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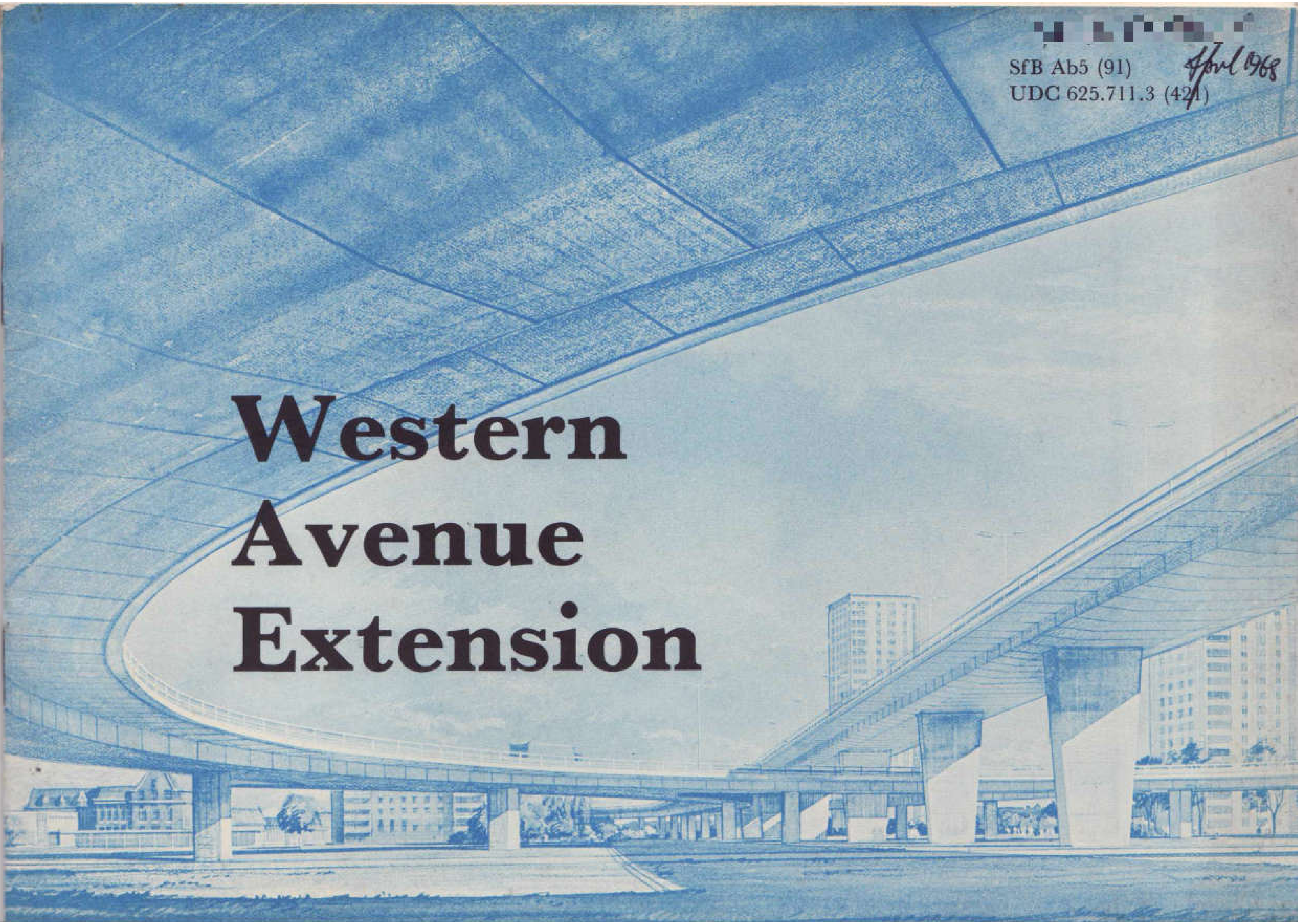
April 1968

Western Avenue Extension



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WESTERN AVENUE EXTENSION

Greater London Council

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William Holford and Partners
Consultant Architects

John Laing Construction Limited
Contractor

CONTENTS

MOTORWAYS FOR LONDON

The Western Avenue Extension is the first motorway-standard highway in urban London to be designed and built as part of a broad overall scheme for urban motorways, rather than as an isolated unit or the inner-area extension of an established motorway.

Intended initially as a high-capacity link between Central London and the A.40 trunk road to the Northolt-Ruislip-Uxbridge suburban belt and South Wales, it will eventually form one of the main *radial arms linking central London with the Inner Motorway Box. The Western Avenue Extension* contract in fact includes the first section of the West Cross Route, part of the Motorway Box.

