Status of Segmental Bridge Construction in Europe

Describes the current use of major segmental construction techniques in Europe. Explanations are offered for the various levels of technological advancement, and examples are presented to demonstrate the wide scope of specific construction methods in use.

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Segmental bridge construction is a method in which concrete segments, either cast in place or precast, are post-tensioned together to form the superstructure of a bridge. Segmental construction methods can also be applied to beam or arch bridges in prestressed or reinforced concrete.

Although many variations are currently in use, only the three main construction methods will be discussed here: the span-by-span method (since 1960); the free cantilever method (cast in place since 1950; precast since 1962); and the incremental launching method (since 1962). Cable-stayed bridges will not be discussed here.

This paper is intended to be a description of the actual situation in Europe (see Fig. 1). The survey is based upon a study of available literature and contacts with several key individuals in the European bridge industry. Where objective statistics are unavailable, the author's subjective observations and comments are offered.

This review covers the situation in 18

Note: This paper is based on a presentation given at the Segmental Concrete Bridge Conference in Kansas City, Missouri, March 9-10, 1982. The Conference was sponsored by the Associated Reinforcing Bar Producers — CRSI, Federal Highway Administration, Portland Cement Association, Post-Tensioning Institute, and Prestressed Concrete Institute.

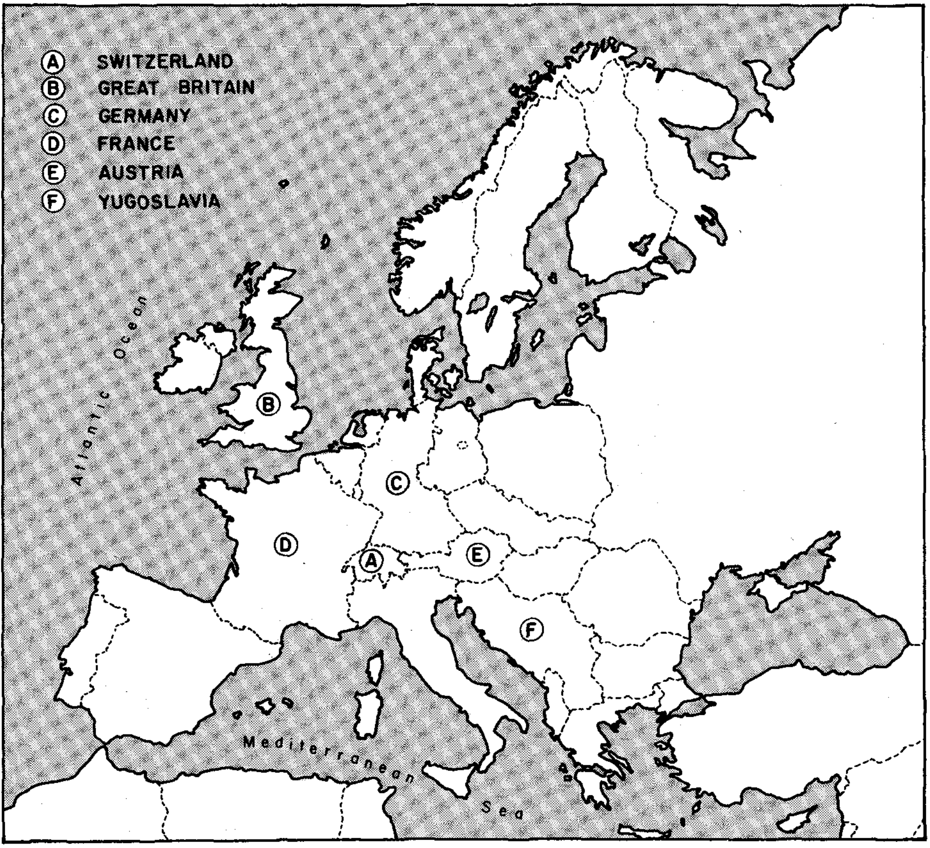

Fig. 1. Map of Europe showing location of countries whose bridges are included in the survey described in article.

Western European (OECD) countries, where more than 18 different languages are spoken. Information (gathered in 1980) comparing the size of Europe in relation to the United States is provided in Table 1. It can be noted that Europe, which is densely populated, achieves with 50 percent more people only 10 percent more in gross national product than the United States. Within Europe, the differences in GNP per capita are enormous, varying from $9244 down to $1901 (in U.S. dollars).

Clearly, Europe is far from being a single entity. A gap in technology between certain countries parallels the economic disparity. Wealthier countries, due to their higher labor costs, generally prefer labor-saving methods with high mechanization. Segmental construction was consequently developed in these countries and is applied to a much lesser extent in the less wealthy regions of Europe.

Right now, Europe does not have a unified standard in civil engineering, nor is it likely that such a standard will be established in the near future. Although a "Eurocode" is in the planning stages, the concept faces so many obstacles that the prospects for adoption do not appear very promising.

The Model Code published jointly by the CEB and FIP in 1978 certainly rep-

Table 1. Statistical comparison of Europe and the United States.

	Area (sq km)	Population (millions)	GNP (billion U.S. $)	GNP/Capita (billion U.S. $)
Europe (OECD)	3,594,320	350	2018	5766
United States	9,363,386	228	1832	8035

resents an excellent achievement. However, as indicated by the title, this is a model rather than a code for regular design work. The situation today is such that each country has its own standards.

It is only logical that differences in national character, economy, and standards have led to differences in construction practices as well. The large number of bridges needed and built during a relatively short period following World War II spurred the development of the wide variety of construction methods known today.

Statistical figures from the Federal Republic of Germany are indicative of European construction trends. Between 1965 and 1975, the total number of bridges in Germany increased by 7710, of which 4174 were prestressed concrete, 3262 were reinforced concrete, 77 were steel, and 197 were composite structures of steel and concrete. Perhaps even more revealing is a comparison of percentages of the areas of bridge decks built during this period:

Prestressed concrete	75.0 percent
Reinforced concrete	14.2 percent
Structural steel	6.7 percent
Composite steel-concrete	4.1 percent

The above figures, which show the importance of prestressed concrete in bridge construction, are applicable not only to West Germany but also to other European countries.

Although similar statistics from the United States were not available, a comparison of the consumed tonnage of prestressing steel in bridges during the decade from 1965 to 1975 appears significant. This comparison is presented in Table 2. Note that the production of prestressed concrete bridges in Europe was more than four times the production in the United States. This is perhaps one of the major reasons why Europe has been so innovative in this field.

WHY SEGMENTAL CONSTRUCTION?

Looking at the costs of concrete structures, the following average percentages stand out:

Labor	38 percent
Material	46 percent
Equipment	9 percent
Transportation	7 percent

Labor and material costs amount to more than 80 percent of the total cost of a project. The ratio of labor to material,

Table 2. Comparison of prestressed concrete bridge construction in Europe and the United States, based on consumption of prestressing steel.

	Total prestressing steel consumption	Prestressing steel per capita	Percent
United States	approx. 75,000 t	0.35 kg	100
Europe	approx. 500,000 t	1.46 kg	417

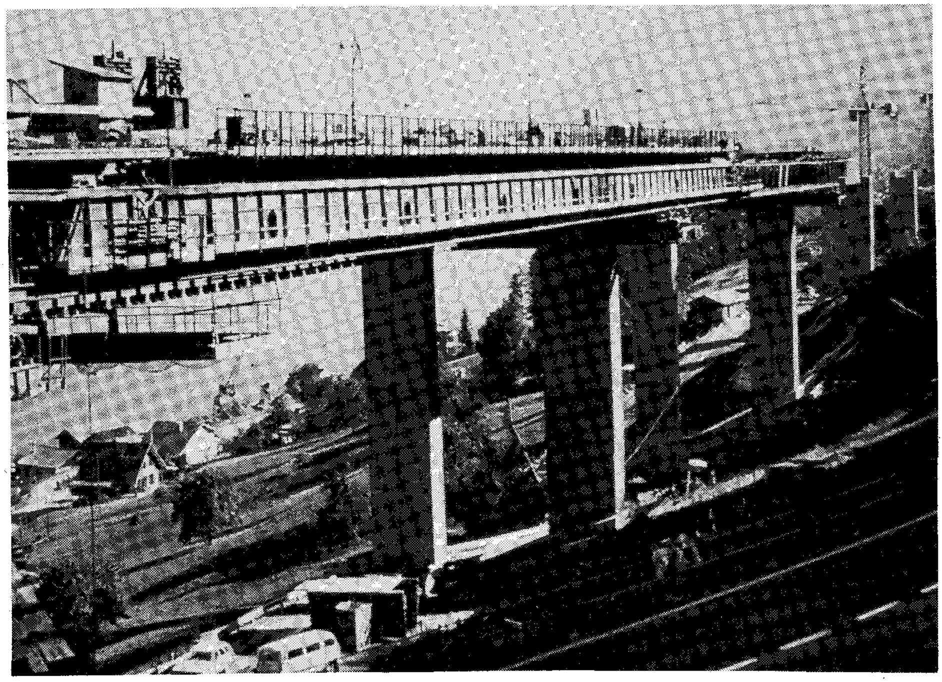

Fig. 2. Beckenried Viaduct, Switzerland.

approximately 45:55, has remained fairly constant for decades. Between 1950 and 1970, however, salaries increased approximately 500 percent and social welfare costs increased to an even greater degree; yet material costs for concrete or reinforcing steel increased only about 200 percent.*

A drastic reduction in man-hours over the years explains why the labor to materials cost ratio has remained constant. Reasons for the reduction include increased mechanization of construction sites, rationalization of single operations, and, last but not least, the development of efficient segmental construction techniques.

