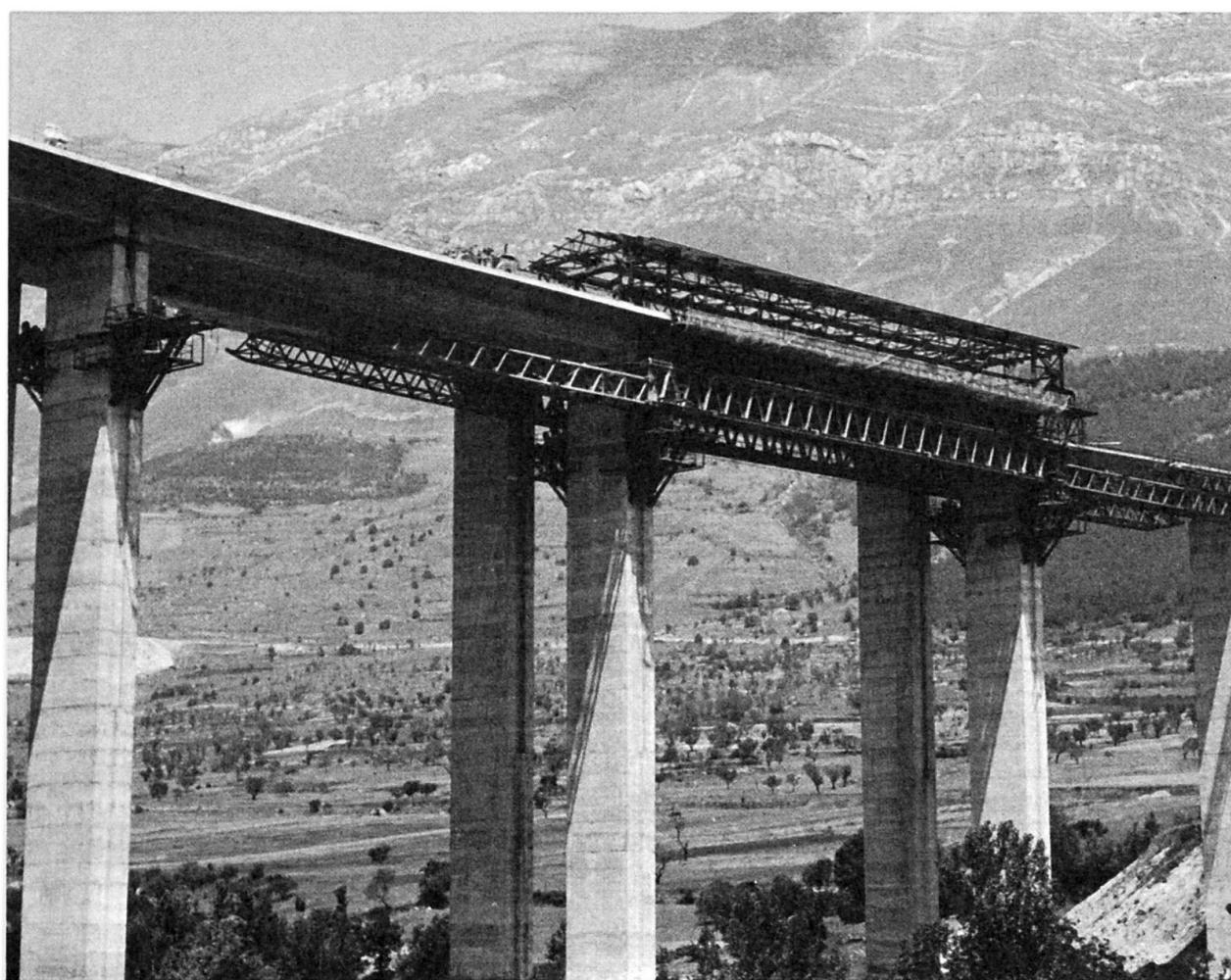


Fig. 17



c) Type for Highway L'Aquila - Villa Vomano

Owner: Cogefar
Manufacturer: Sacma

Concept

The main beams and noses are truss girders. The front nose can rotate. The girder is supported during all stages on pier brackets, (3 pairs of brackets necessary). Launching is done by means of hydraulic winches placed on the front nose, (rope fixing point on the preceding pier). Material supply and construction cycle as for types a) and b).