A basic principle in the planning of urban motorways for the Greater London Council has been to choose locations that avoid, wherever possible, the creation of new physical barriers through existing districts and neighbourhoods. In London, as in most cities, the most readily accessible 'corridors' of this kind are railway lines, most of which have formed divisions between areas for a century or more and are now firmly established. Roads following these railway 'corridors' cause a minimum of disruption to the existing urban and suburban traffic: at the same time they best serve the needs of suburbs and outer urban areas that have grown up around the railways.

Railways also present one of the very few sources of urban space which has not been fully developed. Building over railways - or alongside them where land was either bought for expansion that never took place or where modernization and rationalization of the rail system has made available land formerly used for railway purposes but now surplus - has obvious cost and social advantages.

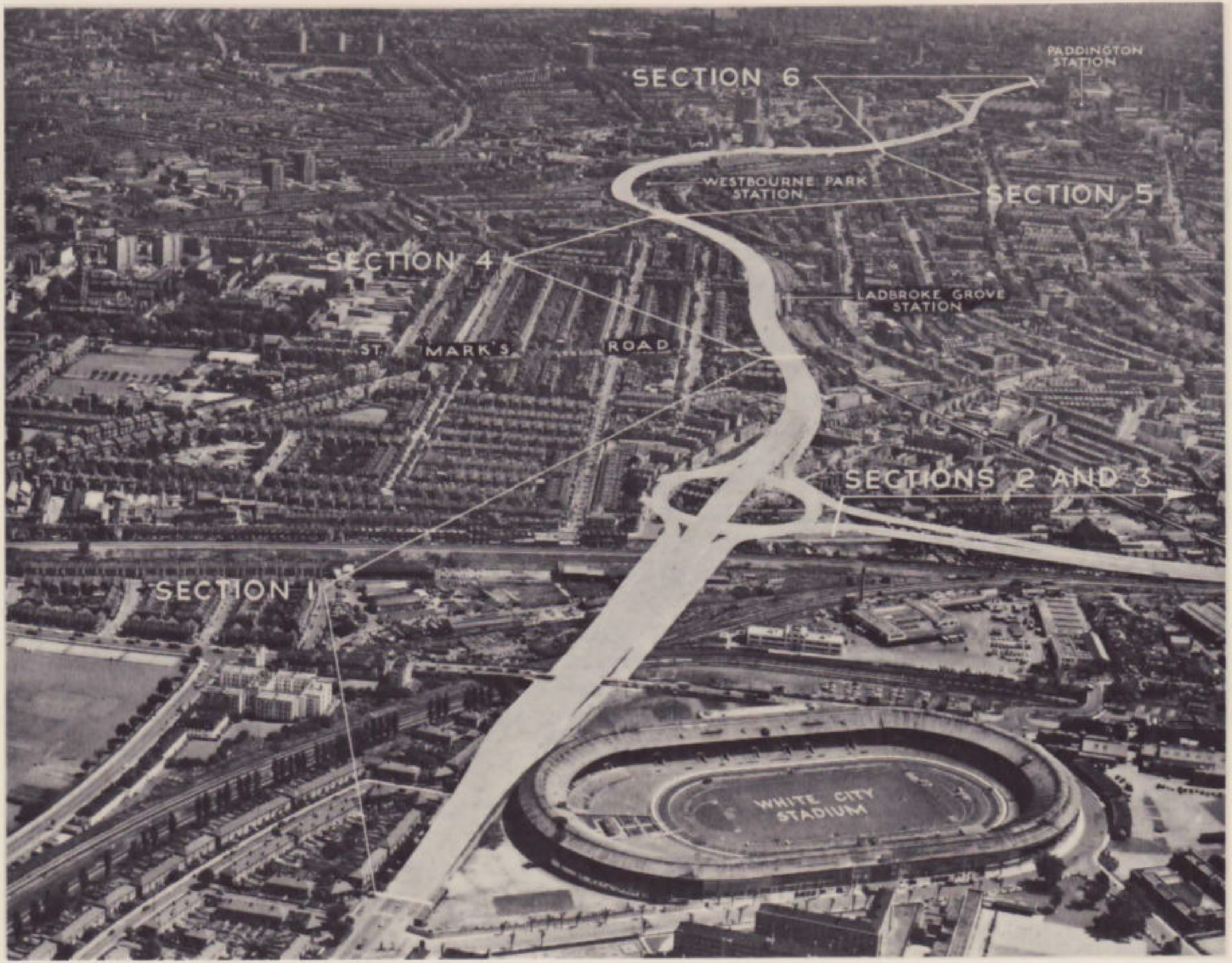


Figure 1: Route of the elevated road looking eastward.