A highly repetitive, standardized construction cycle with a minimum of alterations throughout a particular job brings the number of man-hours to a minimum, due to the advantages of the learning curve. It is obvious, therefore, that the segmental construction method is competitive only if a bridge has a certain minimum length and a straightforward layout. Unusual topography or other conditions may also lead to the requirement of a segmental method.

One might question the need for several types of segmental construction methods and the reasons why one segmental method is not sufficient to cover all needs. It might also be argued that these methods have been developed in "old" Europe, therefore reflecting the in-grained customs of different regions or countries. However, examples show that, if correctly applied, all the different construction methods have their justification. Furthermore, it should be noted that the development of the various methods was made possible by the parallel development of the post-tensioning technique.

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*Internal documentation, Losinger Ltd., Berne, Switzerland.

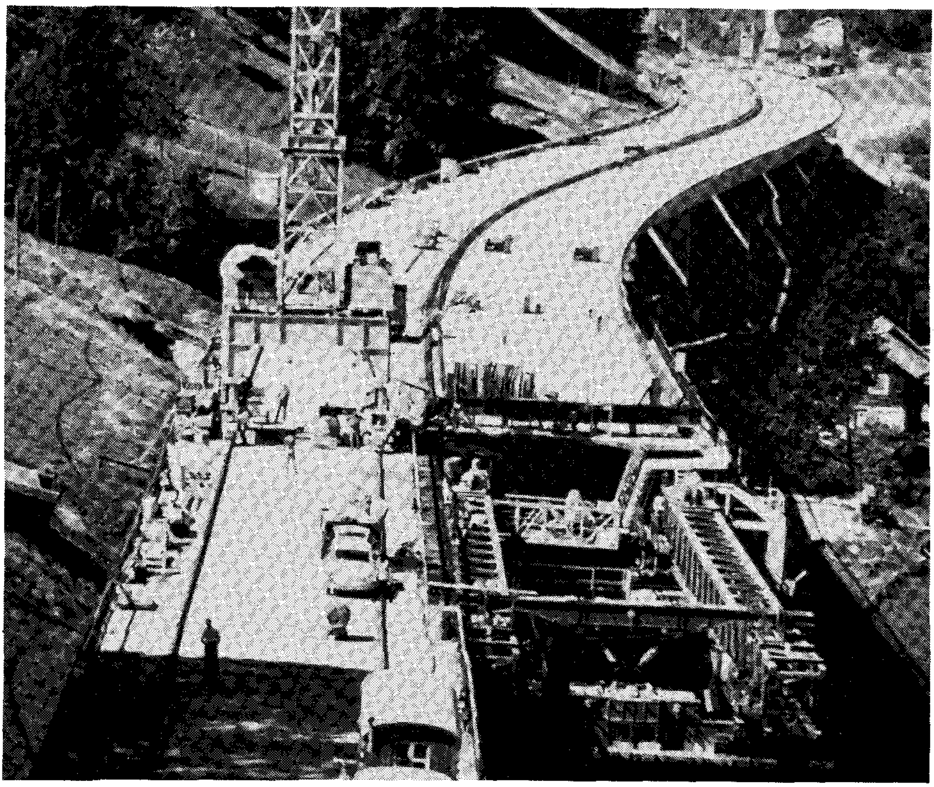

Fig. 3. Beckenried Viaduct, Switzerland.

SPAN-BY-SPAN METHOD

The span-by-span method, which uses a movable scaffold system, dates back to 1960. In the past 22 years, this construction technique has been used extensively in Europe, mainly in West Germany, Austria, and Switzerland. A variety of launching trusses have been developed, but basically two types can be distinguished, namely, the underlying type and the overlying type.

Figs. 2 and 3 show an underlying type of truss, which was used for the more than 10,000 ft (3048 m) long Beckenried Viaduct in Switzerland.[1] The viaduct has two parallel superstructures, each 35.4 ft (10.8 m) wide and having typical spans of 180 ft (55 m). It took two weeks to assemble one span. The total cost per launching truss (total weight about 750 tons each), including initial erection and dismantling, was about \$1.7 million or \$4.65 per sq ft of bridge deck (\$50 per m^2).*

Note that the movable scaffold systems were reused for a prestressed segmental bridge crossing the Tigris River in Iraq.

Fig. 4 shows an overlying type of truss which was used for the Ahrtalbridge in West Germany. It was designed for a maximum span of 348 ft (106 m). The truss, without formwork, weighed about 2100 tons. The bridge, completed in 1976, has a total length of 5000 ft (1500 m) and consists of two parallel structures with a width of 49.5

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*This and subsequent cost indications are taken either from available literature or the best estimates of the author.

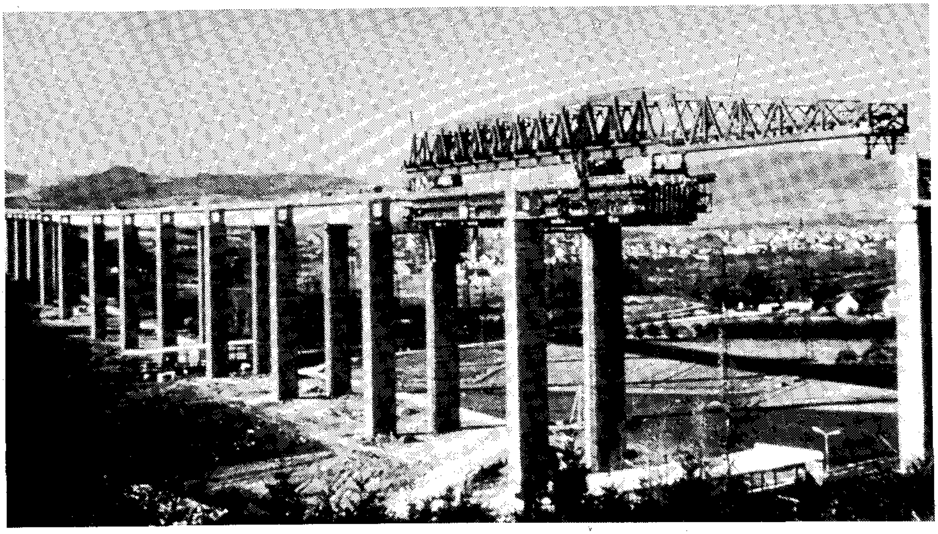

Fig. 4. Ahrtalbridge, Federal Republic of Germany.

ft (15.1 m) each. To the author's knowledge, the truss was never reused. This means that the cost, at least $4.5 million or $9.30 per sq ft ($100 per m²), had to be depreciated on this job.

A compromise was found for the construction of the more than 6700 ft (2000 m) long Gruyère Viaduct in Switzerland, which was built from 1975 to 1979. The typical span is 198 ft (60.5 m) and the superstructure consists of a single box with a deck slab 78 ft (23.7 m) wide (see Figs. 5, 6, and 7).

For this project, the segmental principle was amplified in that the superstructure was subdivided not only longitudinally, but also transversally. A comparatively light movable scaffold system with a total weight of about 660 tons was used to cast the box only within a 3-week cycle. Note that of the system's total tonnage, about 505 tons were structural steel and the rest were for formwork, working platforms, roof cover, equipment, and counterweight. The cantilever slabs and their supporting ribs were constructed by a separate movable carriage following about 650 ft (200 m) behind. Stages of 32.8 ft (10 m) were completed every third day, so that the same rate of progress was achieved for both the box and the side slabs (Fig. 8).

A special feature of the chosen concept is the bottom slab of the concrete box girder, made from precast panels. This allowed the elimination of the costly, heavy, tiltable bottom slab formwork, resulting in a relatively light launching truss.

The total costs of the movable scaffold system and the cantilever carriage, both tailor-made for this project, amounted to $1.4 million, or $2.80 per sq ft ($30 per m²). With the exception of some mechanical and hydraulic equipment, the truss was never used again and was subsequently scrapped.

It is the author's belief that the span-by-span method is very feasible for a span range of 100 to 200 ft (30 to 60 m) and a minimum bridge length of 3300 and 6600 ft (1000 and 2000 m), respectively. Experience has shown that a contractor should try to depreciate such equipment on his first job, unless he has guarantees for future applications.

