VIADUCTS IN THE HIGH-SPEED TRAIN LINE BETWEEN MADRID AND SEVILLE (STRETCH ADAMUZ - VILLANUEVA).

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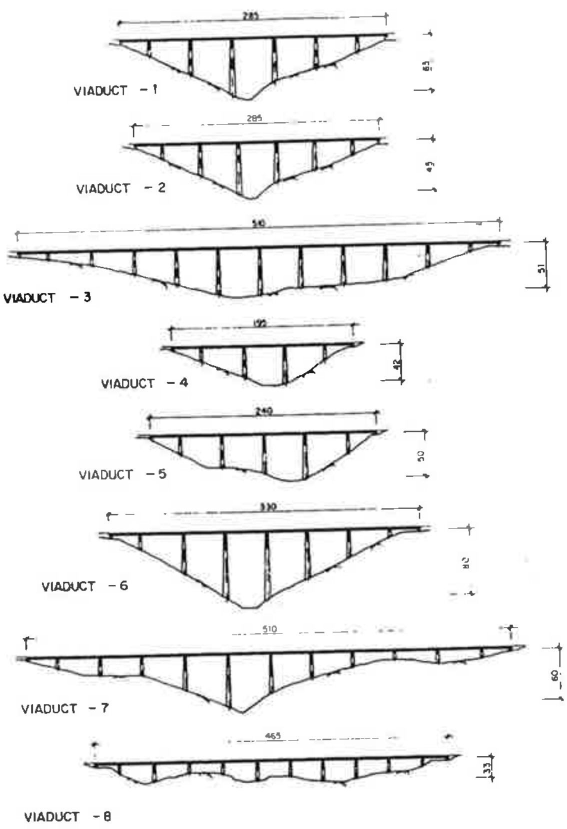
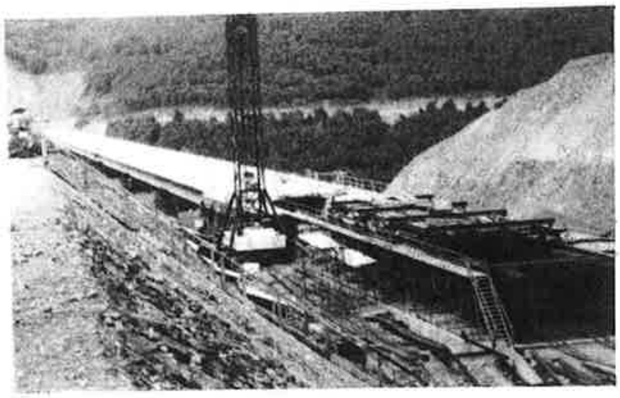
INTRODUCTION

The new high-speed train link between Madrid and Seville crosses the Sierra Morena through a zone which called for a number of tunnels and eight viaducts. Because of the nature of the terrain, some of the latter called for piers of considerable height.

GENERAL DESCRIPTION

Fig 1 shows the general dimensions of each of the viaducts. The deck is continuous across the full width for the length of each viaduct and consists of a box girder 3.30 m. in depth. The longitudinal slope of the deck - 1.2% - is the same for all viaducts. In plan, five of the viaducts are on curves of radius 2300 m., one on a curve of 4000 m. radius and the others on straigth lines.





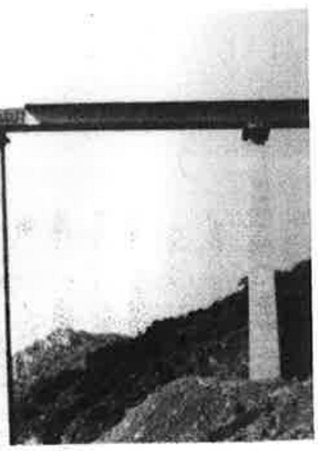


Fig 1

DESIGN CRITERIA

Given the magnitude of the work and the overall length of 2820 m., which was going to be carried out by one single contractor, careful consideration was given to the design, bearing in mind structural type, speed of construction, economy of materials and durability of the structures.

