Interrelation between design and methods of construction for elevated highways

Autor(en): **Vlught, B.W. van der**

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IV

Interrelation between Design and Methods of Construction for Elevated Highways

Influences réciproques entre le projet et les méthodes d'exécution pour les routes surélevées

Wechselbeziehung von Entwurf und Baumethoden bei Hochstraßen

B.W. VAN DER VLUGHT
Netherlands

Introduction.

This paper deals with the interaction between design and execution of elevated motor roads, i.e. flyovers, approach-spans to large river-crossings and viaducts constructed alongside steep slopes. River- and valley-crossings are not taken into consideration; the scope of the paper covers types of span construction up to 50 m. approximately.
New developments which do not have a direct bearing on the above-mentioned interaction, such as lightweight concrete and stress-ribbon bridges, are not taken into consideration.
Attention is paid not only to the technical aspects of the subject, but also to the process itself.

The Interaction Process.

The relation and interaction between design and execution, and the development which results therefrom, cannot be seen in its own light.
In order to assess the process properly, other factors should be taken into consideration, too.

The design stems from a set of basic requirements - purely functional as well as esthetical - to be embodied in a design, in which consideration must be paid to realization (technology), local conditions (situation) and economy.

The execution is the economic realization of the design with the aid of human labour, mechanical techniques and organisation.

Additional external factors, which also influence the design and execution are:
In the case of the design:
1. functional criteria: traffic requirements, such as less expansion joints, column flyovers, roadsurface-heating and the like, and shorter construction periods.

2. esthetical criteria: for instance, closed underside of the superstructure of a small number of box girders instead of a large number of ordinary girders.
3. new safety conceptions and new calculation possibilities.
4. more know-how concerning the materials and their interaction.
5. new materials: for instance, lightweight concrete, epoxy resins.

and finally the execution:

In the case of the execution:
1. the design and
2. the development of execution techniques, e.g. development of lifting equipment and jacks, sliding shuttering.
3. economic developments, e.g. the relatively high increase in wages.
4. organisational and administrative developments: critical path method, a more detailed insight in the actual costs thanks to automation of the administration.

The relation and interaction between design and execution is part of the continuous process brought about by new requirements, dictated by clients and society in general, and by new possibilities created by research and developments in other industries. This results in new initiatives in the field of design and execution, as well as a continuous feedback from execution to design and from design and execution to all external influences.

For the sake of clarity, please note that when we speak of design and execution, that does not mean the dividing line between, on the one hand, the consulting engineer and the client's design-office and, on the other hand, the contractor.
The contractor's design-office comes under the heading of design; a resident engineer on the site comes under the heading of execution.
It is also possible for one and the same person to interchange the duties of designing and executing.
In order to understand the proper meaning of the process, it is important that there should be no doubt as to who comes under the respective headings of designer and executor.

A good development in the process of building is possible only when the interaction between all the groups engaged in carrying out the various tasks is at its very best. In the case of interaction between design and execution this means that the intentions of the designer should be absolutely clear to the executor, and that the desires of the executor are also clear to the designer.
If we consider the implications of this for just one project, then we see that the first of the two lastmentioned conditions is reasonably assured of success thanks to drawings and specifications, supervision and regular meetings. The feedback is usually not so definite and decided: this is usually left to the discretion of a few individuals. It is by no means certain that, in particular, the organisational problems and experiences ever achieve the proper feedback to the designers. In view of the necessity for an effective interaction there is a lot to be said for a feedback at the end of the execution, which is in proportion to the information contained in drawings and specifications at the beginning of the execution. This feedback could take the form of a report by the

executors, containing criticism of the design and suggestions for improvements.

Further to the on-the-spot interactions between designers and executors there is also the more broad interaction in the form of publications, lectures, excursions, congresses, etc. Here also, however, much more attention is paid to the design as such than to the evaluation of the design based on the experiences gained during the execution.

Consequently it is my firm belief that, for an effective development, much more attention should be paid to the feedback from execution to design.