THE ROUTE

The route of the Western Avenue Extension is the most extended development to date of this planning principle. From its commencement, north of White City Stadium, the $2\frac{1}{2}$ mile elevated roadway of the extension proper crosses the Central Line of London Transport where it passes under Wood Lane and the West London Line of British Rail, and the mixed industrial area that has grown up among the railway lines in the area. Next it follows closely along the north side of London Transport's Hammersmith and City Line past Ladbroke Grove Station, then crosses the main approach tracks to Paddington Station on the skew at Westbourne Park Station and continues to follow the Western Region approach tracks - now on their north side - for some distance before it diverges and terminates at Paddington Green adjacent to the new Harrow Road Flyover across Edgware Road, leading into the main Marylebone Road-Euston Road east-west route passing just to the north of London's commercial centre.

The length of the West Cross Route included in the contract also follows a main railway route, the West London line of British Rail. From an elevated roundabout junction with the Extension just east of the railway, the West Cross Route portion of the contract follows close along the eastern side of the railway to a new ground-level roundabout at Holland Park Avenue.

DESIGN REQUIREMENTS

The Extension was designed for a mean speed of 50 mph on the through routes and 30 mph on slip roads. Maximum gradients are 1 in 25 on the main structure and approach ramps and 1 in 20 on slip roads.

The elevated structures were designed for Ministry of Transport HA loadings and checked for an HB loading of 180 tons, as the route is a primary one for heavy vehicles through and to London.

Vertical clearances above all carriageways are a minimum of 16 ft 6 in. throughout, while clearances over all lines range from 13 ft to 16 ft as agreed with British Rail and London Transport authorities.

Figure 2: Route looking westward.

From Westway to an elevated roundabout on the east side of the West London railway line the main elevated route will have dual three-lane carriageways, while the through flyover above the interchange roundabout will carry dual two-lane carriageways. From just east of the roundabout the road will have three lanes and an 8-ft hard shoulder in each direction as far as a slip-road interchange at Westbourne Terrace Bridge, and two lanes and an 8 ft hard shoulder in each direction from there to Paddington Green.

The decision by the Greater London Council and the Ministry, during tender stage, to widen the road to include hard shoulders created major problems for the consulting engineers and their computer installation played an important part in the task of redesigning the structure in a short time.

The length of the West Cross Route included in the contract will be of dual four-lane construction at ground level: for the present these will be operated as a dual three-lane carriageway with hard shoulders.

FOUNDATIONS

A series of boreholes along the length of the route confirmed the presence of London clay underlying the whole area of the works, with beds of ballast, soil and made-up ground over the clay. The consulting engineers decided to use large-diameter bored cylindrical piles with belled bases founded in the clay, in some cases reaching a depth of 100 ft. In order to gain additional information on expected settlement, 24 in.-diameter plate bearing tests were carried out under a separate contract by George Wimpey and Company Limited. In addition two specially constructed cylinders were tested to ultimate load and a number of the cylinders incorporated in the actual works were subjected to working load and proof load tests; much useful information has been obtained from this relatively new form of large-scale testing.

STRUCTURAL MODEL TESTS

Two structural scale models were built and tested during the development of the design, one by the Cement and Concrete Association's Research and Development Station at Wexham Springs and the other by Imperial College, London.

The first was a 1:16 scale micro-concrete model of one of the 204 ft spans of Section 5, the segmental precast prestressed concrete structure over the railway lines near Westbourne Park Station, together with one quarter of each adjoining span. Many configurations of design loading were applied to the model and it was eventually loaded to collapse. The complex bending, shear and torsion stresses were measured by mechanical and electrical resistance gauges and the readings were translated into punched tape by data loggers and processed by the Association's Sirius computer.

Before making the micro-concrete model the Association's engineers made a perspex model of half of the cross section of the structure to study the distribution of transverse prestress in the elements.

The Imperial College tests were carried out to study the composite behaviour of the concrete deck and steel portal frames used for Section 6 at the Paddington end of the works. A composite beam to a scale of 1:3, representing part of one of the welded portal frames used to support the prestressed concrete box beam deck structure, was tested to study the behaviour of the composite action of a new type of shear connector developed by the consulting engineers and based on vertical prestressing by Macalloy bars. Detailed observations of the behaviour of the whole beam to collapse were made.

