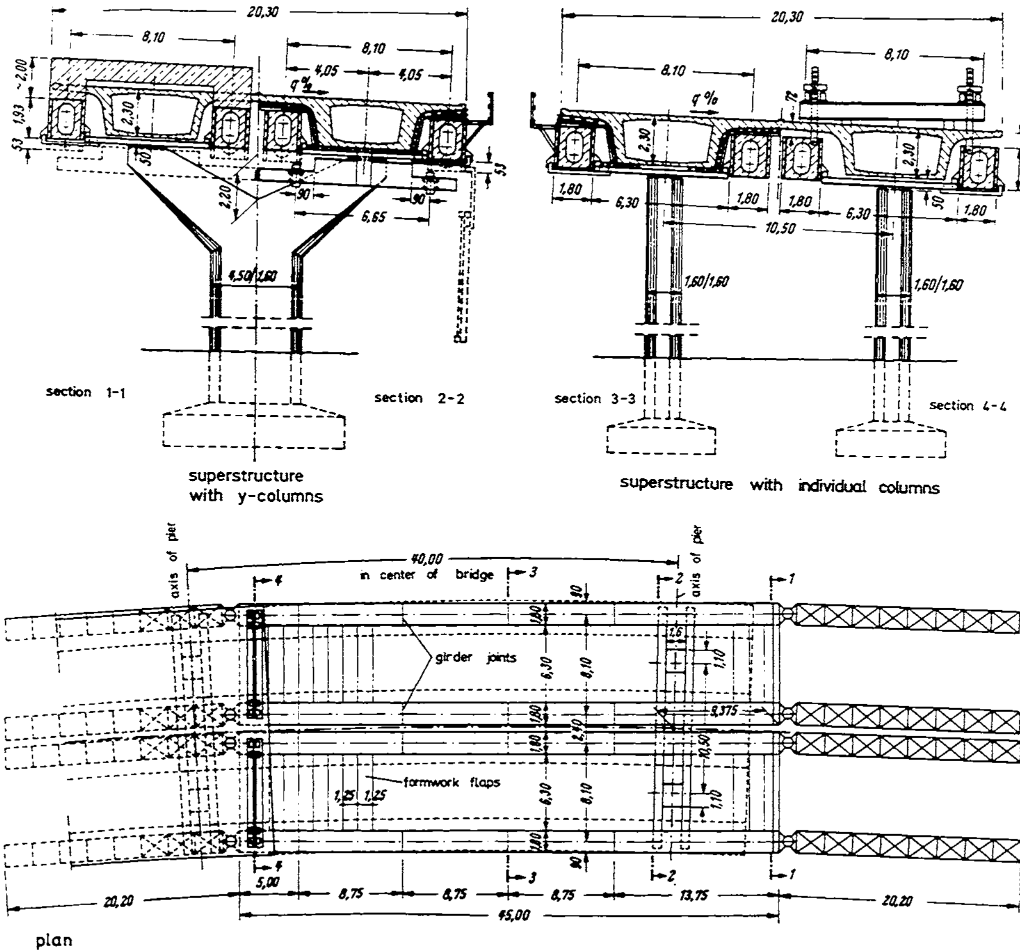

Fig. 28-31 - Stepping Formwork Equipment of Downtown Bypass in Mainz

Fig. 28-32 - Design Illustration of Stor Bridge at Itzehoe

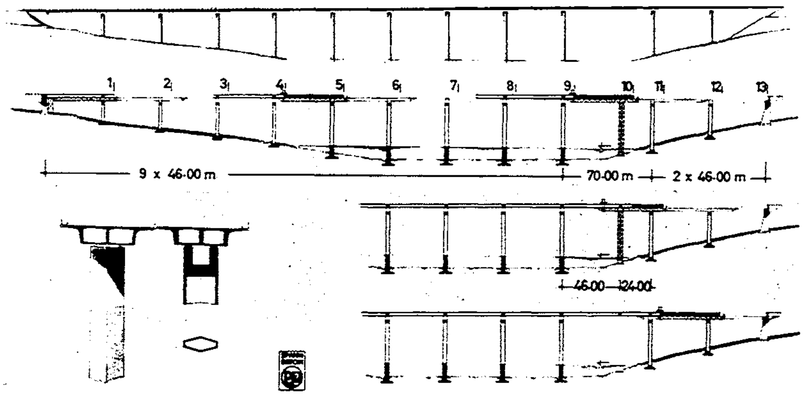

Fig. 28-33 - Dollback Viaduct Construction Scheme
with Auxiliary Column

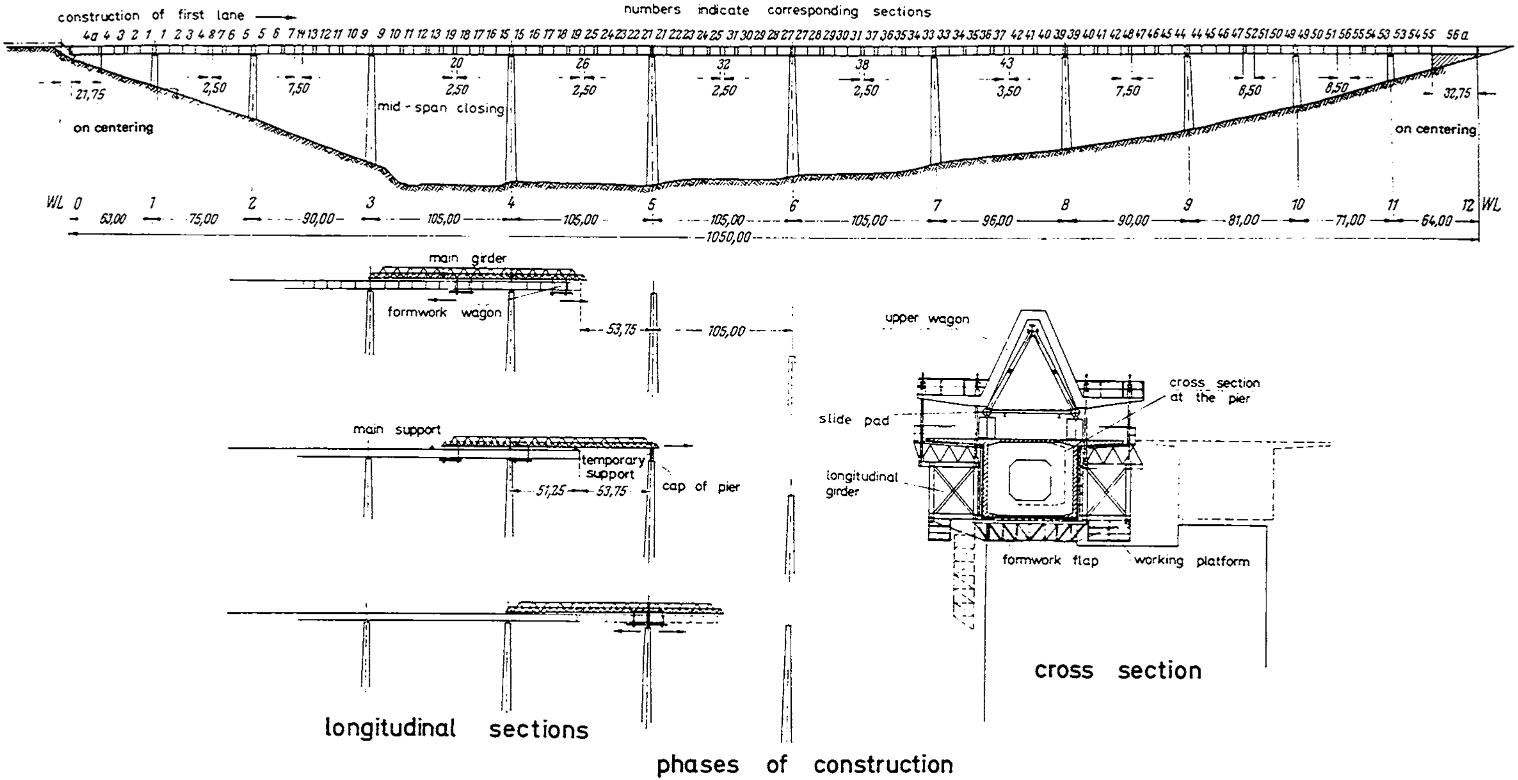

Fig. 28-34 - Stepping Scheme for Long Spans

Bettingen Bridge

The orthodox cantilever construction was abandoned for the first time in favor of the sectionwise construction with centering traveling on the ground when constructing the bridge over the Main at Bettingen.[6,7] The weight of a new section was carried at first by the centerings and later transferred by prestressing to the cantilever arm of the completed superstructure so that the casting lengths could vary within a wide range as opposed to the orthodox cantilever method, and there were practically no moments in the superstructure during construction.