The first actual interaction that takes place is that between the criteria which bind the designer, and his knowledge of the execution possibilities. During the design he should continually bear in mind a way in which the project can be executed, both technically and organisationally, and develop his design accordingly.

It is desirable that, for each project which deviates from the normal run of things, the designer keep a continual check on the effects of his design on the execution with the aid of schematic drawings of the set-up of the building-site, of special equipment and of various phases of the execution, and by means of network planning.
This information could be given to the contractors together with the specifications as a motivation for the design.

Criteria.

In the development of modern methods of execution the investment in special equipment plays an important part. This investment may run to several £ 100.000.
Such sums cannot usually be accounted for in one single project. This prompts the question, as to whether it would not be possible to arrive at standard types of bridges with fixed dimensions for the purpose of ensuring reasonable use of new equipment, which has been developed for a specific type of bridge with standardized spans, pier-shapes, widths and skewness.
It has been found that the variation in local circumstances and requirements have, as well as the increase in traffic requirements, hitherto proved an obstacle to genuine standardization.
Only in the case of factory-made bridge girders, spanning up to 25 m., has it been possible to achieve standardization. This, however, only has a bearing on part of the construction.
This means that in the development of new systems of execution the most flexible of possibilities should be considered with respect to the investments, bearing in mind the various criteria.
These criteria are partly functional and partly esthetical.
Hereunder an attempt has been made at a summation of criteria that could be of importance.

A. Functional:

1. possibility of horizontal and vertical curves.
2. possibility of widening for acceleration- and deceleration lanes, and connections to sliproads.
3. flexibility in the positioning and shaping of piers.

4. few expansion-joints in the road surface.
5. simple solutions for water drainage, fastening of guardrails and lamp posts, etc.
6. a monolithic joint between 2 bridge-halves providing flexibility of road-division.
7. small construction depth.
8. in countries with heavy snow-fall, protection against spraying salts.
9. crash-proof piers and underside of superstructure.
10. minimum hindrance to traffic passing under flyover during construction.
11. quick execution.
12. independence of soil conditions between piers.
13. possibility of widening bridge.
14. possibility of dismantling bridge.
15. economy.

B. Esthetical.

1. simplicity: visible constructive and functional design.
2. slenderness.
3. in the case of long flyovers, a straight underside with the exception of a strengthened part above the pier (which part has a limited width).
4. no capping-beams on the piers.

The degree of importance attached to the various criteria is, of course, not always the same. Furthermore, the increase in traffic volume gives an associated increase in new criteria to be considered.
The problem of noise, for instance, is receiving ever-increasing attention. Up to now it has been possible to solve this problem to any extent only in the case of rail transport.

The development of various systems of execution is based on the following motives.

1. reduction of the number of manhours on the building-site, in particular, in the case of formwork and scaffolding.
2. agreement with the demands that hindrance to traffic under the viaducts be kept at a minimum.
3. independence of soil conditions between piers.
4. in the case of approach-spans to large river-crossings, independence of high waterlevels.

The different motives in points 2,3 and 4 usually lead to the same result.
Motive No. 1 will usually be of a financial nature. Generally speaking, preference is given to a modern system of execution if this is cheaper.
In some cases, however, it is necessary to use labour-saving methods, even though they may be more expensive, as the number of labourers, necessary for a more traditional labour-consuming system of execution within the time prescribed, is not available.
This is becoming a present trend in industrialized countries.

An important organizational advantage attached to a modern system of execution as opposed to a traditional system is that there is a better and more constant distribution of man-power on the site.

Furthermore, there is also a more constant succession of identical activities, whereby the advantage of series production is utilized more fully. It is well known that the number of manhours in the case of large series production is reduced by more than 50% as compared to single production.

In order to get the full benefit from the organizational advantages, it is necessary that they be incorporated in detail in the design:
This means:
1. where possible, equal spans.
2. all recesses and all fittings to be cast in the concrete for the purpose of water drainage, lighting, etc., must have exactly the same position in the segment in the case of segmental construction.
3. the design of the connections to the slip-roads should be such that there will be no hindrance to construction progress on the main viaduct.