Compared with other segmental methods, the following characteristics can also be noted:

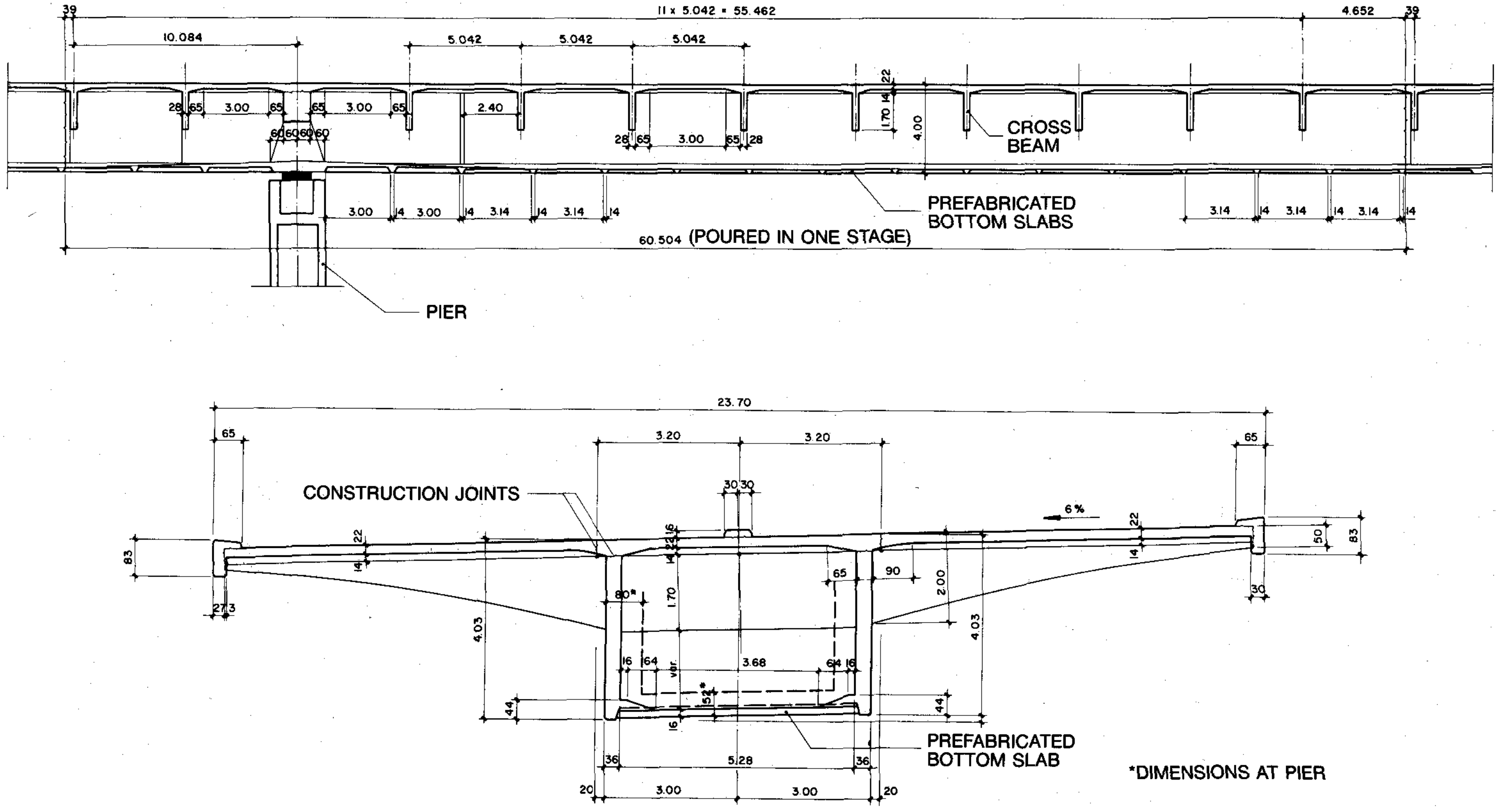

Fig. 5. Gruyère Viaduct, Switzerland. Longitudinal section (top) and cross section at midspan (bottom).

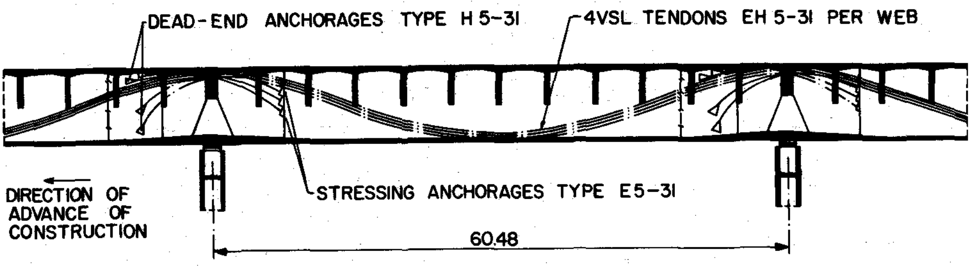

Fig. 6. Gruyère Viaduct, Switzerland. Typical layout of post-tensioning tendons.

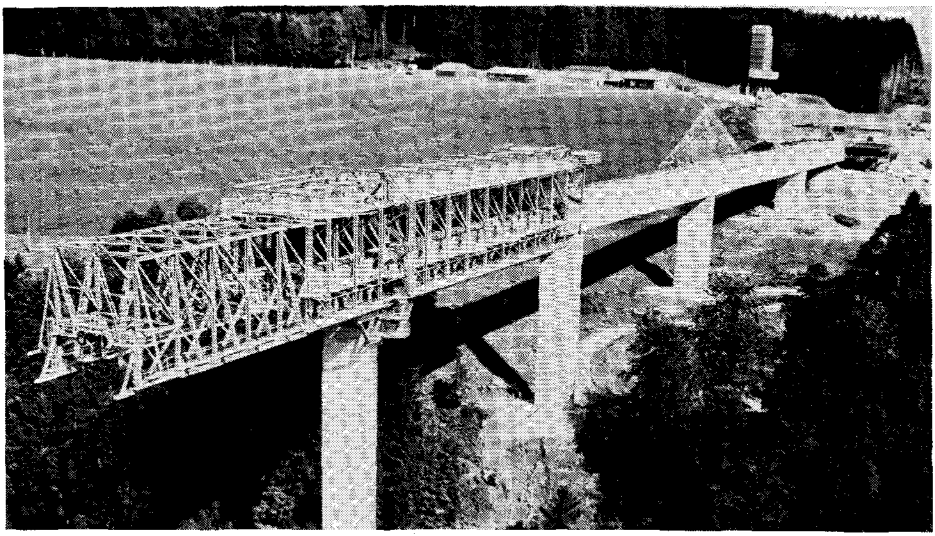

Fig. 7. Gruyère Viaduct, Switzerland. Launching truss in operation.

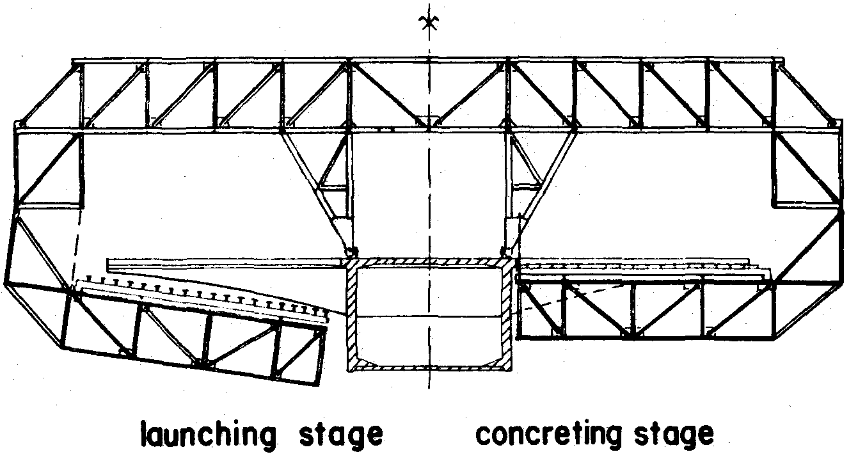

Fig. 8. Gruyère Viaduct, Switzerland. Formwork carriage.

- The materials (concrete, reinforcing and prestressing steel) needed can be minimized because the superstructure is constructed in its final position and very close to the final statical system. This is particularly true when the very successful concept of partially prestressed concrete is applied, which unfortunately is still not yet permitted in all European countries.
- Variations in superstructure geometry (varying horizontal and vertical curvatures, etc.) are more easily accommodated than with other segmental methods.

To combine a launching truss with precast segments is not yet very common in Europe. The use of unbonded tendons and dry match-cast joints might change this. An obvious advantage of this procedure would be rapid construction.