THE ELEVATED ROAD

The entire contract is divided into six sections, of which four (Sections 1, 4, 5 and 6) comprise the elevated roadway forming the main west-east Western Avenue Extension itself. Sections 2 and 3 form part of the future West Cross Route of the Motorway Box and are linked to the Western Avenue Extension proper at the elevated roundabout.

SECTION 1

Design

Section 1 extends from the abutments of the approach ramp at Westway, adjacent to the White City Stadium, to St Marks Road and includes the most important interchange in the present contract, that between the Western Avenue Extension and the West Cross Route. Construction throughout consists of prestressed concrete box-section spine beams with cantilever side slabs. The cross-sections used vary between one and three cells in the main spine beam; the structure will be monolithic when completed throughout its length. Span lengths are generally 115 ft and segmental precast units weighing up to 45 tons were used except for the roundabout and tapering portions of the structure, which are of in situ construction.

The design of this section is unusual in two ways, first in being built without a fixed anchorage in the usual sense and second in being built in four parts which are independently continuous during construction but will be linked into a single monolithic structure on completion.

The anchorage, instead of being provided at an abutment and firmly fixed as in usual continuous design practice, will be provided by the ring structure of the elevated roundabout. Like all of Section 1, this will consist of hollow box spine beams with side cantilevers, carried on sliding bearings on the in situ supporting columns. Bearings of the roundabout ring are, however, designed to move only in a radial direction and thermal movements in the structure will therefore be evenly distributed around the ring: the theoretical centre will remain fixed, and the ring as a whole will act as the anchorage for the rest of the structure in all directions, specially-designed expansion joints being provided at abutments of the extremities.

Construction

The basic construction of the section is by the span-by-span method using precast concrete segmental units erected on falsework and stressed together in two stages to carry dead and full live loads, similar to the method used previously in the construction of Mancunian Way in Manchester. The method could perhaps better be described as '$\frac{3}{4}$ span - $\frac{1}{4}$ span' construction: spans are erected not from pier to pier but from a cantilever, extending approximately one fourth of a span beyond the last pier, to a point the same distance beyond the next pier, and thus forming the next cantilever in the sequence.

Prestressing cables extend over two spans; those for each pair of spans overlap the tendons previously installed by one span length. As each span is completed it is given first-stage prestress sufficient to carry dead load so that the falsework can be moved ahead for the next span, while the span behind is given the second or final stage of prestress.

Section 1 is being built in four parts: the roundabout itself, which serves as the anchor for the completed structure; the main structure to the east and to the west of the roundabout; and the dual two-lane flyover above the roundabout. Each of those parts is being built as a continuous structure during construction, with gaps allowed for the final linking up of all four into a single monolithic entity.