Technical details

Gross weight: 550 tons

Capacity

- Max. span: 42 m (730 tons), for single span
- Min. horizontal radius: 450 m

Application

- San Nicola Viaduct, 1 x 774 m
- Le Grotte Viaduct, 1 x 421 m
- Cocollo Viaduct, see Fig. 18



Fig. 18

Two phase types

This launching system is designed by VRG (Joint venture for launching girders; Polensky & Zöllner and Strabag Bau AG). VRG also hires their girders. Today, many of this kind of girder are in use worldwide.

Concept

Launching is done in two steps. The central girder is used for transporting the two outer formwork girders, which are coupled rigidly together. The pair of pier brackets is shifted forward together with the formwork girders. Concreting and launching positions are shown on Fig. 19. Bottom forms are built as shuttering flaps.

The principle elements of the launching girders are:

- Formwork and launching girder at centreline of bridge (built as hollow box girder)
- Two formwork girders beside the piers including the formwork (box girders)
- Brackets at the front pier
- Suspension beam on the rear bridge deck cantilever

Supply of material to the site is done with a tower crane. The normal working cycle is 14 days per span. The method requires a special pier head design (see Fig. 20). Table 2 lists the technical details, capacity, applications and owners of some models.

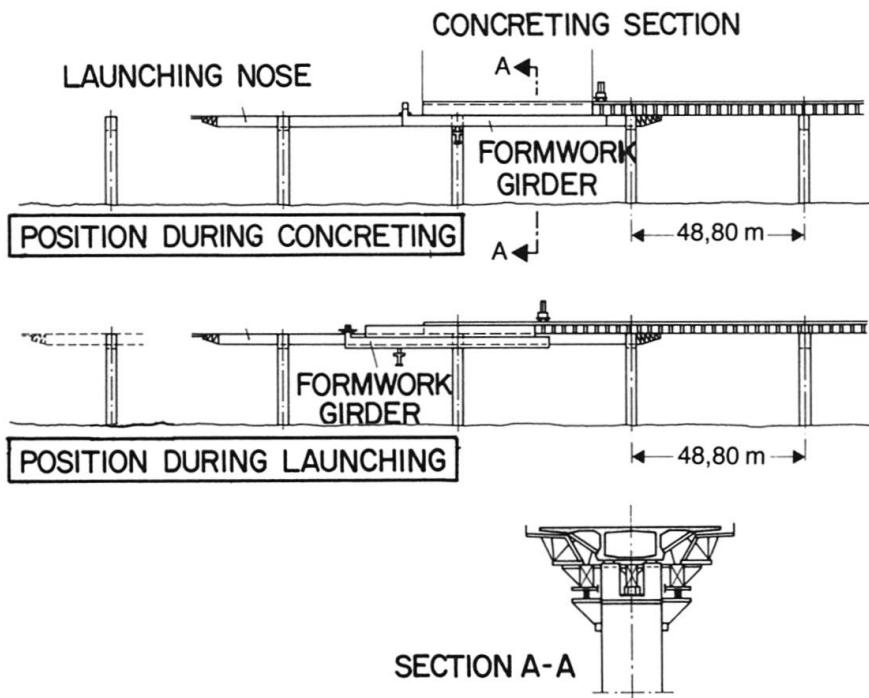


Fig. 19



Type	Capacity			Application	No. of re-uses	Owner
	weight (t)	max. span (m)	admiss. load (t/m)			
E	400	37.5	24	Kattenohl, Sürenhagen, Immecke, Eixendorf, Alzey, 1965-76, all in the FRG	5	VRG
F	450	45	25	Pleichach, Unterrieden, Krögersgrund, Pfeddersheim Ost, Keuschenbauer, Eversberg, 1964-81, all FRG except Keuschenbauer, Austria	6	VRG
G	430	45		Sterbecke, Eichelbleck, 1965-68, FRG	2	VRG, sold
H	510	47.5	26	Döllbach, Kattenbusch, Büschergrund, Alme, Pfeddersheim West, 1966-74, FRG	5	VRG
J	850	55.0	30	Vinxbach, Hammerboden, Brunnsbüttel, 1973-81, Hammerboden in Austria, others FRG	3	VRG
K	600	45.0		Danube Bridge Bratislava, 1980-	1	VRG Licensor and design