Some Methods of Execution.

In the course of time the following systems of execution have been developed:
1. cast-in-place span-by-span construction with the aid of on-the-ground, moveable scaffolding.
2. cast-in-place span-by-span construction with the aid of suspended, self-launching formwork carrier.
3. cast-in-place segmental cantilever construction.
4. prefabricated beams.
5. precast segmental construction supported by scaffolding.
6. precast segmental cantilever construction.
7. self-launching piecemeal system (German "Taktschiebeverfahren")

The first of these methods deviates least from the traditional construction system. The only difference is that the scaffolding is displaced in a more efficient way. The extra costs incurred by transport equipment, rails, jacks and additional steel construction can be turned to economical advantage, beyond a certain length of viaduct. Witfoht mentions 300 m. as being the minimum length, on condition that the overall cross-section is constant. If the length of the viaduct is less than 300 m., then it can be divided in two parts by a longitudinal joint, the same scaffolding being used for both bridge parts. A condition which has to be taken into account when making the design is that the position of the columns be such that the scaffolding has room to pass, which condition is in agreement with the requirements of the client. Furthermore, it should always be possible to detach the formwork in its entirety in order to benefit from the rapid displacement of the formwork. One span can be cast every 2-3 weeks with the aid of one scaffolding.

The second system has the advantage that it is independent of the rail and terrain conditions, which is important in the case of viaducts alongside steep slopes, and for high viaducts.
In this system we make a destinction between two constructions with respect to the statical system.
In both cases casting is done span by span, but in the first case the superstructure is freely supported by the piers, obviating the use of expansion joints, in the second case the superstructure is monolithically connected to the piers, necessitating the use of expansion joints.

Various types of superstructure are possible:
box-girders (Kranenberg bridge, Fed.Rep. of Germany; Roquebrune Motorroad, France); Mushroom bridges (Brenner Motorroad, Austria; Elztal viaduct, Fed.Rep. of Germany) and Tee-beams (Lennetal viaduct, Fed.Rep. of Germany).

The launching of the carrier is effected according to the slide-rule principle: first, a launching girder is launched on to the pier, followed by the formwork carrier and the formwork.
A span can be cast every two weeks or even less. The minimum radius of horizontal curvature is about 400 m.
In the system developed by Dycherhoff & Widmann, the launching and carrying girders move above the superstructure, and the formwork is carried during transport by arms, which encompass the superstructure. These arms also serve as framework for a casting-place housing, so that the work is independent of inclement weather conditions.

The third system is used more in the case of spans, longer than 50 m., where a formwork carrier for the span-by-span construction is too heavy and too expensive. Although the majority of the applications of the system concern river- and valley-crossings, some of these applications can be considered as elevated highroads, such as the Zoo-bridge in Cologne and the Shibuya viaduct in Tokio.
Three methods of execution are possible:

1. on both sides of the pier cantilevers are erected segment by segment up to mid-span with the aid of cantilever trucks, during which equilibrium is attained either by fixation to the pier or by means of auxiliary trestles near the pier.
2. a cantilever is erected segment by segment from one side to the next pier during which the great negative bending moment is temporarily sustained by a pylon with stay-cables or by auxiliary trestles. Whilst in the first case the most economical solution is provided by a haunched underside, in the second case a straight underside is preferred.
3. the first of the last two methods, but with the addition of an auxiliary bridge up to a length of one and a half spans.
   The purpose of this auxiliary bridge is:
   suspension of the cantilever formwork and the last cast segment.
   maintaining balance.
   transport to the next pier.