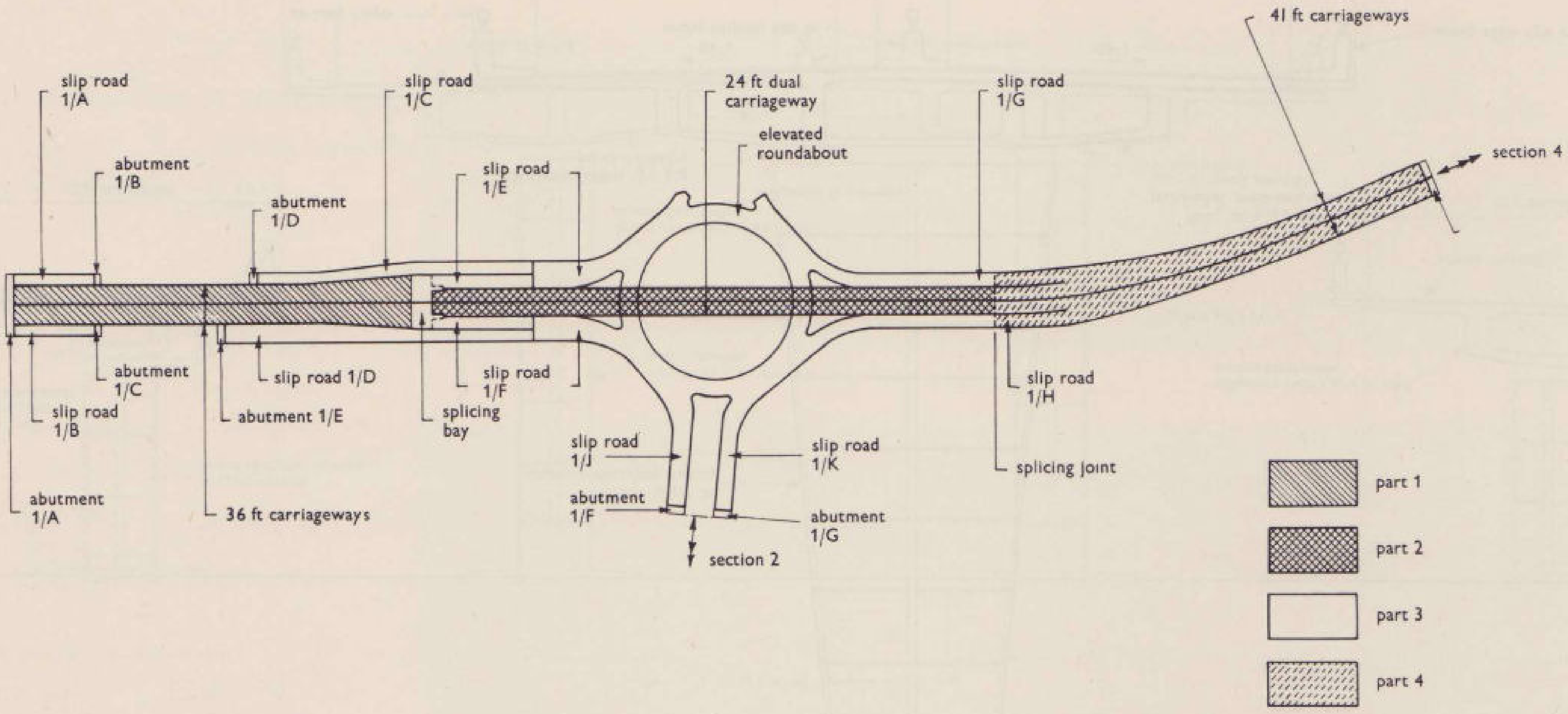


Figure 3: Key plan, Section 1.