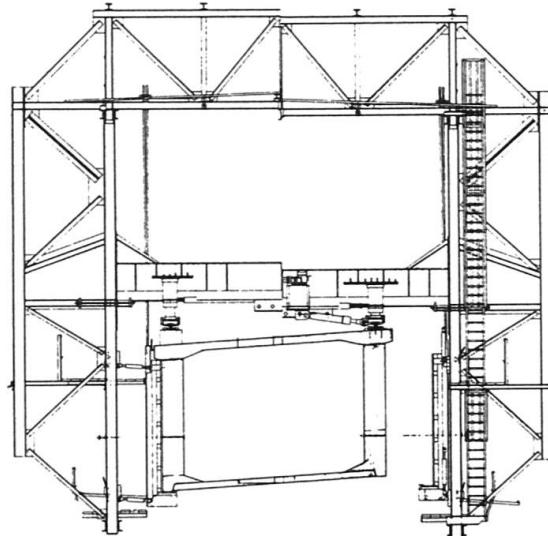
Table 2



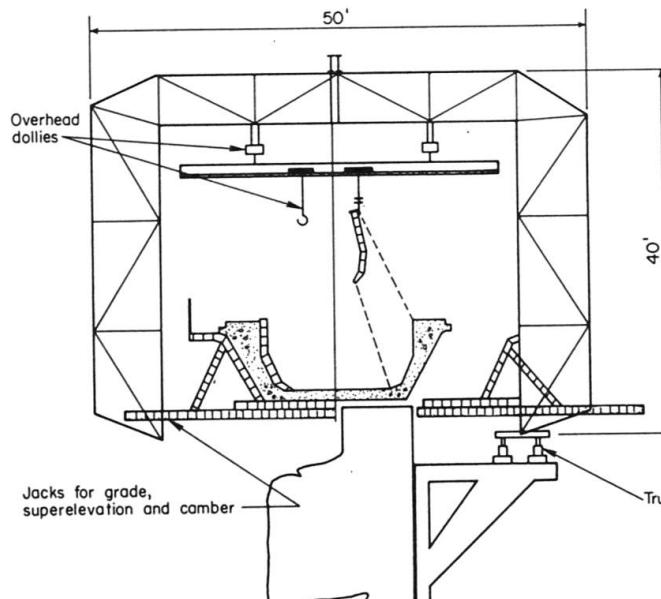
Fig. 20

4.3 Girders "between"

Typical examples are the girders used for Gruyère Viaduct (CH) and the Denny Creek Viaduct (USA). These two girders are described in detail in IABSE STRUCTURES C-17/81. Fig. 21 shows typical sections of the two girders. Both girders were used only for these bridges and could not be reused for others. Today, both are scrapped. (Some mechanical parts of the Denny Creek girder could be installed at the Seven Mile Bridge.)



Gruyère Viaduct



Denny Creek Viaduct

Fig. 21



FREE CANTILEVERING OF THE BRIDGE DECK

The use of a formwork launching girder at the free cantilever is suggested for bridges of this type with several spans. With this method, dismantling and re-erection of the travellers is avoided and in addition, the launching girder stabilizes the deck in the critical two-cantilever construction stage.

The post-tensioning layout is the same as for the conventional free cantilevering method. The free cantilevering is symmetrical. Construction cycle is one week per segment as for the conventional method, but segment lengths can be longer. (Thus, the construction time is shorter.)

The girder can be designed to take the concrete segment weight or just for transporting the self weight of the two forms. In the latter case, the girder is used only for transporting the forms and for the supply of material.

Bridge sections can be parallel box or arched box, since the launching girder is situated above the bridge deck. The starting segment at the pier head can be cast with the front form or be built in advance. The launching girder is built as a three chord steel truss (for bigger spans) or as a hollow box girder. The concreting carriages can be divided into two parts for passing the piers (see Figs. 22 and 23). For support, three roller brackets are necessary. Material supply is done by a crane trolley.

Curved bridges with small radii are possible ($R \text{ min} = 350 \text{ m}$). Adaption for different bridge deck widths is possible. Typical launching positions are shown in Fig. 24. The system was developed by VRG for the Siegtal Viaduct, FRG, and since then used several times in various countries.