CONSTRUCTION METHOD

The special difficulties of access and consideration of the heights of the piers (which, in some cases, reached 80 m.) determined the construction method of each of the decks. Incremental launching from one side was adopted (Fig 2.) with the use of a frontal launching nose. (Fig 3.). The piers were built using sliding forms. (Fig 4.)

Fig 4

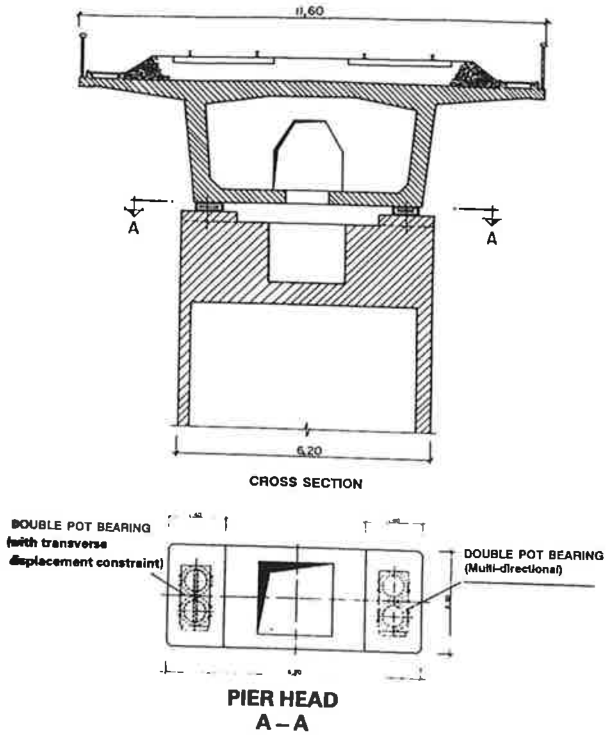


Fig 5

STRUCTURAL NATURE - DECK BEARINGS

The deck of each one of the viaducts is continuous over the full length. Longitudinally, the deck is stressed from one end, over the abutment, with sliding bearings along the rest of the deck over the piers and the other abutment.

This arrangement is common to all viaducts - the individual length is a maximum of 510 m. Forces arising from braking are transmitted through the deck to the fixed support, so that the piers are not affected by such forces, thanks to the sliding bearings.

The deck rests on the piers through two special bearings, one of which allows rotation and displacement in all directions. The other bearing allows rotation and displacement in a longitudinal direction only, as is normal in continuous bridges. (Fig 5.). Transverse forces on the deck (centrifugal force and wind effects) are transmitted to the piers through the bearings. Determination of the structural response of the piers was the result of careful study of the distribution of the forces, with the overall stiffness of the structure in mind. Calculation showed that piers of less height, and thus of greater stiffness, absorb

- a notably greater force than the higher piers and, in some cases, up to three times those due to a uniform distribution. This resulted in the placing of special equipment for resisting transverse braking forces in the shorter piers of curved viaducts, since the ratio of horizontal to vertical forces is very high.

Transmission of horizontal forces in the deck from the fixed support is through a system of neoprene buffers and the addition of prestressing anchorages with horizontal tendons of sufficient length to ensure the free rotation of the deck. (Fig 6.)

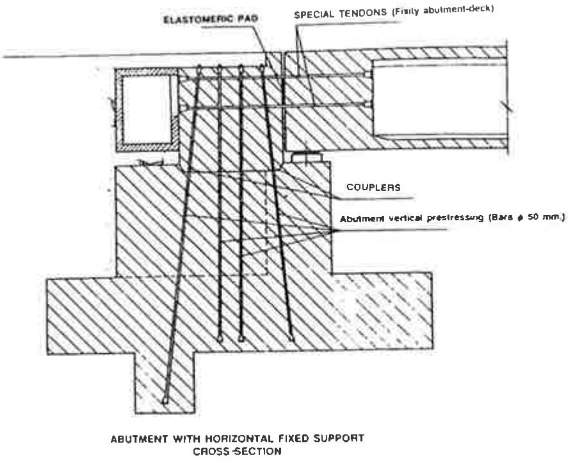


Fig 6

Fig 7
Abutment vertical prestressing
(Bars ϕ 50 mm.)