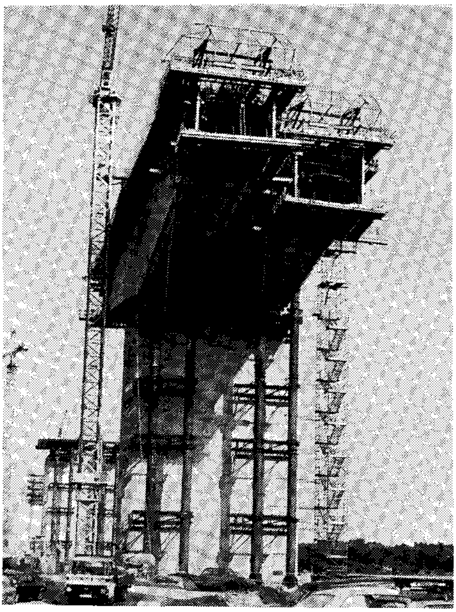

Fig. 9. Orwell Bridge, United Kingdom.

FREE CANTILEVER METHOD

In this section both the cast-in-place and precast methods of free cantilever construction are considered.

Cast-in-Place Method

For spans between 330 and 850 ft (100 and 260 m) and under difficult topographical conditions such as deep valley or river crossings, the free can-

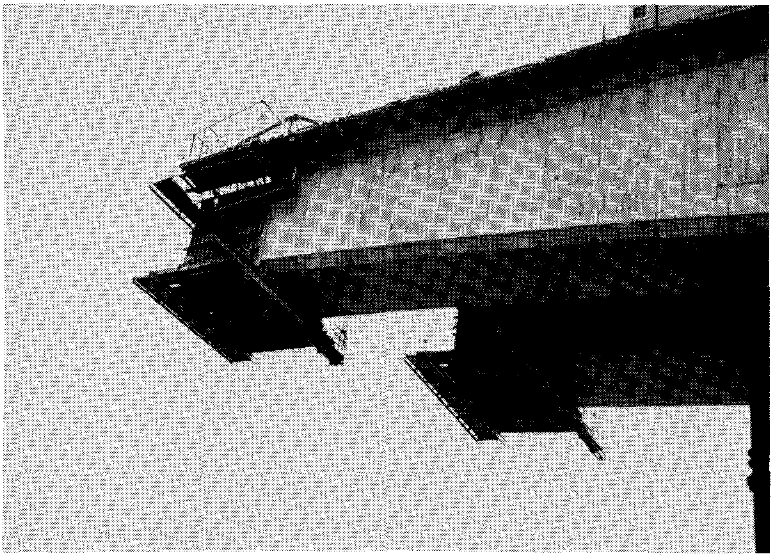

Fig. 10. Orwell Bridge, United Kingdom.

tilever cast-in-place method is often the only feasible solution. Numerous successful applications can be found in almost all European countries. With the increased knowledge of creep behavior and the elimination of hinges at midspan, this type of bridge construction is generally accepted.

The river spans of the Orwell Bridge in the United Kingdom were built using the classical technique (Fig. 9), while the approach spans were constructed using the span-by-span method. The river crossing has a length of 1318 ft (402 m) with spans of 348 - 632 - 348 ft (106 - 190 - 106 m). This portion of the bridge was constructed in segments of maximum length 17 ft (5 m) in a one-week cycle.

The four travellers were of a standard design and had already been used for the Reichsbridge in Vienna. A pair of travellers of this type costs approximately $275,000. For the Orwell Bridge, this amounted to $2.65 per sq ft ($28.5 per m^2). Prospects for reuse of the travellers are generally quite good, at least for the upper parts, and especially if a standard design has been applied (Fig. 10).

An interesting variation of this technique was used for the spectacular Kochertalbridge in West Germany, which was built between 1977 and 1979. The structure has received worldwide attention largely because it bridges a fairly wide valley at a height of at least 600 ft (185 m). Another reason is certainly the applied construction technique. The design of the structure was the result of an alternative proposal presented by a joint venture of two German contractors. The total length is 3700 ft (1129 m) with maximum spans of 453 ft (138 m) and a deck width of 100 ft (30.5 m) (see Figs. 11 and 12).

The superstructure was built in two stages. Only the box was built in the first stage; in the second phase the oblique struts and the cantilevering deck slabs were installed with a mov-

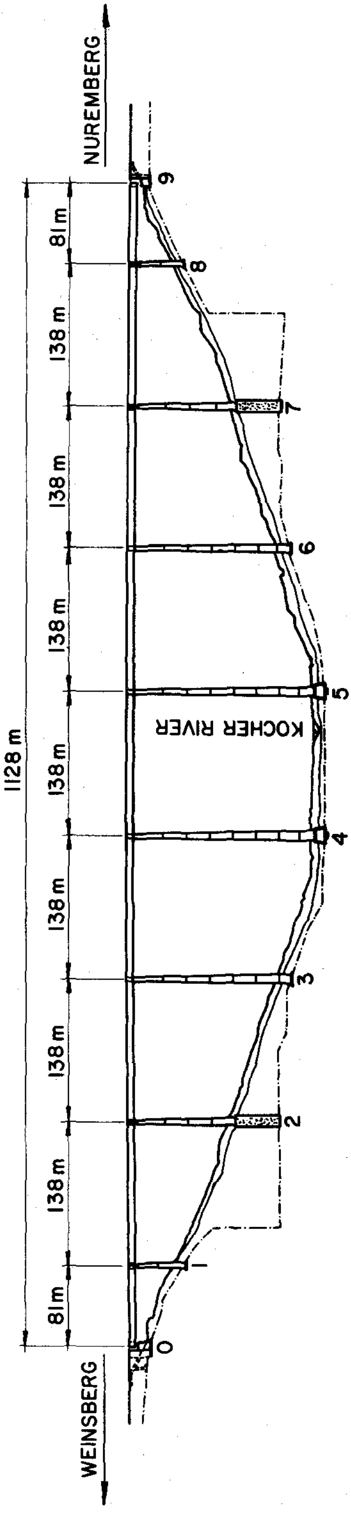

Fig. 11. Kochertal Bridge, Federal Republic of Germany.

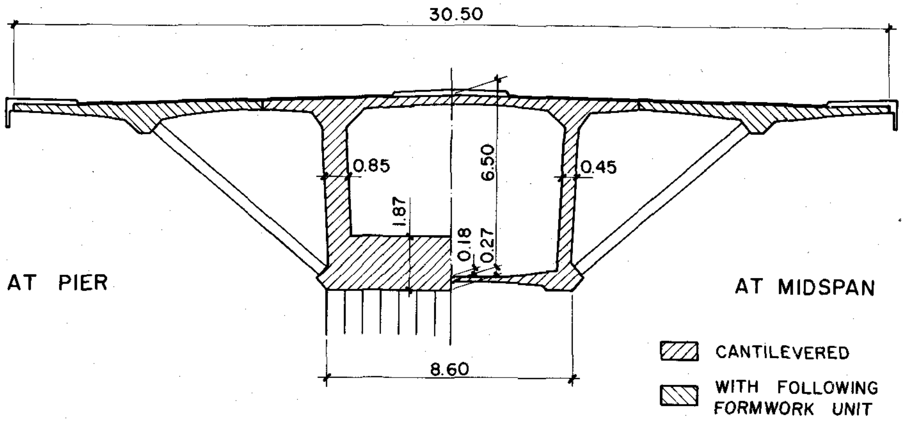

Fig. 12. Kochertal Bridge, Federal Republic of Germany.

able formwork carriage. Cantilever construction at a height of more than 600 ft (180 m) naturally imposes special requirements in regard to the equipment used and the transportation of material.

The optimum solution was found by introducing an auxiliary overlying steel girder (Figs. 13 and 14) which served a double purpose. First, it allowed material to be transported from the abutments to the travellers. Additionally, once an entire cantilever was completed, the underlying travellers (Fig. 15) were suspended on the auxiliary girder and moved to the next pier. The contractor obviously found it feasible to invest more money in equipment in order to speed up construction and reduce transportation costs.[2]

Many other bridges built by the cast-in-place free cantilever method deserve to be mentioned. The Ganter Bridge at Simplon Pass in Switzerland is certainly one of them. The 2225-ft (678 m) long bridge is double-curved in plan, crosses a deep valley with piers up to 400 ft (124.5 m) high, and has a maximum span of 570 ft (174 m)[3] (see Figs. 16 and 17).