The prefabrication of girders is so old that the principle thereof needs no further description. However, the development is not always consistent although, generally speaking, it is easy to distinguish a trend towards simplicity in the execution.
At the beginning of the development most designs were primarly based on a saving of material, for instance, by means of continuity in construction obtained with the aid of continuity prestressing.
This method has been almost discarded as a result of labour-consuming activities.
The continuity in girders with spans up to 25 m.(factory girders) is usually obtained by means of normal reinforcements. In the case of large spans the construction is kept statically determined.
Neither does the execution take kindly to diaphragms.
An interesting example of the trend towards eliminating the problems presented by diaphragms is displayed by the Battignolles viaduct, in the Boulevard Péripherique, Paris. Here there are no intermediate diaphragms, and the end diaphragms are cast after the deck formwork has passed by.

Several countries, however, seem to differ as to the lengths to which this simplification can be taken. Whilst in the Netherlands the inverted T-beams are usually used only with a cast-in-place top layer, in England preference is given to a combination of a cast-in-place layer on the bottom flanges, and a cast-in-place top layer. It would be interesting to make an accurate comparison between the various advantages and disadvantages of both systems.
Other formwork-saving methods in which a good load distribution occurs are the German face-matching joint system and the "top-head" beams with gap-free bottom flanges such as applied in section b of the Western Avenue Extension in London.

Precast girders present a problem when the piers have to be given the form of columns because the girders have to be supported over the whole width of the viaduct. By providing the girders with tooth-shaped ends, it is possible to reduce the depth of the projecting part of a capping-beam.
A good solution is also provided here by the application of preflex girders, as used in the Bijlmermeer viaducts,Amsterdam.
If one wishes to have one central column, then usually the part of the deck above the piers is made as a cast-in-place table plate, monolithically connected to the piers. This leads to a slender construction, whilst differences in length due to either variation in span or to horizontal curvature can be accomodated in the table plate.

The prefabrication of segmental box-sections erected on scaffolding has become very popular in England since the construction of the Hammersmith flyover. The prefabrication renders possible the solution of complicated cross-sections. The most advanced realization up to now is section 5 of the Western Avenue Extension - a box-girder with deeply slanted walls, as a result of which it was possible to support the 28,5 m.wide road on one central column in an elegant way. The weight of one element - 137 tons - indicates that for the time being the possibilities have been stretched to the limit. The segments may be erected on scaffolding or suspended from a gantry.

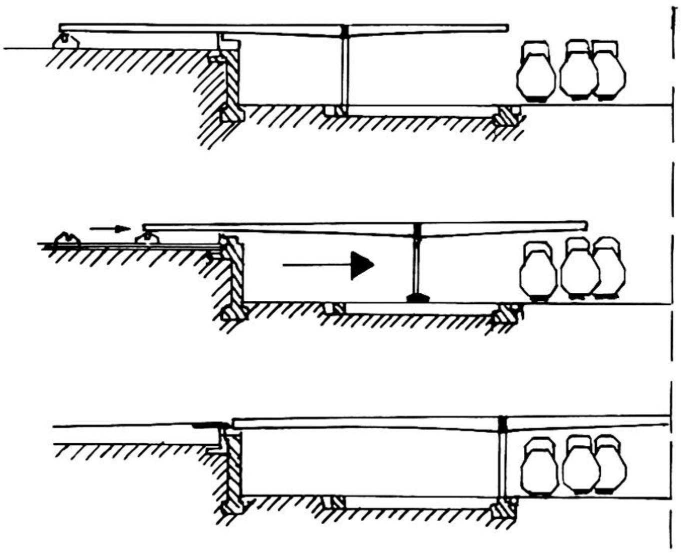
A combination of the precast segmental construction on scaffolding and the cast-in-place cantilever construction is the precast segmental cantilever construction with glued face-matching joints, rendered possible by the introduction of epoxy resins. Two production methods of the segments are possible.

1. the segments are cast end-to-end on a bench, the length of which is at least half a span.
2. the segments are cast in a stationary position and displaced in a longitudinal direction to be used as end form to its mate.