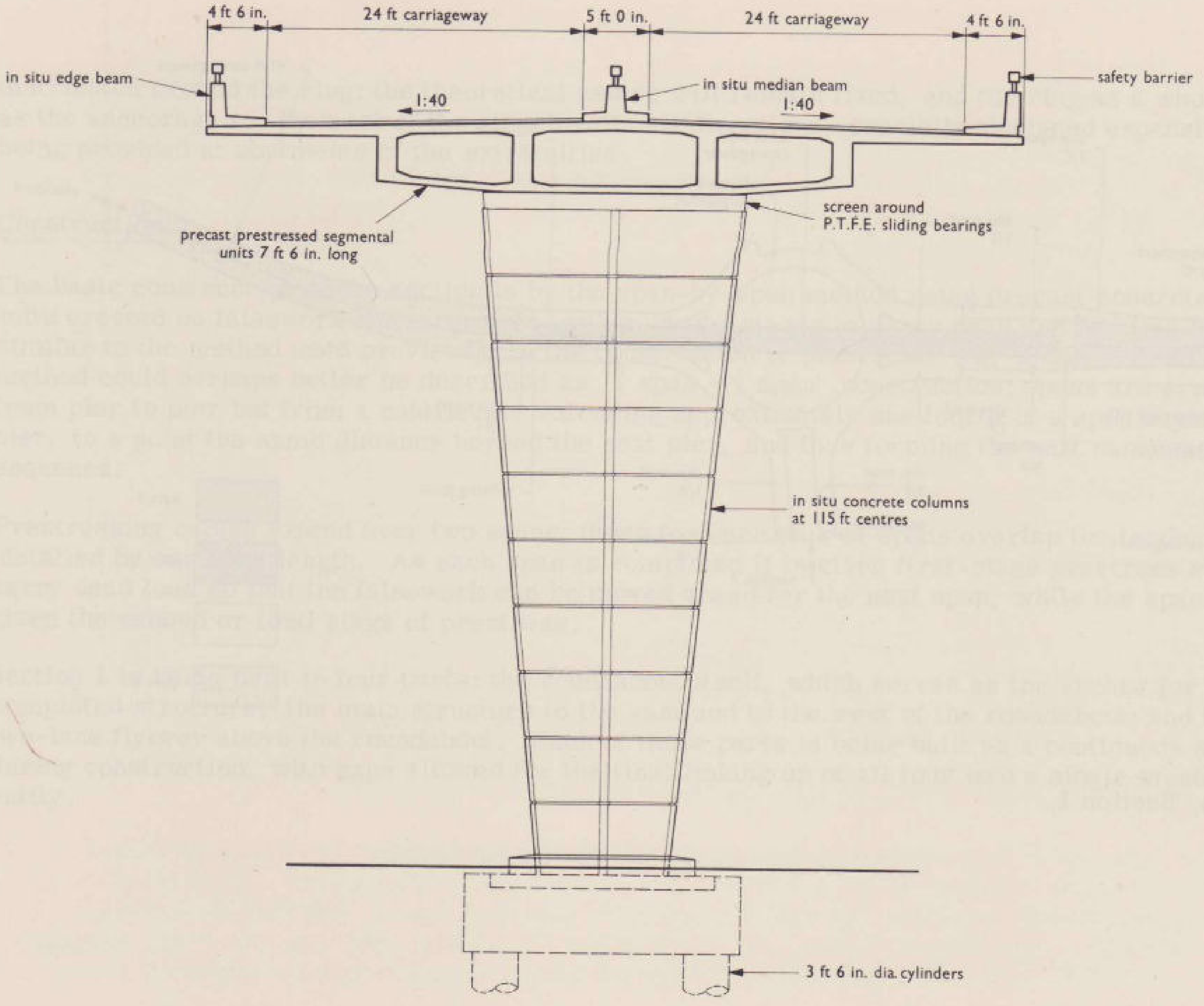


Figure 4: Cross section of dual two-lane flyover above roundabout.

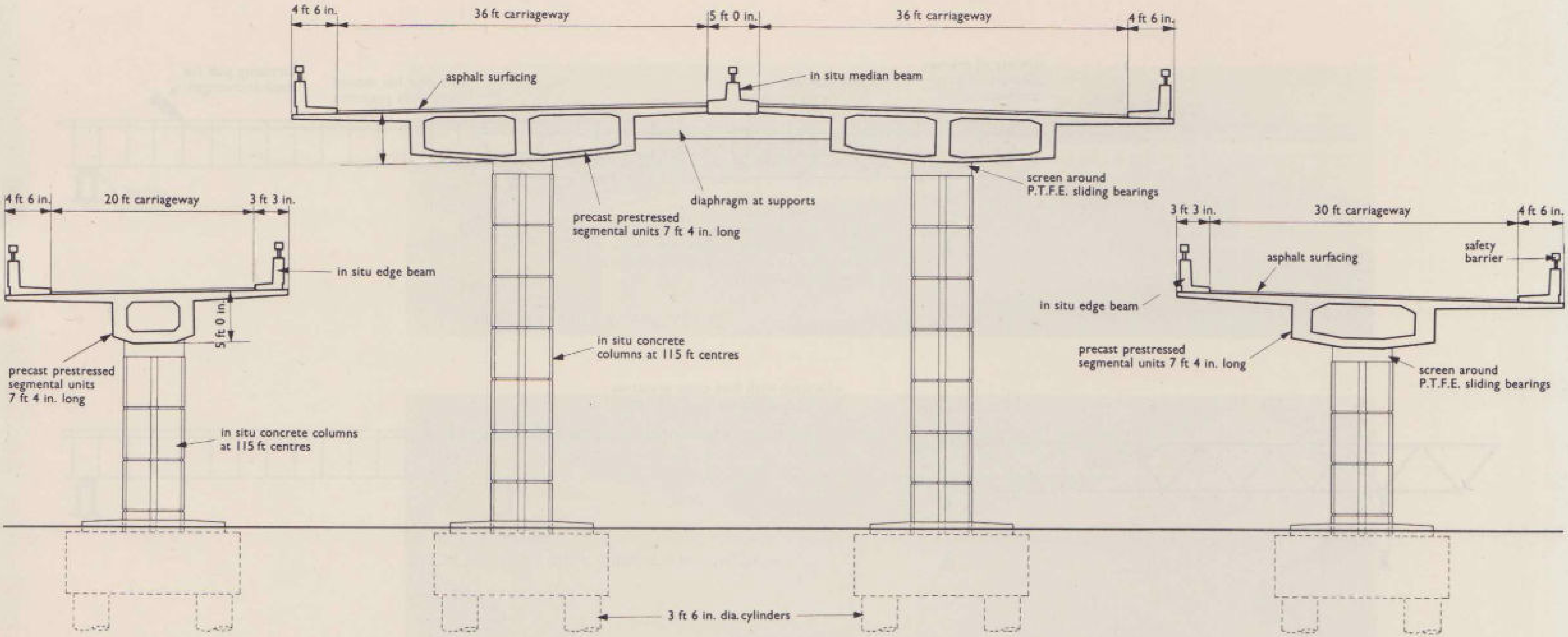


Figure 5: Cross section of dual three-lane and slip road structures.