A final example is the Gateway Bridge, currently under construction in Brisbane, Australia. Although the bridge is built far from Europe, the design of the river spans is European. The main span of 852.2 ft (260 m) will set a new world record and will be constructed by the free cantilever cast-in-place method (Fig. 18). The largest travellers designed to carry a load of more than 400 tons will be used. The superstructure has a 73.5 ft (22.42 m) wide deck slab and consists of a single cell box with a height of 49.2 ft (15 m) at the piers and 17 ft (5.2 m) at midspan. A cable-stayed bridge was not possible because the bridge shape was dictated by an upper limitation due to air traffic from the nearby Brisbane airport as well as the shipping clearance.[4]

Precast Method

The major impetus for precast segmental construction in the western world came from France. Table 3, based on 1980 figures,[5] summarizes the bridges described in the technical literature. The authors of this very comprehensive study made the following comment:

"The table shows a great variety of execution possibilities both with regard

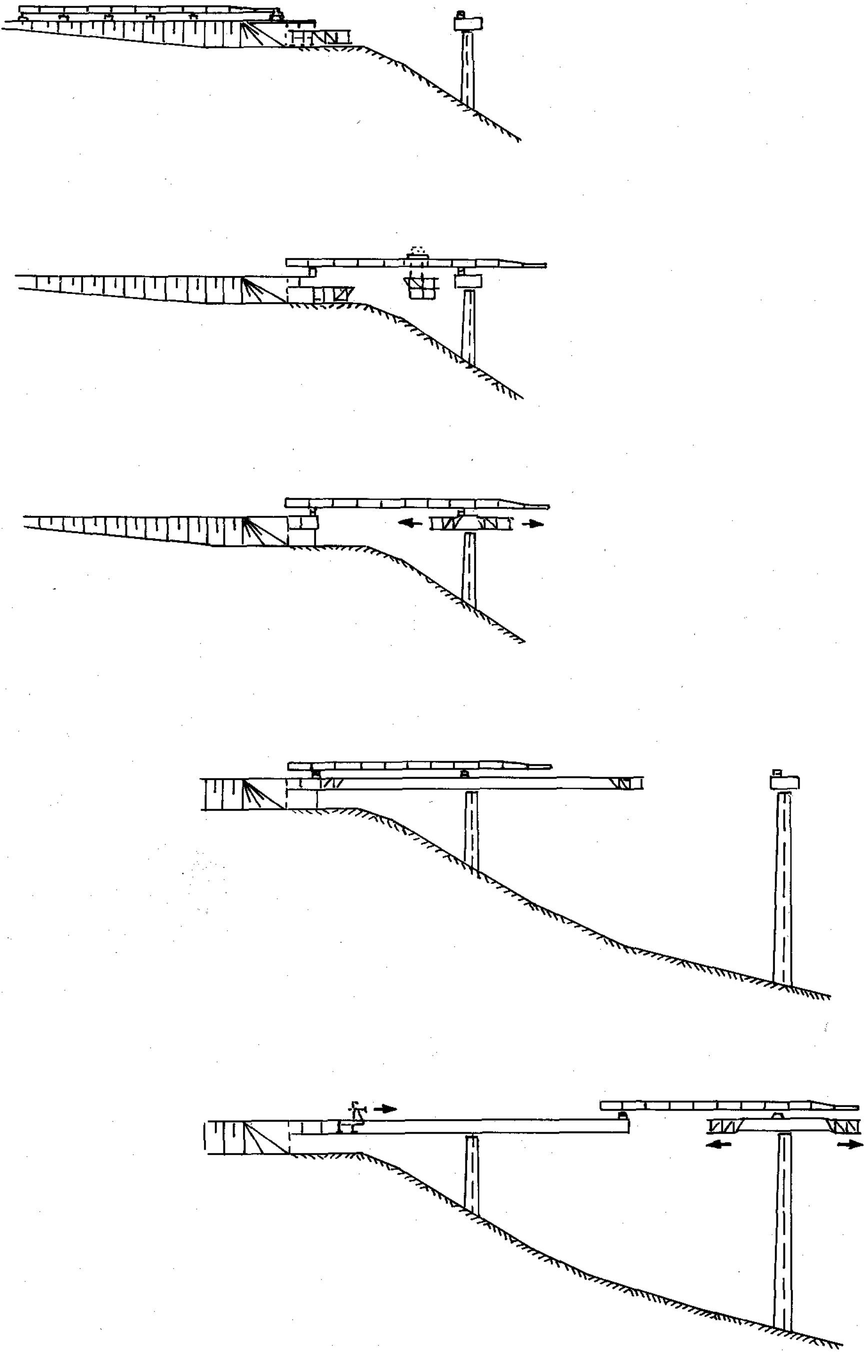

Fig. 13. Kochertal Bridge, Federal Republic of Germany. Construction sequence.

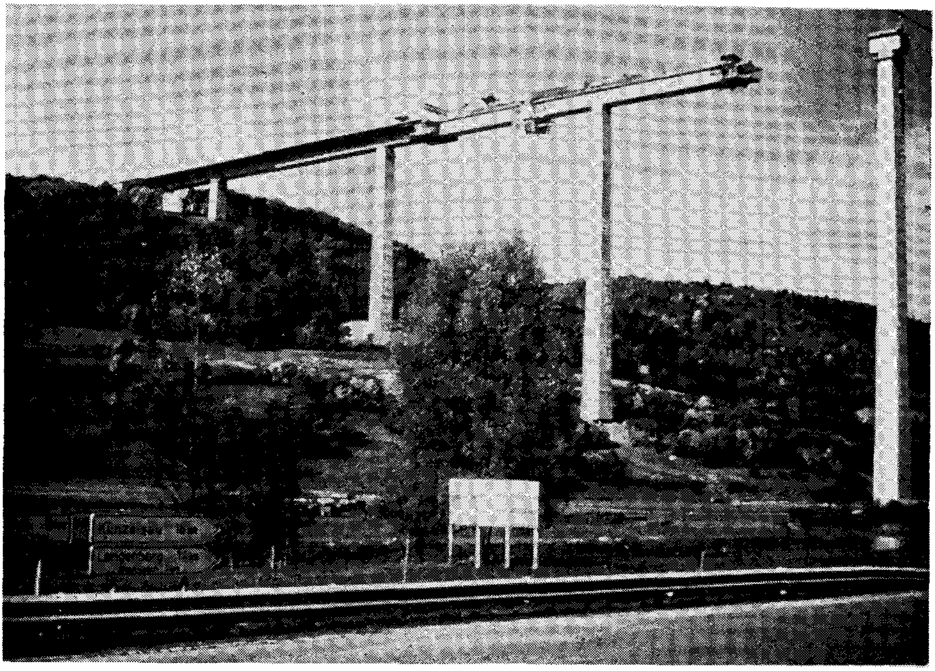

Fig. 14. Kochertal Bridge, Federal Republic of Germany.

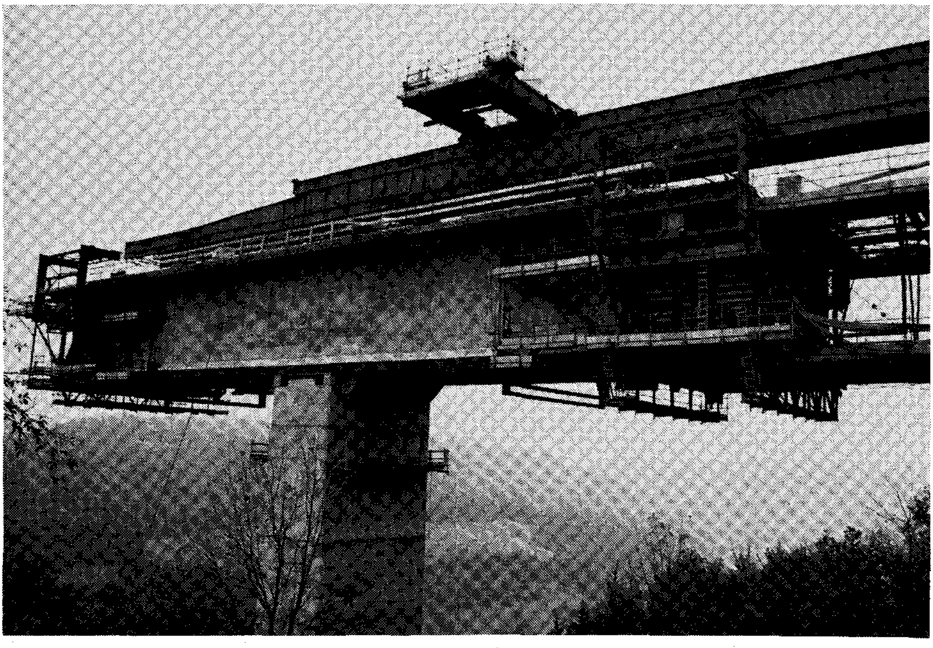

Fig. 15. Kochertal Bridge, Federal Republic of Germany.
Launching girder and travellers.