At the Bettingen site, the longest casting length was 7 m (23 ft). It would naturally have been possible to increase this length to 14 m or even 21 m (45 or 70 ft) without any difficulty, but this was not warranted for cost-saving reasons because of the limited reuse of the centering in this case. In both cases of precast or in-situ construction, subsequent threading-in of the tendons into the ducts is always necessary (Fig. 28-35).

The centerings traveled on runways laid on the ground. If deep valleys, waters, or difficult ground configurations are involved, the auxiliary girder sliding on top may perform the function of a runway so that the construction operations may proceed independent of the ground after erection of the piers.

Sieg Valley Viaduct

In spite of endeavors for many years to exploit the cost-saving features inherent in the stepping formwork construction method for large prestressed concrete bridges,[8] it was not before 1965 that this could be demonstrated in Germany. The occasion was the construction of the viaduct carrying a Federal Motorway across the Sieg valley near Eiserfeld (Fig. 28-36). At that time, the method had already been successfully used abroad in the construction of the Oosterschelde Bridge in The Netherlands[9] and the bridge to the isle Oleron in France.[10] The equipment for the Oosterschelde Bridge was designed for building two spans at the same time in sections of about 12 m (40 ft) each. Both bridges cross open waters. They are 5 km and 3 km long (3 and 2 miles), respectively. The Sieg Valley viaduct is 30.4 m (100 ft) wide and the deck level is about 100 m (330 ft) above ordnance datum. The main spans are 105 m (345 ft).[11,12] The viaduct is divided by a longitudinal joint, and the equipment is run in both directions (Fig. 28-37, 38, 39, 40). The section lengths were 10 m (33 ft). The varying spans from 63 m to 105 m (205 to 345 ft) and the continuous depth of the superstructure of 5.80 m (19 ft) had no detrimental influence on the successful application of the method. The approximately 100-m (330 ft) high and 20.7-m (68 ft) wide piers are divided into recessed diaphragms (Fig. 28-40). Large and high piers should preferably be constructed by the slipform method instead of the climbing form method.

Great Belt Design

A look into the future is given by our design in the competition for a bridge over the Danish Great Belt. This design won first prize.[13] The bridge across the West Channel (Fig. 28-41) is 7100 m (4–1/2 miles) long with maximum spans of 150 m (490 ft); the bridge across the East Channel (Fig. 28-42) is 7300 m long with maximum spans of 325 m (1100 ft).

Similar to the Sieg valley viaduct, starting at one abutment, the superstructure will progress to the other abutment, building two spans at a time (Fig. 28-42). In this procedure, traveling steel formwork equipment of about 350-m (1150-ft) length will be employed. This equipment may be pushed forward two spans at a time without dismantling; except for the long spans of more than 300 m, where the equipment is used for one span only. For the forward movement, an auxiliary support by ship at the tip of the beam will be required. The traveling formwork equipment is wide enough to permit both superstructures to be built at the same time. Four erection vehicles will be available – two for each superstructure – which will take the prefabricated parts, delivered by ship, into the right position.