DESIGN FORCES

Consideration of the Spanish Codes for railway bridges showed that a number of unusual problems had to be taken into account because of the magnitud of the horizontal forces to be resisted by the structures.

Viaducts V3 and V7 are each 510 m. long. In both of them the horizontal force due to braking, according to the Code, could reach a value of 1300 t., which had to be resisted by the abutment to which the deck was fixed. Vertical prestressing with bars ϕ 50 mm. was provides in abutment in order to resist the effects of the horizontal force (Figs 6 and 7).

Information available as to the actual weights of the trains and comparisons with other foreign Codes gave rise to the thought that the horizontal actions to be taken into account were excessively conservative and that a review of the current Code seemed advisable. The horizontal action based on trains, weighing from 10 to 12 t/m length travelling at 200 km/h, did not seem adequate in the case of high speed trains.

In the viaducts in the High-speed train between Madrid and Seville, the centrifugal force was calculated in accordance with the Code. The position of viaducts in a mountainous region called for piers ranging from 13 to 80 m. in height, within the same viaduct. As mentioned earlier, an examination was made of the distribution of horizontal loads due to centrifugal action and to wind. Through this, it was possible to take into account the actual geography at each viaduct - the number and height of the piers and the stiffness of the structural members. In the most unfavourable case, bearings have to transmit calculated horizontal loads of 300 t.

BEARINGS

Each bearing consists of a combination of twin devices, made up of a cylinder filled with a rubber piston (Fig 5). All bearings allow sliding in the horizontal direction along the viaduct, and one bearing at each pier has a device which allows transfer of transverse forces to the pier, thanks to a side restaint consisting of a strong bar attached to the top plate which prevents the two rockers from sliding simultaneously in anything other than the longitudinal direction of the viaduct.

Using this special type of bearing has proved extraordinarily advantageous for this kind of project because of the increased capacity offered of transferring transverse forces, which is greater that that with simple 'Pot' bearings.

At launching of the deck, because of the dispositions of the two cylinders in each bearing, the vertical load of the box beam webs is transferred to the piers without causing any bending stresses in the lower horizontal slab. There is a transverse diaphragm inside the beam, situated near the bearings above each pier. Transfer of loads is carried out without difficulty, because of the way these bearings are positioned. In this way, the transverse diaphragm scarcely needs to function as a 'bridge' distributing loads. This systema makes it possible to open a large space inside the beam. (Fig 8) In the future, this space will enable light vehicles to be used within the hollow box beam from one end to the other.

The structural function of the diaphragms is limited, in practice, to reducing transverse distortion of the deck and to transmitting transverse forces to the bearings. They are also capable of strengthening the zone and their locations allow the positioning of hydraulic jacks which might have to be used for occasional lifting of the deck, in order to replace bearings.

The magnitude of the horizontal loads which the diaphragms have to transmit called for a detailed study, and a considerable amount of passive reinforcement was introduced to resist the design forces.