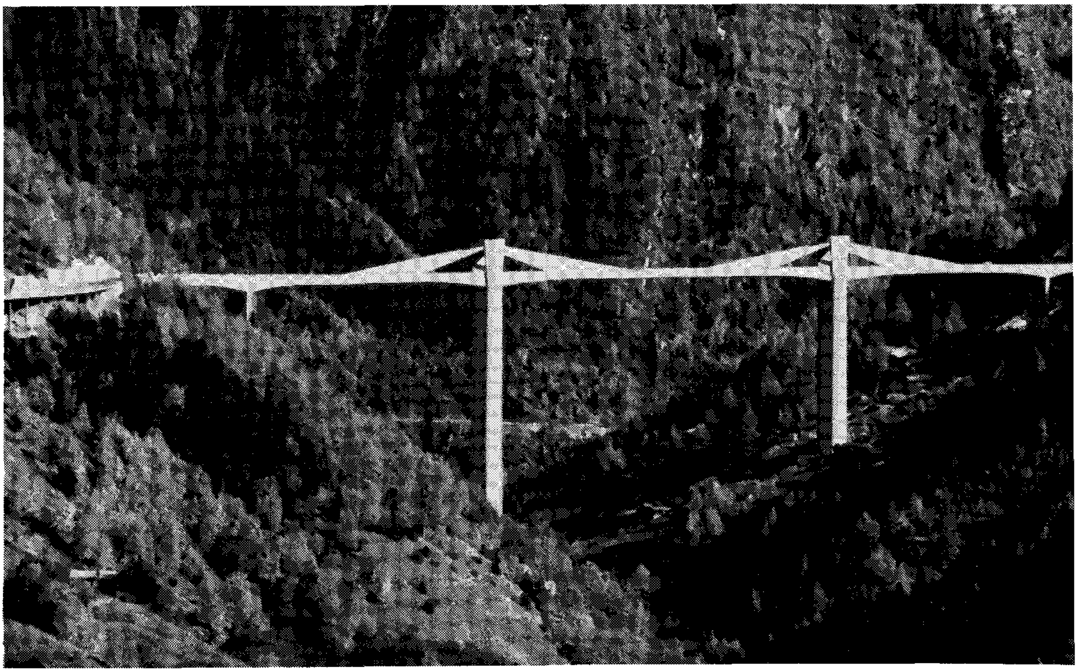

Fig. 17. Ganter Bridge, Switzerland.

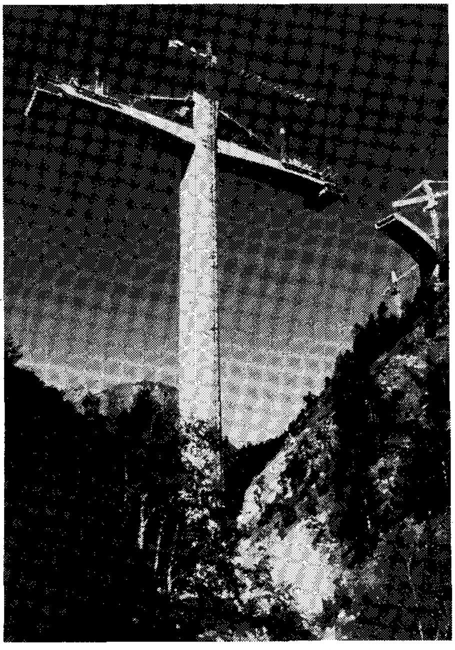

Fig. 16. Ganter Bridge, Switzerland. Piers are up to 400 ft (124.5 m) high.

to the erection technique and the type of joint. With 98 bridges the match-cast joint with epoxy resin joining material plays a dominant role. The leading position of France is obvious. It was however noted that in the last five years in France especially for main spans of more than 300 ft (100 m) the cast-in-place free cantilever method has re-established its dominance. This development was probably influenced by the relatively short total length of the bridges in question and by the fact that the cast-in-place construction has become faster. The scarce application of the precast segmental technique in Germany can be explained by the topographical situation which seldom requires very long bridges. On the other hand, there was so far no DIN-standard allowing this form of construction and this was probably an even stronger reason."

In West Germany, a comprehensive

Table 3: Prestressed concrete bridges with precast segmental superstructures [beyond 130 ft (40 m) main span and without reinforcement through the joints].

Method of Erection					Type of Joint				
					Thin Joint		Thick Joint		
	Free cantilevering	Others without scaffolding	On scaffolding	Dry joint	Epoxy resin	Cement mortar	Cement mortar	Micro concrete	Total
France	41	9	1	—	44	—	7	—	51
F R G	1	—	3	—	2	—	2	—	4
Rest of Europe Incl. USSR	35	3	5	2	31	—	7	3	43
Countries outside Europe	23	—	6	—	21	1	—	7	29
Total	100	12	15	2	98	1	16	10	127

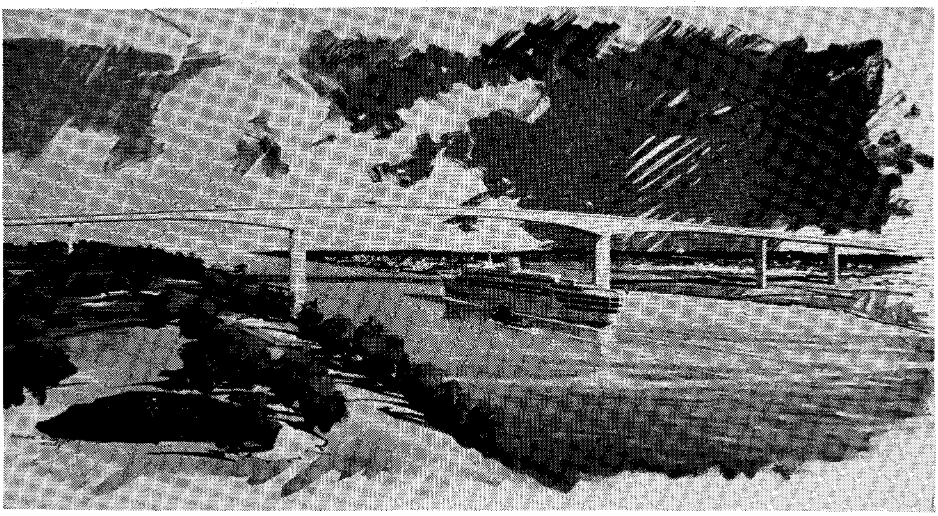

Fig. 18. Gateway Bridge, Australia, river span 852.2 ft (260 m).

draft of DIN-standard 4227 Part 3E, regarding the precast segmental method, exists and its final version is expected in due course. Highlights of the report include the following:

- Microconcrete is mentioned in addition to epoxy resins as a jointing material. The maximum thickness is limited to ⅙ in. (4 mm).
- At serviceability limit state in tension zones a minimum compression stress of 145 psi (1 MPa) must be maintained, even under additional temperature gradient loading.

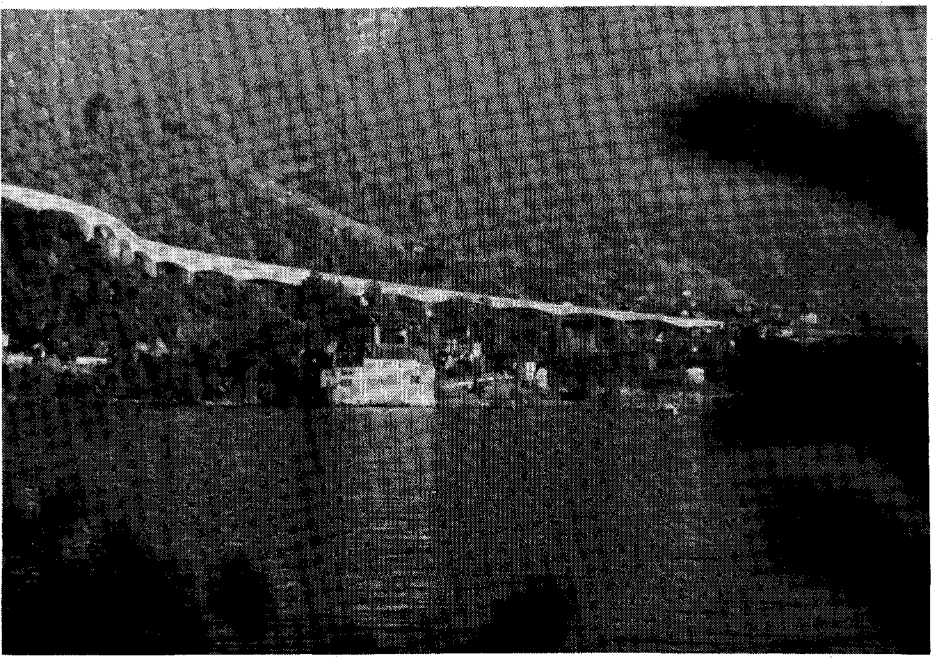

Fig. 19. Chillon Viaduct, Switzerland.