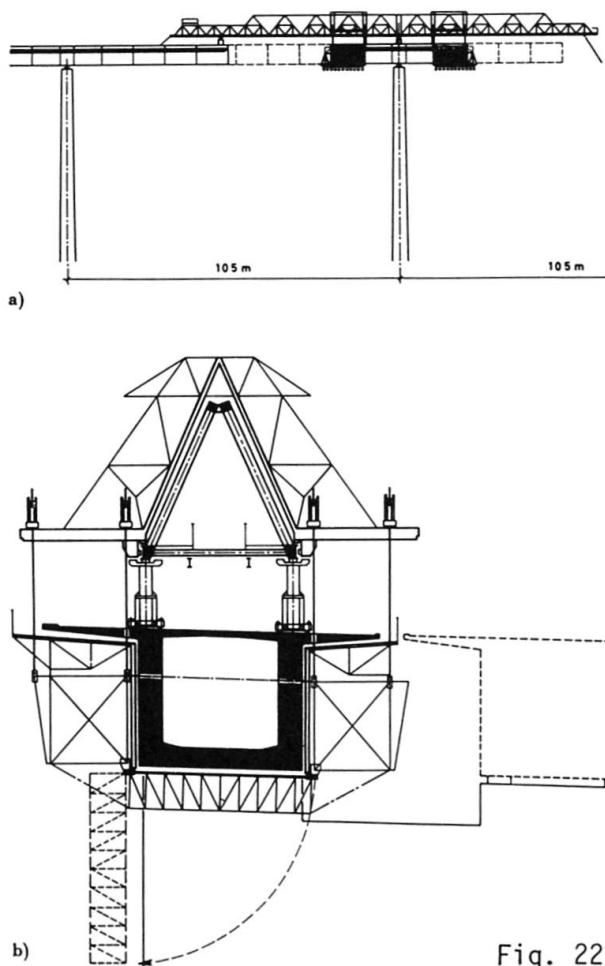


Fig. 22

Table 3 lists the details of several versions of formwork launching girders of this type.

Type	Technical details				Application	No. of re-uses	Owner
	weight (t)	length (m)	max. span (m)	segment length (m)			
L	560	135	105	10	Siegtal Viaduct Eiserfeld, 1966-69, FRG Köhlbrandramps, 1971-73 FRG	2	Polensky & Zöllner
	750		70	10			
M	465		100	10	Savio Viaduct, Italy, 1978-80	1	?
N	350	86	69	6.5	Gmünd Viaduct, Austria, 1974-76 Donnergraben Bridge, Austria, 1977-79 St. Pellegrino Viaduct, CH, 1981-	3	Pedretti
O	365		101	5.0	Gutachtal Bridge, FRG, 1979-81	1	Polensky & Zöllner
P			70.8		Larzenbach Viaduct, Austria, 1977-79	1	?
			84.5		Tonegawa Bridge, Japan, 1981-	1	