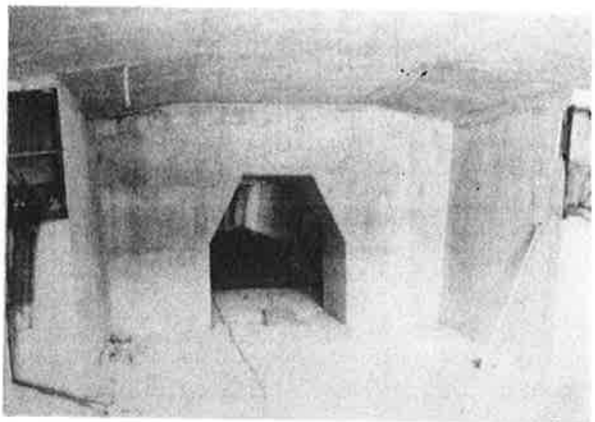


Fig 8

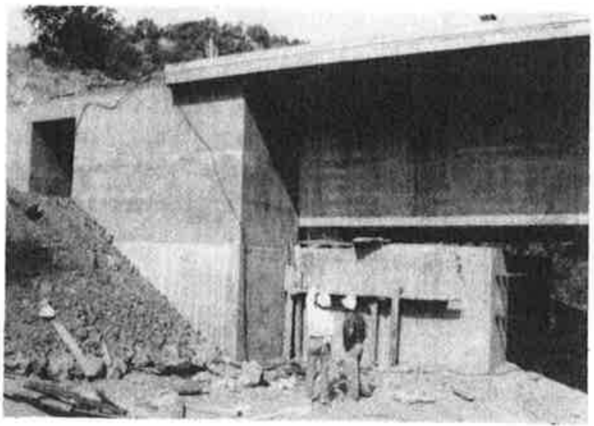


Fig 9. Access to concrete girder

MAINTENANCE

The location of the viaducts, in a mountainous region, and the great height of some of the piers make it difficult to obtain access to the viaducts and to carry out inspections and maintenance of the decks, in particular of the bearings. With all this in mind, the design of the structures was based on the following requirements:

- Internal access to the box girders through a door in one of the abutments of each viaduct. Entry had to be in an accessible zone and had to allow loading and unloading of all materials necessary for maintenance. (Fig 9.)

- Creation of conditions within the box girders to enable movement of vehicles to transport personnel and equipment dealing with maintenance and with any required replacing of bearings. The loads involved could be of the order of 2 t. (Fig 10.)

- Access through small openings in the bottom slab of the girder at the head of each pier. (Fig 11.) The dimensiones of these openings are such that they allow the entry of personnel and replacement bearings. The addition of a small winch fixed to the top of the diaphragm opening in the girder simplified the operations of hoisting equipment. (Fig 12 shows the opening in the bottom slab during forward movements so that it has not yet reached its final position.)

- Forming of an opening over the head of the pier, suitably dimensioned to permit passage of personnel and equipment for the handling of bearings, lifting of the deck, etc. (Fig 13)

- Possibility of replacing the deck anchorages at the abutment. (See Fig 6.) The fixing system between deck and abutment is designed for high capacity tendons, horizontally placed, fitted at their ends with screw anchorages. They compress, permanently, the top of the abutment, the end of the deck and buffers formed of elastomeric pads. (Fig 6.) The active steel is housed in ducts injected with anticorrosive grease.

The magnitude of the braking forces to be transmitted (which, in some cases, could reach 1300t according to the calculations imposed) determined the system, which ensures longitudinal fixation of the deck and allows some rotation. The nature of the system and the properties required of the materials, with permanent prestress, are such that there is a permanent guarantee against fatigue. At all times, replacement is possible, given the possible risk of corrosion and to facilitate any future requirement concerning maintenance.