- If a joint is located above a support or less than half of the beam height away, the minimum compression stress must be increased 217.5 psi (1.5 MPa).
- It must be demonstrated by calculation that under a certain load combination the developing crack width is not more than 1/170 in. (0.15 mm).
- Within the joints, ducts of post-tensioning tendons should be coupled. If this is impossible, other measures should be taken to guarantee the seal of the duct.
- The insulation of the bridge deck must be improved locally, above the joints.

Obviously, these requirements (when finally adopted) will be far more stringent than current practice in other countries, such as France.

Switzerland was among the first countries to apply the precast segmental method for construction. The Chillon Viaduct, built between 1966 and 1969, has a total length of 6900 ft (2100 m) and consists of two parallel superstructures each 42.6 ft (13 m) wide (see Fig. 19). The precast elements were made in five formwork batteries (using the short-line method) and the erection was done using an overhead launching truss with a total weight of about 230 tons and a maximum lifting capacity of approximately 80 tons (Fig. 20). The total cost (1982 prices) for the five formwork units and the launching girder is estimated at $1.7 million, or $5.77 per sq ft ($62 per m^2).

This project began during the early days of the epoxy-jointing technique, and material problems occurred after a certain period. The designer was compelled to develop a microconcrete, which was successfully used for the remaining spans.

Although the Chillon Viaduct is esthetically one of the most pleasing structures in Switzerland and the method was later recommended for use on a number of other bridges, it was

Fig. 20. Chillon Viaduct, Switzerland.

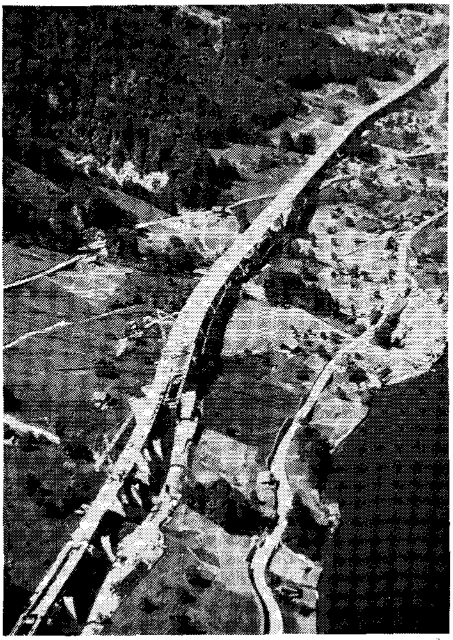

Fig. 21. Beckenried Viaduct, Switzerland.

never again successful. The Beckenreid Viaduct, which actually should have been ideal for precast segmental construction, is an example (Fig. 21). In fact, one of the bidders suggested a precast segmental solution but was underbid by the span-by-span proposal.

In recent years, the grouting of post-tensioning tendons has become a major issue in Europe, as its decisive importance for the durability of a bridge has been rediscovered. It is well known that precast segmental construction requires special attention with regard to the grouting technique. Some projects have experienced inter-connections in the joints and groups of ducts have had to be simultaneously grouted.[6]

It is obvious that these problems could be avoided if the ducts were coupled in the joints. Proposals and a few applications are known, but to the author's knowledge they have all been given up as unfeasible. It will be interesting to see how this problem will be solved in West Germany when requirements for a tight duct connection are adopted.

The Byker Viaduct in Newcastle, Great Britain, is a more recent example of the precast segmental method. It is a single box girder bridge, 2625 ft (800 m) long, with horizontal and vertical curves and carrying two tracks of a Metro line. The three longest spans of 226 ft (69 m) and the two adjacent spans were built as balanced cantilevers from the four main piers. The other approaching spans of 173, 169, and 119 ft (52.8, 51.6, and 36.3 m) were constructed as continuous cantilevers with temporary supports.

The 253 segments, each approximately 10 ft (3 m) long, were precast on site and erected using a simple hoist. The joints consist of epoxy resin combined with layers of fiberglass to correct the alignment at the construction stage.

The microconcrete mentioned earlier (trade name "Tixojoint") was later used again as a jointing material for other precast segmental bridges, including the General Belgrano Bridge[7] and Viaducts Motorway Udine-Carnia-Tarvisio in Italy. It is a pure mineral material made of special aluminous cement, quartz sand, water, and additives. It has the same physical properties, mechanical behavior, and internal stability as the surrounding concrete and meets the requirements for a jointing material. The joint thickness resulting from the use of microconcrete is $^{1}/_{12.5}$ in. (1 to 2 mm).

In summary, the precast segmental technique has been successfully applied for many years in some countries, whereas a considerable reluctance can be noticed in others. It is the author's belief that if a bridge has a certain minimum length, if a high construction speed is required, and if in design and construction the particularities of the technique are respected, the precast segmental method certainly is advantageous.

INCREMENTAL LAUNCHING METHOD

The incremental launching method dates back to 1962 when the Caroni Bridge was built in Venezuela. The method as it is applied today was first used in 1965 for the Kufstein Inn Bridge in Austria. Since that time, more than 200 bridges have been constructed using this technique. Interestingly enough, only one bridge of this kind has been built in the United States. Straight or uniformly curved bridges (vertical and horizontal) with regular spans from 100 to 300 ft (30 to 60 m) and a minimum length of 500 to 650 ft (150 to 200 m) are very well suited to be pushed out from a stationary production plant.

The advantages include savings in man-hours and a relatively modest investment in equipment. On the other hand, material needs (concrete, reinforcing and prestressing steel) are greater than if the superstructure were built by the span-by-span method.

A recent example is the Steinaggertal Bridge in West Germany, which was completed in 1981. It consists of two parallel superstructures, each 1540 ft (469.5 m) long and 49 ft (15 m) wide with typical spans of 156 ft (47.5 m). The cost for special equipment (e.g., the launching nose, stationary formwork, etc.) required for such a bridge is approximately $240,000, or $1.58 per sq ft ($17 per m^2), a relatively modest sum compared with other techniques.

For the Steinaggertal Bridge, the longitudinal slope was 5 percent and the fabrication area could only be accommodated at the upper end (Fig. 22). A special pushing and hold-back device had to be developed and it worked as

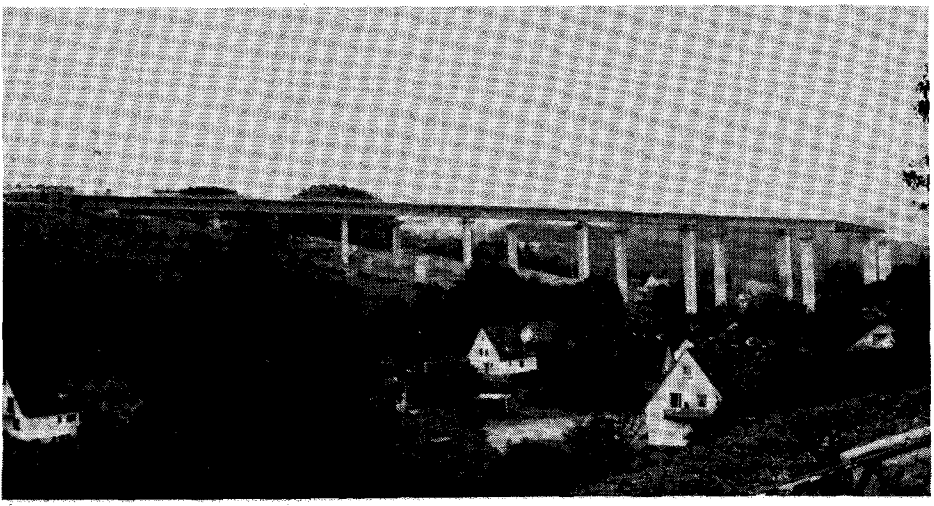

Fig. 22. Steinaggertal Bridge, Federal Republic of Germany.

intended. The construction speed is comparable to the span-by-span method. Segments of 50 to 80 ft (15 to 25 m) in length can be constructed in a one-week cycle.

The Danube Bridge at Wörth demonstrates that spans up to 660 ft (168 m) are possible if temporary supports are used. The 1325 ft (404 m) long bridge consists of two parallel superstructures which were both pushed longitudinally out of the stationary formwork. This necessitated a subsequent transversal push on one of them. Each superstructure weighed about 16,200 tons.

Experience in Europe has shown that, under proper circumstances, the incremental launching method is the most economical method for bridge construction.

ARCH BRIDGES

The recent development of arch bridges is a good example of segmental construction techniques. Arch bridges have been built on scaffolding for many years. Many of these scaffolding systems were masterpieces, as, for example, the famous Salginatobel Bridge in Switzerland, designed by R. Maillart (Fig. 23).

An interesting variation was used for the Lorraine Bridge in Switzerland (1929; also designed by Maillart) where precast concrete blocks were used for the first time to form the bearing arch. Erection of the blocks began at the centerline of the bridge and moved toward the outer sides of the arch. As a result, the scaffolding could be much lighter because the arch itself took most of the load once a complete row of blocks was in place.