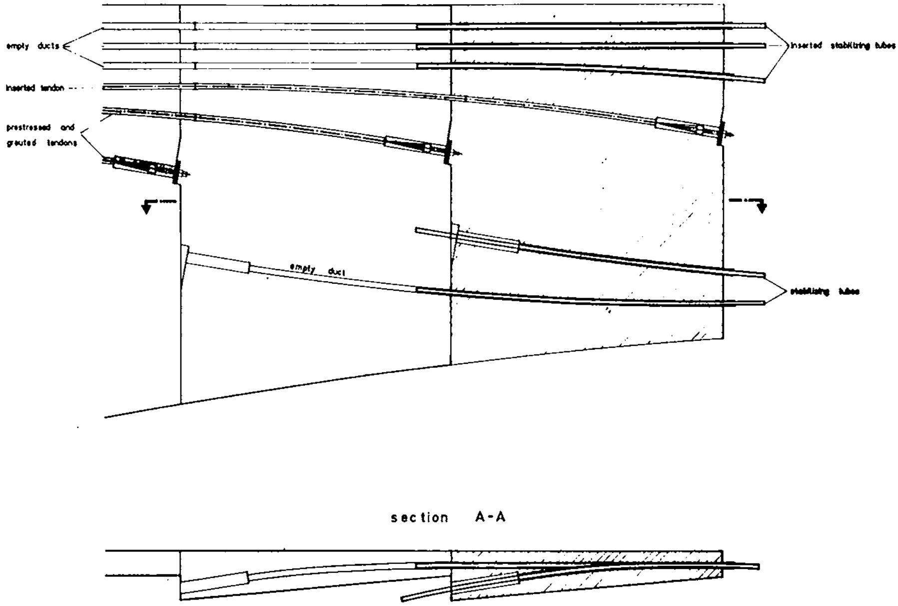

Fig. 28-35 - Tendon Arrangement of Bridge Crossing the Main Near Bettingen

Fig. 28-36 - Siegtal Viaduct Near Eiserfeld

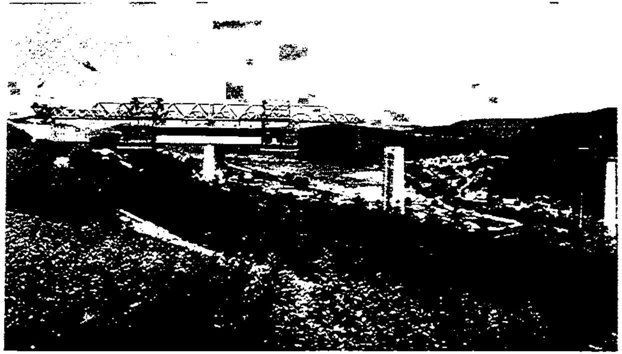

Fig. 28-37 - Half-Spans Nearing Completion at First Pier

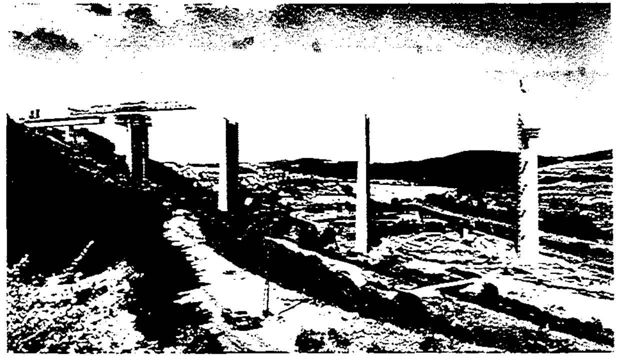

Fig. 28-38 - Starting at Second Pier

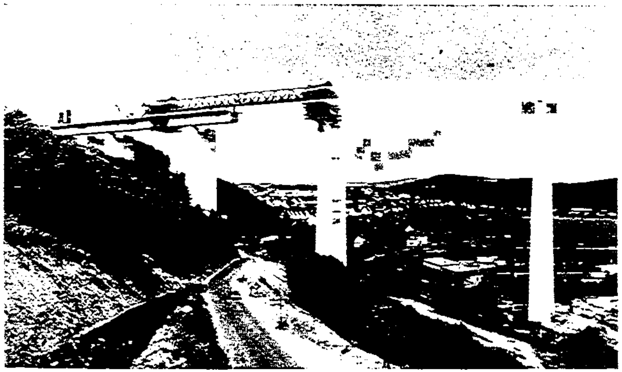

Fig. 28-39 - Advancing to New Starting Position at Third Pier

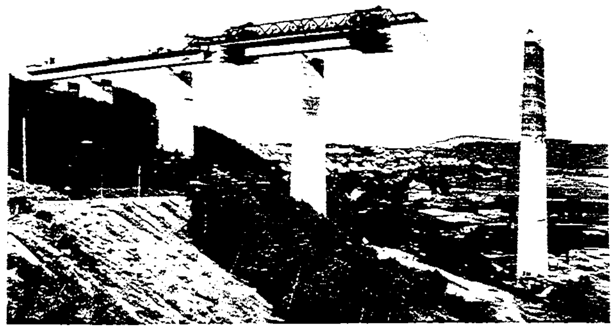

Fig. 28-40 - Half-Spans Nearing Completion at Third Pier

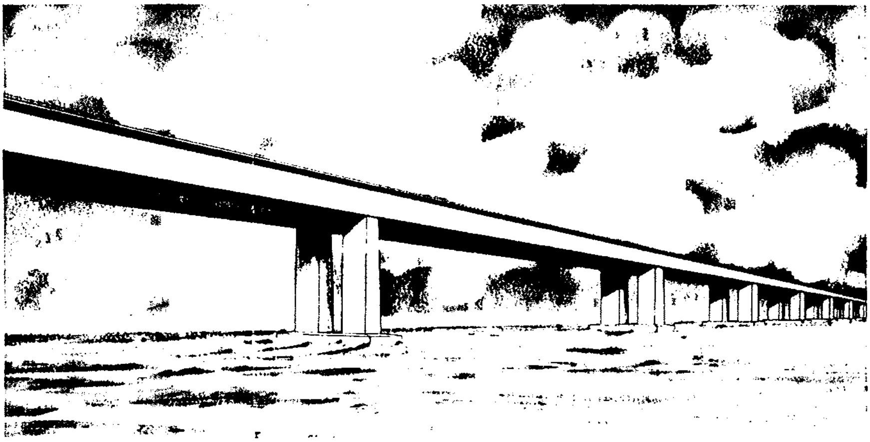

Fig. 28-41 - Bridge Design for the Danish Great Belt - West Channel Crossing

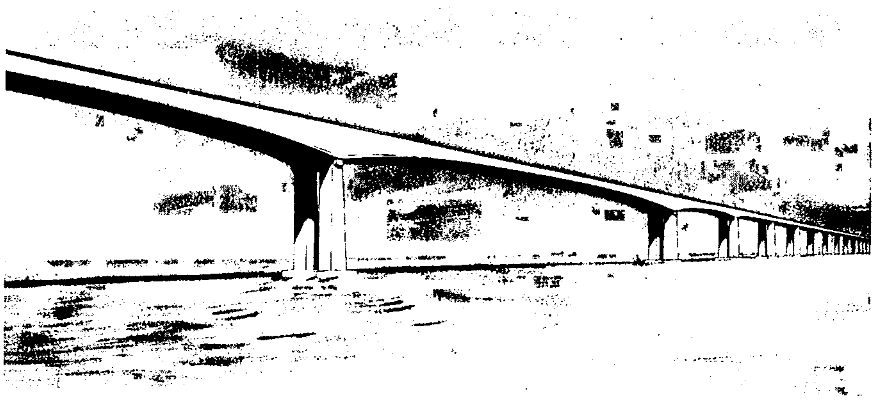

Fig. 28-42 - Bridge Design for the Danish Great Belt - East Channel Crossing

CONCLUSION

The question whether motorway viaducts constructed with stepping formwork equipment should preferably have divided carriageways or not has often been raised. The need to make as many reuses of the equipment as possible without alterations requires the divided carriageway for long structures. This was always found to be true when calculating the costs on an equal basis.

Savings in quantities can hardly be expected when building an undivided carriageway along the same construction principle as a divided one. The construction of an undivided deck involves higher investment costs for the heavy equipment and higher erection and dismantling costs because of the greater weight. It is therefore only recommended if the structure is long enough to permit sufficient equal working cycles and favorable writing-off of the equipment. If the time available for construction is short, two rigs working in echelon are required for divided carriageways.