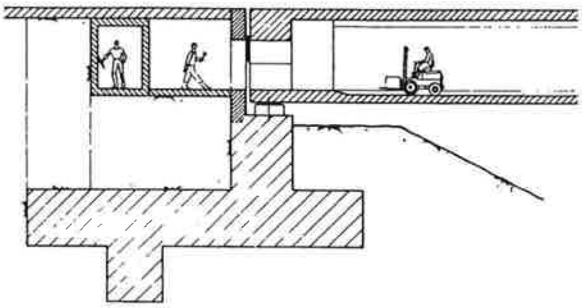


Fig 10

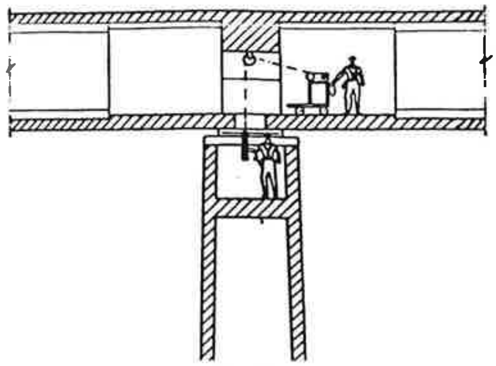


Fig 11

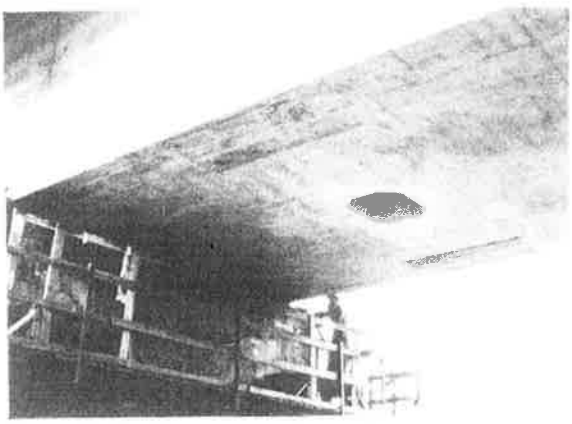


Fig 12. Access manhole to beam

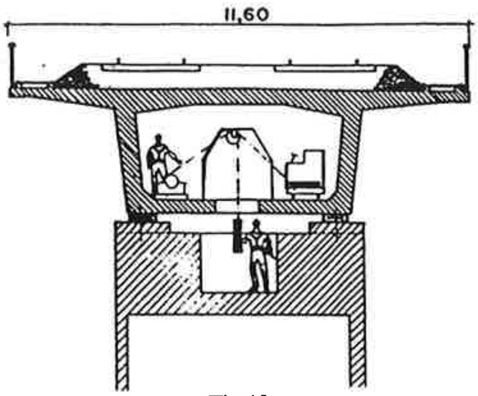


Fig 13

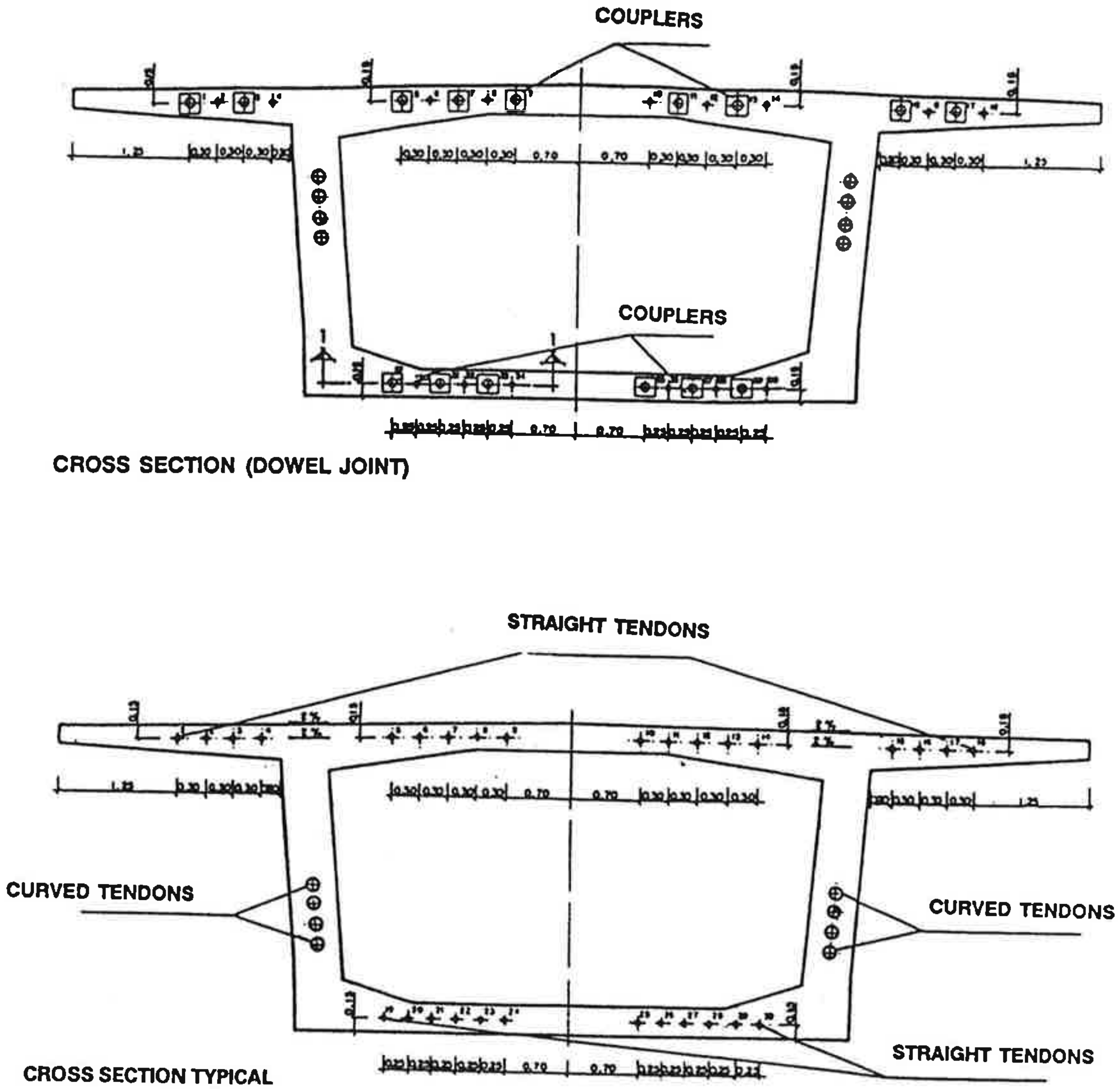


Fig 14

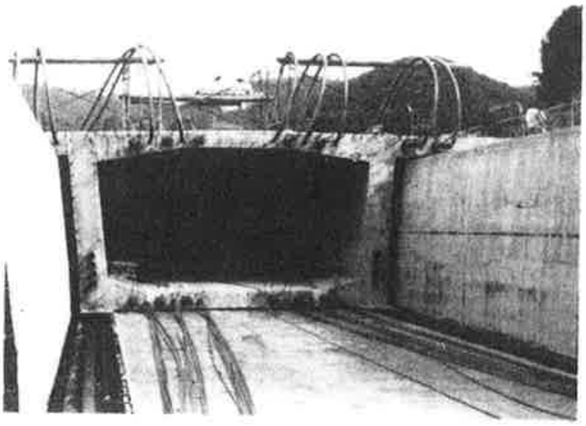


Fig 15

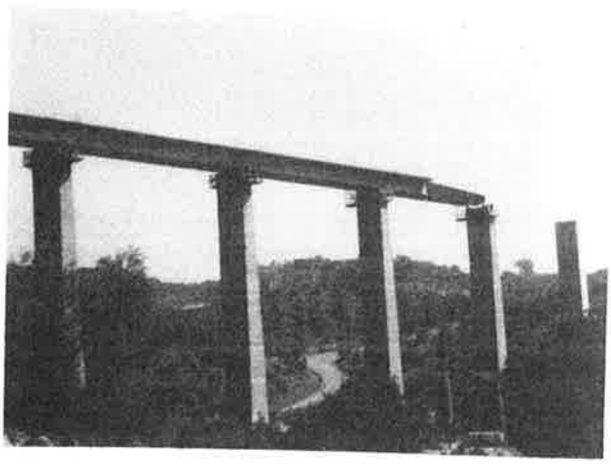


Fig 16

PRESTRESS IN THE DECK

Longitudinal prestress in the deck is provided by two separate sets of members. (Figs 14 and 15) The first of these, straight tendons, lie in the upper and lower slabs and are designed to resist stresses during launching. Stressing of these straight tendons in each segment was done in two stages: the first, immediately after setting of the concrete and prior to initial launching; the second, following the next cycle which coincided with the stressing of the following segment, just concreted. Continuity of the tendons is ensured through couplers in the active anchorages.

The second prestressing system was applied once launching had been completed and the launching nose removed. This consisted of curved tendons places in the webs of the box sections.

ANALYSIS OF THE STABILITY OF THE PIERS

Throughout the development of the project, the stability of each pier was examined, using the forces laid down in the Codes. The actual geometric section of the concrete section, which varies with the height, and the disposition of reinforcement were taken into account, together with the second order bending due to skew, using a specially designed computer programme.