All details, such as anchorages, shear keys, etc., must be as equal as possible for all segments. This also holds good to a certain extent for the overall dimensions of the section, but here other considerations have to be taken into account such as the required quantities of prestressing steel and concrete. Although the construction at mid-span is made continuous, a haunched underside during the cantilever construction would seem the most obvious solution.
However in the case of medium-sized spans ($\leq$ 60 m.?) the straight underside will be more economical as a result of the possibility to keep the mould constant.
Erection takes place by means of a self-launching auxiliary bridge or by means of a crane or derricks on top of the structure.

As opposed to the cast-in-place cantilever construction, the advantage is the higher speed of construction, whilst the cast-in-place cantilever method proceeds at a rate of 3.5 m. a week on both sides of a pier; in the case of the precast method this is 1 to 2 elements, equal to 3.5-7 m. per day.
We are presented with the problem, however, that the alignment can only be adjusted to a certain extent, and can never be forecast to within 1 cm.
Furthermore, the epoxy-glue is sensitive to temperatures around freezing point.
For spans of 35-40 m. the minimum curvature is 150-200 m.

As far as has been possible to discover, the self-launching piecemeal system has been used up to now exclusively for valley- and river-crossings. This is due to the fact that the superstructure has to be either straight or have a constant curve, both horizontally as well as vertically, and furthermore that building without scaffolding is much more advantageous in the case of great heights. Complete freedom from the terrain conditions together with the small number of man-hours required per m^2 of bridge-deck prompts the question as to whether the system should not also be used for other viaducts.



VIADUCT AT HALLEIN

The way in which the problem of crossing a railway yard with overhead wires was solved in Hallein (Austria), for instance, resembles in many ways the self-launching system, even though the bridge-halves were manufactured as one piece, and were not made to glide over the piers.

The sideways insertion of railway bridges in railway tracks in use also resembles, in principle, the self-launching system: they have in common, that the superstructure is manufactured either in the extension of the bridge or parallel thereto, after which the entire superstructure is slid into position.
For the temporary support of the long cantilever during launching, auxiliary support can be used; this can also be done with the aid of a pylon and stay cables, as was done in the Semorila-viaduct near Rapallo, Italy.
An interesting feature of the construction system, used in this viaduct is that the deck of the box-girder was cast after launching in order to achieve a saving in weight during launching.

The Statical System: Bearings, cross-section, piers.

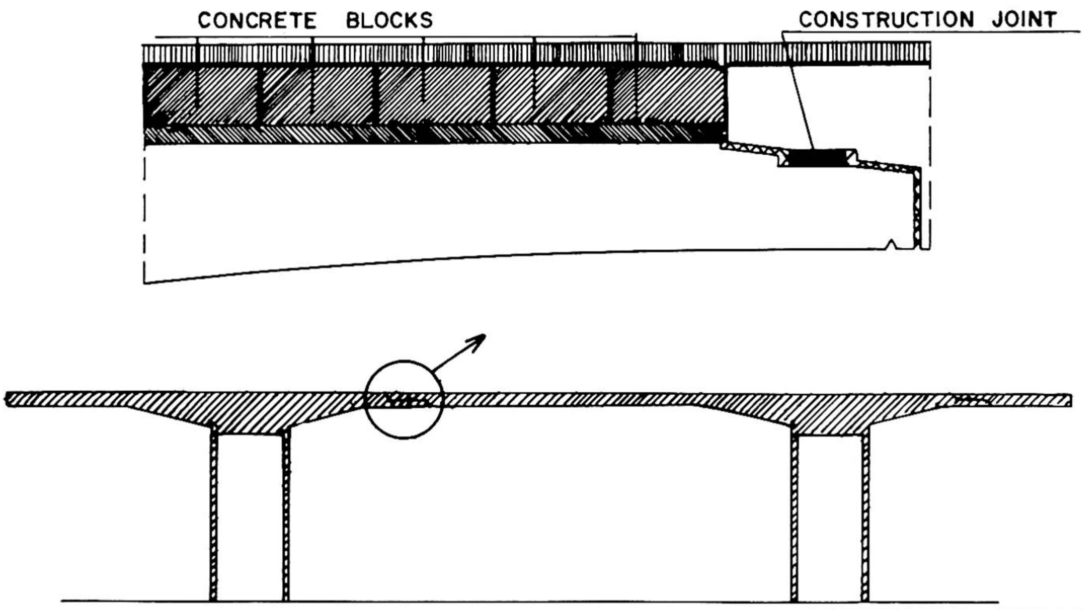
When analysing the statical system the following questions will arise:

1. what provisions are made for expansion?
2. how is the load carried in longitudinal direction?
3. how is an excentric load sustained?
4. what provisions are made for horizontal forces, in particular, resulting from earthquakes?
5. what inconvenience will be caused to traffic by joints and incalculable deformations?
6. what is the simplest solution with regard to the method of execution?

The development in the field of bearings and joint constructions are closely related to the foregoing.
The inconvenience to traffic, caused by closely placed joints and the damage to joints caused by the increasing volume of traffic and by the increased use of spraying salts, has resulted in a concentration of expansion at great distances from each other.
The introduction of rubber bearing-pads and sliding bearings with teflon rendered it possible to make viaducts longer than 1 km. without expansion joints, with the exception of those at the abutments. By providing a number of piers in the middle of the viaduct with rubber bearings and the rest with sliding bearings, it is possible to distribute the horizontal load over more than

one pier.
These great distances between joints are not ideal for every method of execution.
From the point of view of the execution a statically determined system, in which the beams are supported at their ends on the piers, provides the simplest solution in the case of precast beams.
Refinements in which the beams of successive spans are connected monolithically by continuity cables have become obsolete.
Nowadays, however, the roadsurface is sometimes made as one continuous piece by making the deck slab continuous over the pier.
Although the bearings should be designed for greater displacements, this does mean that one is no longer inconvenienced by the large number of joints.
Furthermore, it also has the advantage that, in places where earthquakes occur, it is possible to transmit the horizontal forces.
It is not possible to connect precast beams in successive spans in the aforementioned way if the superstructure consists alternately of precast beams and table plates, rigidly connected to the piers.

As the columns are very rigid, this involves one expansion joint per span in the case of low viaducts.
A similar statical system for mushroom viaducts is that in which instead of precast beams, for this type of construction Dycherhoff & Widmann Comp., have developed a trantional construction,



TRANSITIONAL CONSTRUCTION WITH PLASTIC DEFORMABLE ASPHALT LAYER

consisting of a series of concrete blocks, which are elastically connected to the two construction parts by means of prestressing bars.

This means that the expansion in the construction joint can be distributed over the joints between the blocks. Consequently the asphalt deck can run continuously over the joint.

It is also possible to construct a continuous asphalt layer over a construction joint by reinforcing the asphalt layer itself.
Mats have been developed by the plastic and fiber industry which serve for this purpose. A displacement of some cms. can be covered in this way.
These developments offer new possibilities for those construction forms which, as a result of the considerable amount of joints necessary, have fallen out of favour in the past few years.
As well as these solutions with continuous asphalt layers, solutions have also been found, consisting of a neoprene waterstop, fitted in cast-in-place epoxy resin.

This expansion and the watertightness is provided for by a neoprene waterstop. The permissible relative displacement up till now is 3 cm.
The joint construction is carried out after the asphalt has been laid so that the asphalting can be effected without interruption as in the latter case; this is particularly beneficial to the quality near the joints in skew bridges.

Another factor which influences the position as well as the number of joints is the risk of undersized deformation.
If the cantilever construction continues up to mid-span the obvious solution which seems to suggest itself is to position the joint at mid-span.