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THE PRACTICAL DESIGN OF REDUNDANT PRESTRESSED CONCRETE BRIDGES

By A. MURRAY LOUNT

In this article the author discusses the application of continuity to prestressed concrete, making reference to a number of structures so designed. A method of analysis is demonstrated that may be used to simplify the design and cable layout in such structures. This method develops an influence line for secondary moments expressed in terms of unit prestress applied at unit eccentricity over a finite segment of structure. In this manner coefficients may be derived rapidly enabling the designers to investigate alternate cable locations without a complete reanalysis, or without having to approximate concordant cable lines. Typical coefficients for prismatic and haunched fixed beams are given thus enabling the designer to derive secondary moments quickly by moment distribution.

Keywords: bridges (structures); continuity (structural); influence lines; moments; prestressed concrete; stresses; structural design.

☐ Applications of prestressed concrete have been usually limited to simple spans, and most designers associate prestressed concrete with precast concrete. This, association however, relates to a secondary position a most important class of prestressed structure--the cast-in-place post-tensioned continuous bridge or slab.

Experience in reinforced concrete has shown the great flexibility and adaptability of concrete to meet functional demands, and the advantages of flat-slab floors, box-girder bridges, rigid-frame bridges and monolithic reinforced-concrete structures are well known. The use of prestressed concrete to extend the useful and economical span range of concrete is, however, not so well known.

Perhaps the magic in the words prestressed concrete has blinded us to the practical reality of what we are doing. When we consider the behavior of structures at ultimate capacity, a prestressed structure in reality behaves in a very similar manner to reinforced concrete. Prestressing the structure permits us, in effect, to use less weight of steel by substituting very-high-strength steel tendons in lieu of ordinary reinforcing steel. Problems of excessive cracking due to steel elongation at working loads are overcome by the prestressing process. In combination with higher strengths of concrete, we are thus able to make efficient use of improved quality of materials, since otherwise performance at working-stress levels would be unsatisfactory.

In precast concrete it is obvious that the resultant savings in weight and crack resistance have permitted the evolution of a whole industry. This industry is, of course, understandably interested in furthering the uses of its product, and consequently much energy has been devoted to precast prestressed concrete as distinct from cast-in-place concrete.

This paper is not meant to detract in any way from the importance of precast concrete as a material. It does however plead the cause of continuous cast-in-place

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prestressed concrete which does not have a well-organized industry to speak for it. It is also meant to show that it is, in reality, not the formidable design chore that it is often considered to be.

ADVANTAGES OF CAST-IN-PLACE CONTINUOUS PRESTRESSED CONCRETE

(1) Cast-in-place continuous prestressed concrete extends the economic range of hollow box girder bridges, rigid frames, and slabs.

(2) It permits simple, aesthetic concrete structures to be used on sharp skew crossings and at complicated interchanges.

(3) By virtue of its continuity it is inherently stronger than comparable simple-span structures using the same allowable stresses. To demonstrate this fact, consider the probability of plastic hinges developing in structures. A simple-span girder requires but one hinge for failure; a continuous bridge at least two, possibly three. The probability of encountering one batch of under-strength concrete is far greater than two or three where reasonable inspection and control have been maintained.

(4) In earthquake areas, continuity is an important asset as is the lower weight and greater crack resistance of prestressed structures.

(5) Experience has shown that, in the range of longer-span intermediate-size bridges and in interchange structures, it is the most economical and the most aesthetic method of construction.

EXAMPLES OF CAST-IN-PLACE CONTINUOUS PRESTRESSED CONCRETE

The Niagara Township Interchange (Fig. 29-1) was one of the first such structures in Ontario if not in North America. It carries the eastbound lane of Highway 405 going to Queenston-Lewiston and the New York Throughway over the westbound lane of the Queen Elizabeth Highway from Fort Erie, Buffalo, and Niagara Falls to Hamilton and Toronto.

The Sheppard Avenue CPR Underpass at Agincourt (Fig. 29-2) is the first continuous prestressed concrete railway bridge in North America. Crossing Sheppard Avenue in a northern suburb of Toronto, the CPR makes a sharp skew angle of 22 deg. A continuous hollow box grid slab provided a most economical solution to the problem. The depth of the slab and the amount of reinforcing steel required ruled out ordinary reinforced concrete, but the prestressed alternative not only satisfied the functional requirements and provided a pleasing structure but was about 10 percent more economical than the welded steel alternative also considered.