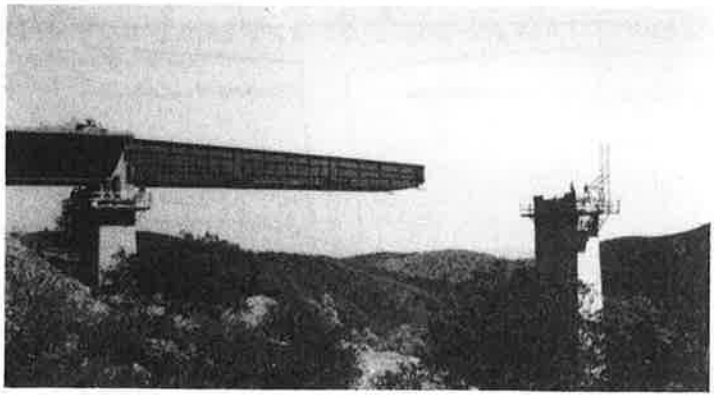


Fig 17

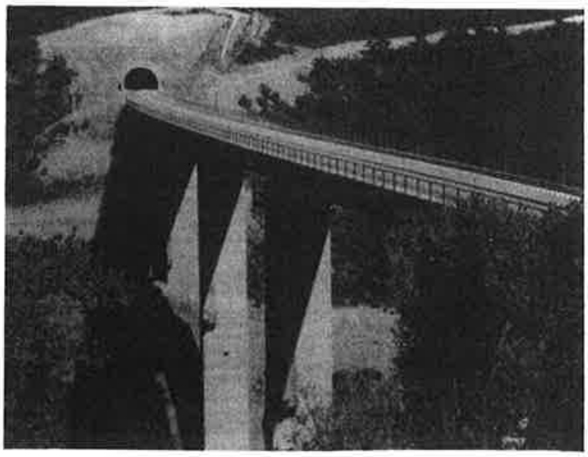


Fig 18

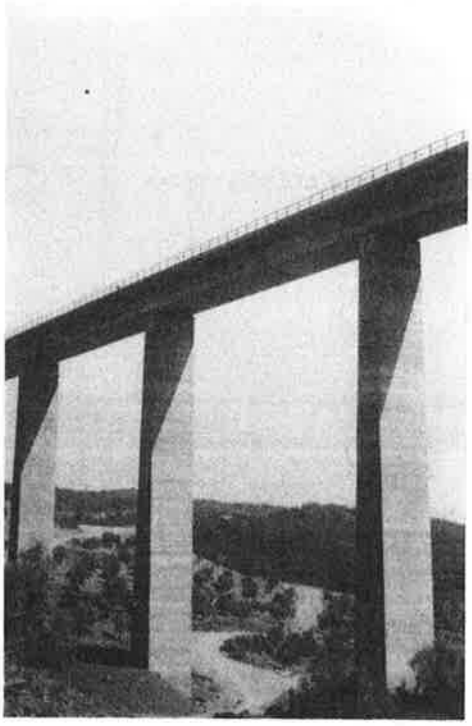


Fig 19

CONSTRUCTION PROGRAMME

As already mentioned, the piers were constructed using sliding shutters and the bridge itself by incremental launching from one side.

Each of the sections in the construction cycle was 22.50m long, corresponding to half the main spans, the exceptions being the end spans of 23.30 and 15.80 m. Launching was done with the aid of a steel launching nose (Figs 16 and 17), fixed to the forward end by prestressing bars. Concreting of each section was carried out in two stages. In the first stage the lower slab and the two side walls were cast, forming a horizontal joint to connect the walls with the top slab. Once the shutters for the vertical walls had been removed, the top slab was immediately cast. Concreting of each section was completed before any movement of the bridge took place.

Such a procedure provides full guarantee of the structural stability of the deck and eliminates risks which exist with other methods, when some movement takes place before concreting is completed for a full section.

A programme was established based on one section, or 22.50 lineal meters of deck/week, including launching. The actual rhythm on site agreed with this plan and, once established, occasionally resulted in the cycle being completed in 6 days.

Construction of the eight viaducts took place at such a pace that, at any time, work was being carried out on three sections simultaneously, resulting in the production of three sections/week - quite a 'record' and a tribute to the organisation. Figs 18 and 19 show two of the structures.

OWNER: The Spanish Ministry of Public Works and Transportation
CONTRACTOR:
Dragados y Construcciones
Entrecanales y Tavora
Comsa
PRESTRESSING SYSTEM: CTT - Stronghold