Table 3

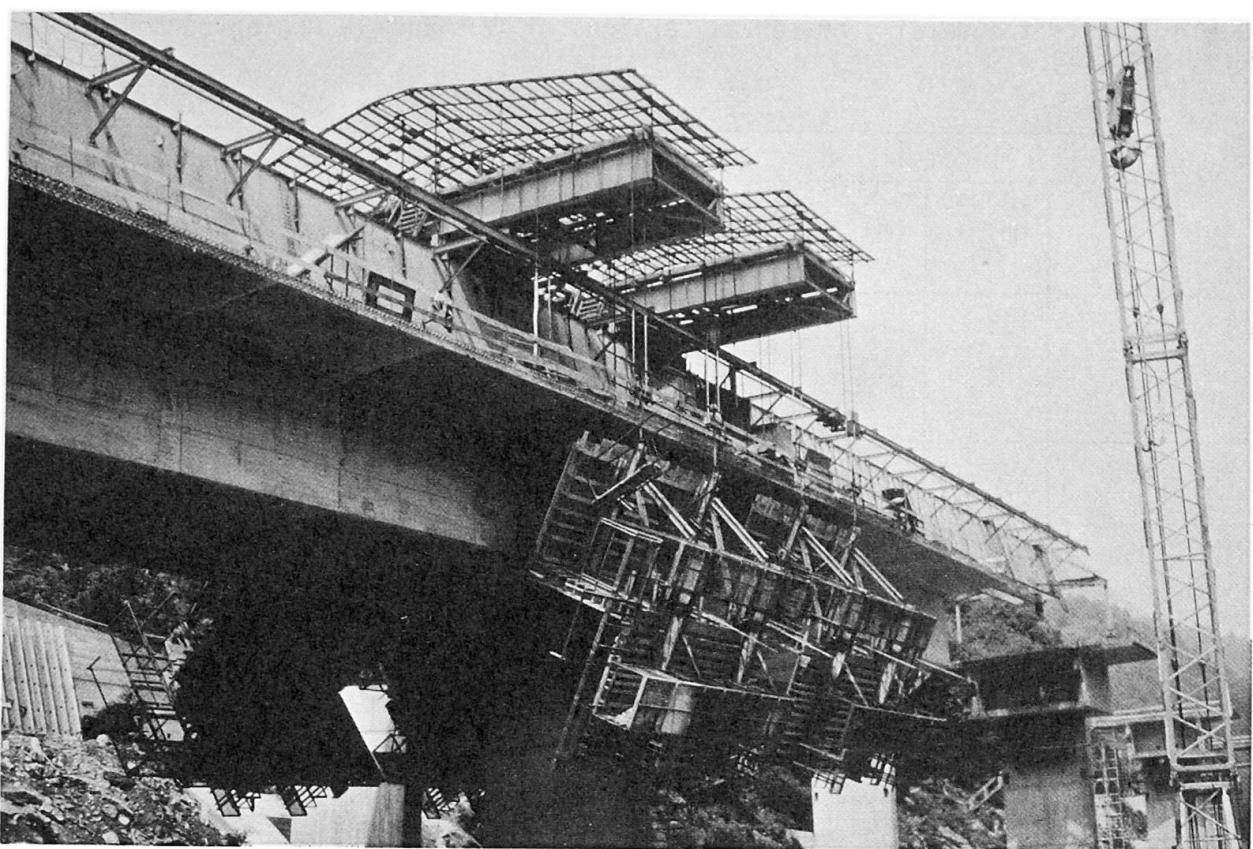


Fig. 23

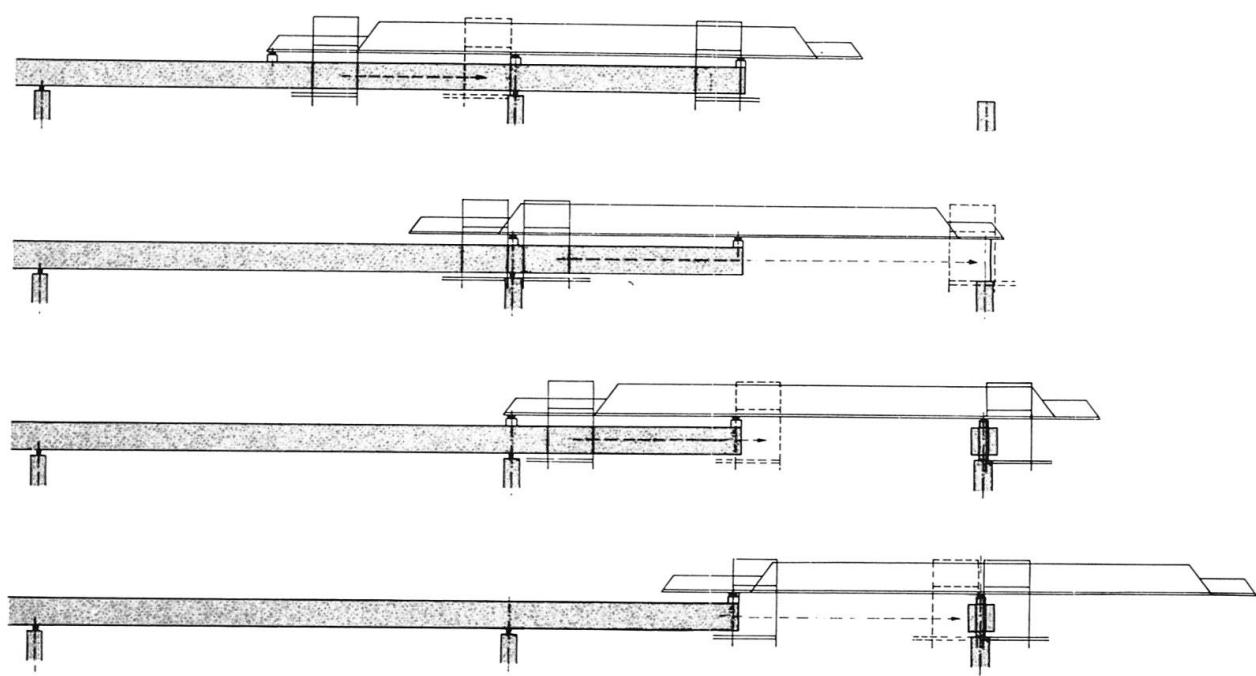


Fig. 24