However, this has the drawback that the displacement and angle rotation at the joint resulting from lifeload, creep and prestressing losses will be much greater than if the joint is positioned near the point at which the moment would be zero in case of a statical system without a joint. On making a comparative calculation the Frenchman Jean Muller arrived at a factor 3 for the angle rotation.
In the case of the Oleron bridge Campenon Bernard found a solution for the problem of a joint in the cantilever by making the joint construction rigid during the execution. Furthermore, the number of joints is limited by supporting the superstructure on rubber bearing-pads. A temporary fixation to the pier is realized by means of high-tensile bolted rods.

The form of the cross-section of the superstructure is directly connected with the form of the pier.
In the case of a central column underneath a superstructure having a width of 10-15 m. a natural solution is to direct the forces gradually from the superstructure to the pier. A good example of this is the mushroom bridge in which the mushroom does not necessarily have to take the form of a solid plate but can be split up into beams. Dycherhoff & Widmann who introduced this type of bridge-construction refer to it as the T-shaped mushroom bridge.
A similar construction is formed by the table plate with precast girders.

If the superstructure is to be constructed as prismatically as possible over the piers then the cross-section can be made such that at the pier only a slight sideways transmission of forces is necessary. A good cross-section form of this is the box-girders with projecting roadslabs. In order to avoid making these projecting roadslabs too big, the outer walls of the box-girder are slanted. The box-girder form of the Western Avenue Extension Section 5 as well as the Chillon viaduct (Switzerland) can be mentioned as examples of the incorporation of sidewalls with multipurpose functions: part of the bottom slab, serving as side-wall, and bottom slab for the cantilever.
The aforementioned examples show that the freedom of choice in shaping the superstructure, which permits of a combination consisting of a good transmission of forces to the pier and a solution pleasing to the eye, is not hampered by the trend towards efficiency in the execution; we may even say that in some cases it is increased by the way in which efficiency is arrived at: an efficient system of scaffolding in the case of the mushroom bridge; the greater possibilities of prefabrication in the case of complicated box girders.

Prestressing.

When we speak of the development of the execution techniques for bridges we are automatically inclined to include the development of prestressing.
From the historical point of view this is only as it should be, as prestressing was an indispensable factor in the development of these techniques. Yet we may very well ask ourselves if a further development of the prestressing systems is really necessary at this moment for the development of bridge building.
In addition to the costs of the prestressing system,(material+ man-hours), there are, in my opinion, three factors which determine the applicability:

1. the maximum force of a tendon and the variety of tendons. In most systems, the rupture force of the largest tendons is more than 200 tons. This would seem to be a reasonable maximum for bridges with a span of more than 100 m. The minimum concrete dimensions necessary for the anchorage would then be more than 35 cm. This would seem to be the limit at which the anchorages can be lodged in the concrete without further cumbersome provisions. All systems lend themselves to a variation of prestressing force, which is necessary in the case of transverse prestressing.
2. possibility of coupling.
3. possibility of inserting cables in ducts already cast in the concrete.

In the development of execution systems a correlation can be seen between the possibility offered by the prestressing systems and the method of execution: the span-by-span construction has been developed with prestressing systems, which provide for easy coupling of the tendons; the systems in which precast elements are connected by inserted cables have been developed with prestressing systems in which cables could easily be inserted. Since then, however, the respective prestressing systems have eliminated the limitation as much as possible so that they have become more gradual than absolute. The system in its entirety gives every opportunity of achieving an effective application of the methods of execution aimed at.

Finally, I should like to draw attention to a part of the development in design which should not be neglected in the interaction between design and execution:
We must always take into consideration all those factors which in any way whatsoever may affect the structure.
The National Specifications stipulate a strongly schematic loading for the bridge.
During the last few years the IABSE and the CEB have devoted much attention to the problem of safety and the importance of probabiliorism.
A survey of the amount of dammage sustained by viaducts shows that a large part of this occurs during construction and that the rest can be attributed, for the major part, to careless execution, inaccurate detailing, influence of temperature, collisions, deterioration due to spraying salt, and the like. Hardly ever do we hear of collapse of dammage due to the kind of loading prescribed by the specification.
It seems that the loading specifications have much too great an influence on the development of construction forms. An example of this is a beam-grillage.
The most unfavourable position of the loading is taken as starting point for every part of the construction calculation. The result of this is that the strength of the entire bridge is much greater than required.
Surely it would be better to use the surplus involved in order to limit the damage caused by other factors.