After World War II, as labor costs became a major factor, arch bridges became less common. Only in recent years has a certain revival been noticed, due perhaps to the segmental construction technique. Two examples are provided to demonstrate this.

The Krk I Bridge in Yugoslavia, built between 1976 and 1979, presently holds the world record for concrete arches, with a 1280-ft (390 m) span. The three-cell arch was made primarily of precast elements 16.4 ft (5 m) long and jointed together with cast-in-place concrete joints. The cantilevering technique using temporary stays was applied to erect the arch (Fig. 24).

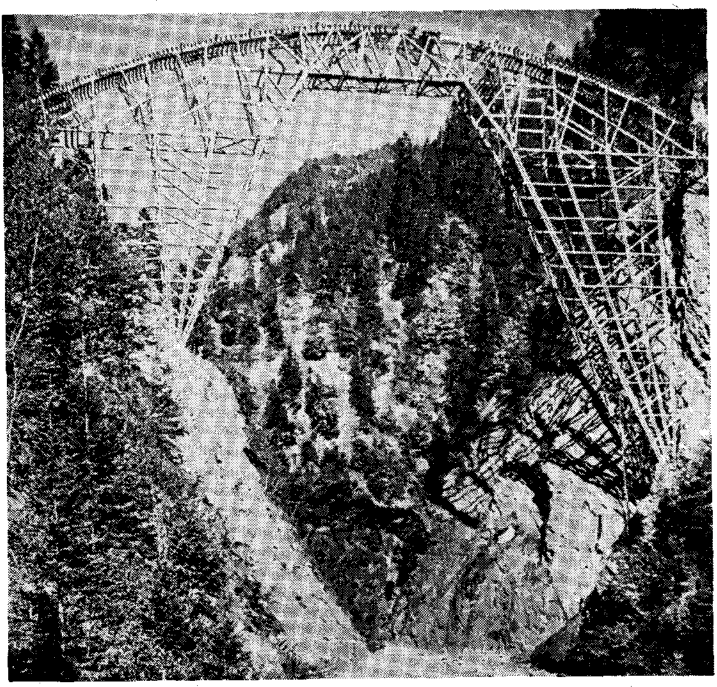

Fig. 23. Salginatobelbridge, Switzerland. Scaffolding.

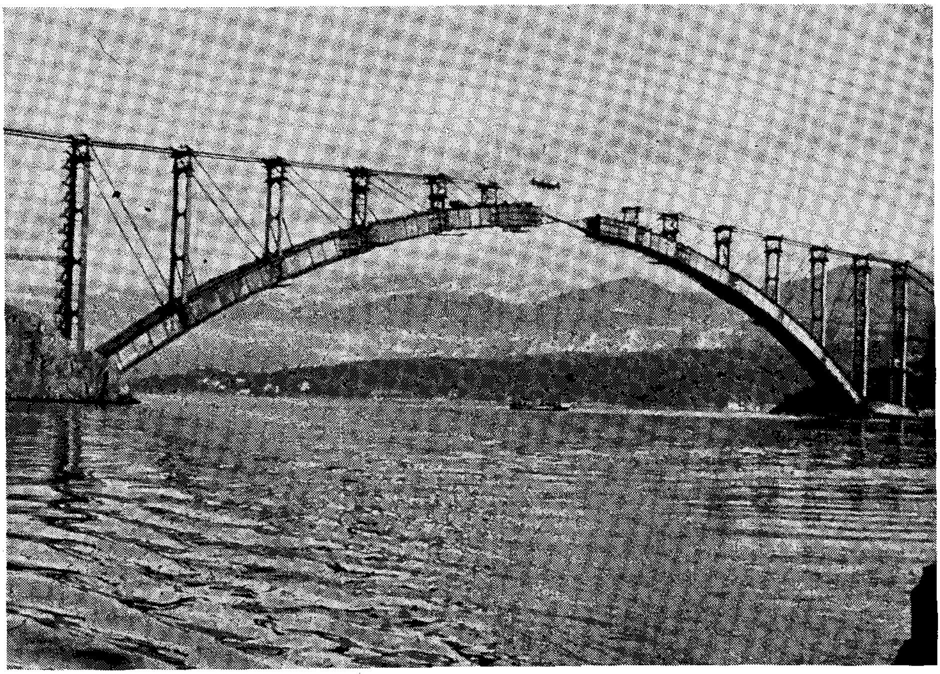

Fig. 24. Krk Bridge, Yugoslavia.

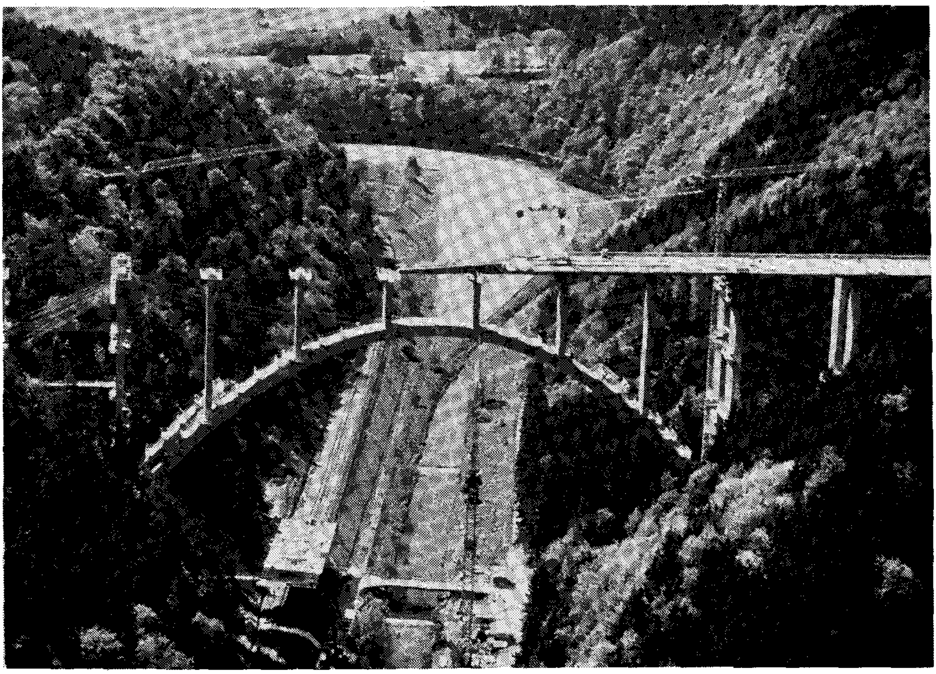

Fig. 25. Neckarburgbridge, Federal Republic of Germany. Launching of superstructure.

Another example was the construction of the Neckarburgbridge in Germany. This structure was completed in 1978. Here, the 506-ft (154.4 m) arch span was made by the cantilever cast-in-place method using temporary stays. The superstructure was built using the incremental launching method thus successfully combining two segmental techniques in one bridge (Fig. 25).

EUROPEAN BIDDING PRACTICES

There is no uniform bidding system in Europe. However, those countries which have been most innovative in bridge design and construction tend to have more liberal bidding systems. Procedures vary considerably even within countries, but they have one common denominator, namely, consultants and contractors can present alternative designs.

For the Beckenried Viaduct, the owner basically outlined the scope of work to be done in the bidding phase, giving the data needed (i.e., geological report, road geometry, construction time, etc.) for preparing a comprehensive proposal. During a prequalification phase, the owner selected six different joint venture groups of contractors and independent consultants.The bidders had eight months to prepare their own designs and price them accordingly.

Bidders were free to choose the spans, structural system, materials, and construction technique. The location of the abutment was fixed at one end, but flexibility was provided in regard to how and where to end the bridge.

The owner expected from each of the six groups a technically sound and esthetically pleasing project at minimum cost with minimum risk during construction in addition to a subsequently low maintenance cost. Each joint venture had to price its proposal on the basis of a bill of quantity established according to the specific solution. To cover at least a part of the bidder's costs, the owner paid $90,000 to each joint venture group. In addition, a total of $200,000 was distributed among the groups, ranging from $135,000 given to the winning team to $115,000 to the sixth-ranked team.

The proposals were then evaluated by a jury consisting of experts from administration, universities, and consulting firms, and the results were published. As in most cases, the low bidder was selected for the job. However, there were other bids where the best solution was adopted but priced higher for technical and esthetic reasons.

Such a flexible bidding system has a great benefit in that it brings forward new ideas to ultimately advance the bridge industry. However, it is only justified for bridge projects of a fairly large size.

CONCLUDING REMARKS

In general, segmental construction is very popular in Europe. Its development has certainly helped to keep bridge costs on a reasonable level despite overall inflation. Due to the varying parameters in bridge design (span, length, geometry, construction time, and other factors), each specific method can be justified, as long as it is applied judiciously.

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