Summary.

The interaction between design and execution is part of the process of the development of new construction forms. If this process is to function properly, more attention should be paid to the feedback from execution to design.
Various execution systems for bridges are briefly described viz:

1. cast-in-place span-by-span construction with the aid of on-the-ground, moveable scaffolding.
2. cast-in-place span-by-span construction with the aid of suspended, self-launching formwork carrier.
3. cast-in-place segmental cantilever construction.
4. prefabricated beams.
5. precast segmental construction supported by scaffolding.
6. precast segmental cantilever construction.
7. self-launching piecemeal system (German "Taktschiebeverfahren")

In the section on the statical system attention is paid to the development of a joint construction in which the roadsurface is not interrupted.
This can have favourable consequences for those systems which make use of a great number of joint.
Mention is made of some good solutions for connecting the superstructure to concentrated pier columns.

The writer is of the opinion that at the moment there is not much point in furthering the development of prestressing as far as the development of bridgeconstruction is concerned.

Zusammenfassung

Die Wechselwirkung zwischen Entwurf und Ausführung ist ein Teil des Entwicklungsprozesses von neuen Konstruktionsformen. Zum einwandfreien Funktionieren dieses Prozesses sollte man dem Informationsrückfluss von der Ausführung zum Projekt mehr Beachtung schenken. Verschiedene Ausführungsarten von Brücken werden kurz beschrieben:

1. Ortsbeton, eine Spannung nach der andern mit Hilfe eines am Boden abgestützten, beweglichen Lehrgerüsts ausgeführt.
2. Ortsbeton, eine Spannung nach der andern mit Hilfe eines abgespannten, freitragenden Schalungsträgers.
3. Ortsbeton, abschnittweiser Freivorbau
4. Vorfabrizierte Träger
5. Abschnittweise vorfabriziert, durch Lehrgerüst unterstützt
6. Freivorbau mit vorfabrizierten Abschnitten
7. Taktschiebeverfahren, Taktvorschub

Im Abschnitt über das statische System wird speziell auf die Entwicklung einer Fugenausbildung ohne Unterbruch des Fahrbahnbelags hingewiesen. Das wirkt sich natürlich bei Brücken mit grösserer Fugenzahl besonders vorteilhaft aus.
Einige gute Lösungen des Anschlusses des Ueberbaus an Einzelstützen werden erwähnt.

Der Autor ist der Ansicht, dass es zur Zeit wenig sinnvoll ist, die Entwicklung der Vorspannung, soweit es den Brückenbau betrifft, weiter voran zu treiben.

Résumé

L'interaction entre la conception et l'exécution fait partie du développement de nouvelles formes de construction. Pour que ce procédé fonctionne proprement, il faut prêter plus d'attention à l'influence de l'exécution sur la conception.
Différents systèmes d'exécution de ponts sont brièvement décrits:

1. Béton coulé sur place, travée par travée, à l'aide d'un échafaudage mobile et appuyé sur le sol.
2. Béton coulé sur place, travée par travée, à l'aide d'un coffrage suspendu en porte-à-faux.
3. Béton coulé sur place, construction en encorbellement par étapes.
4. Poutres préfabriquées.
5. Préfabriqué par étapes, appuyé sur un échafaudage
6. Construction en encorbellement, par étapes préfabriquées.
7. Lancement en port-à-faux.

Dans le chapitre consacré au système statique on étudie le développement de la construction de joints sans interruption de la chaussée, qui sont les bienvenus dans les systèmes comptant de nombreux joints. On cite ensuite quelques bonnes solutions pour la liaison de la superstructure aux piles.

L'auteur est d'avis qu'actuellement il ne faut pas chercher à développer la technique de la précontrainte appliquée à la construction des ponts.

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