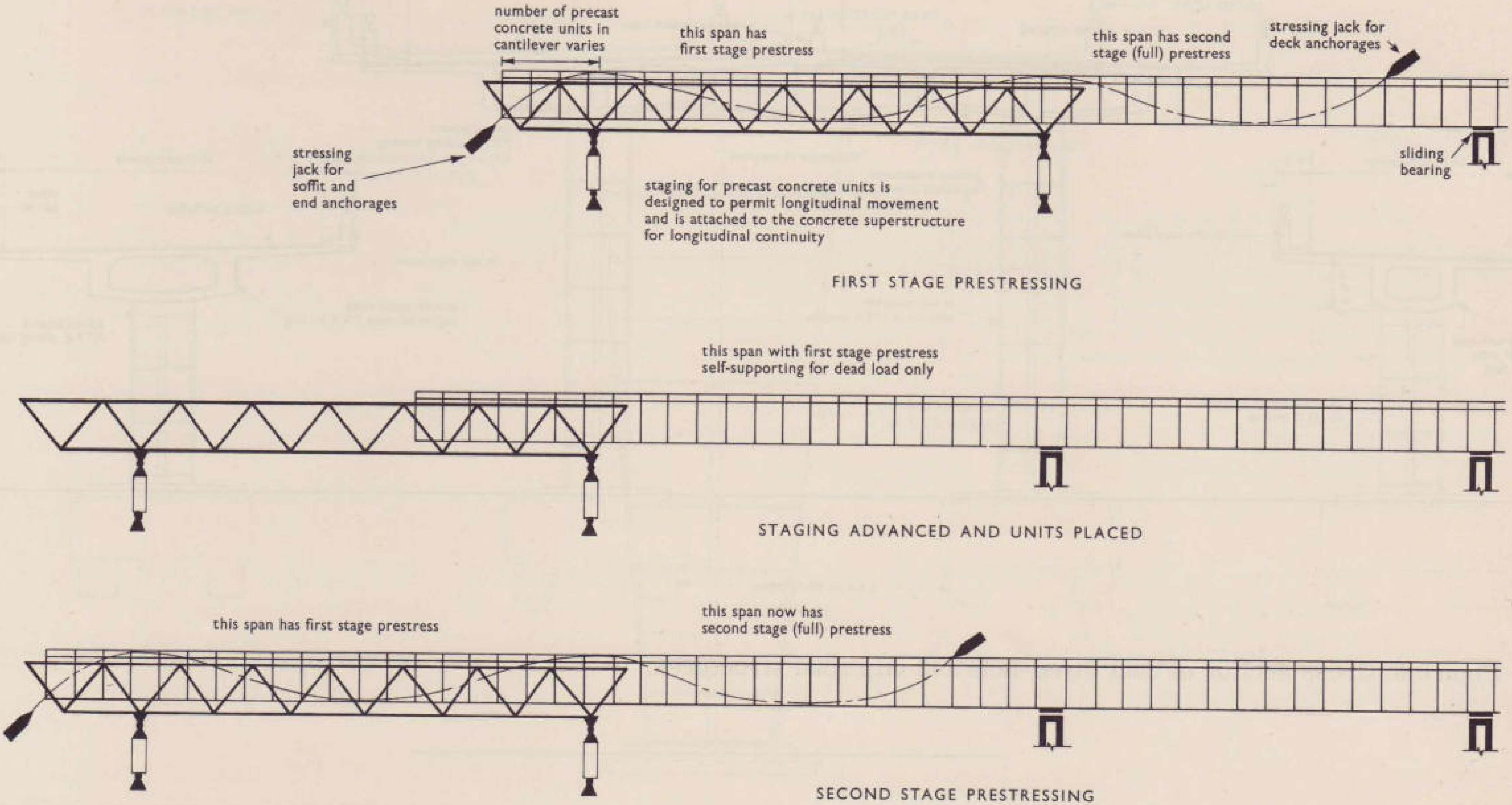
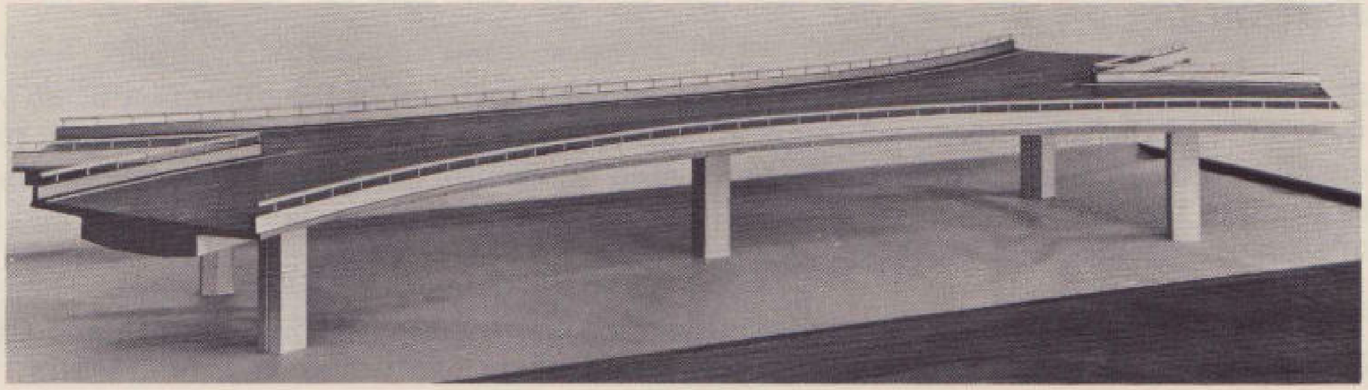
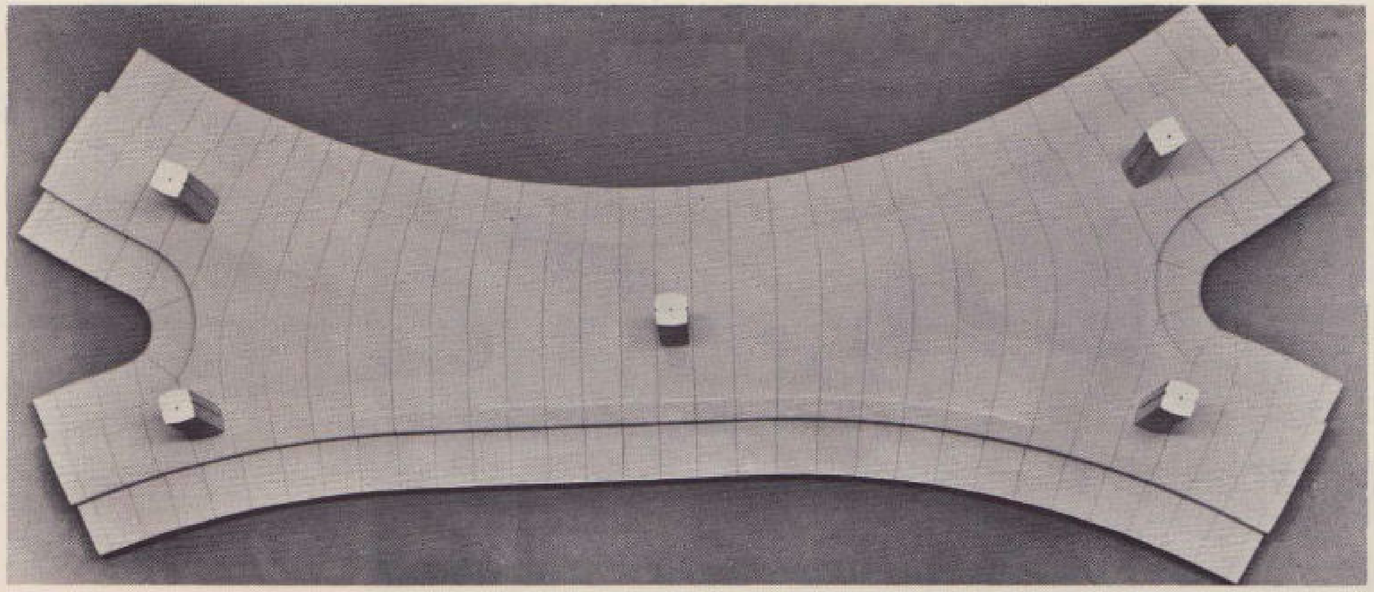


Figure 6: Sequence of operations for span-by-span construction of segmental precast structure.





Figures 7 and 8: Model of elevated roundabout and slip-road structure showing in situ construction.

SECTION 4

Section 4, approximately 2, 200 ft long from the east side of the abutment at St Mark's road to the west side of the abutment at Acklam Road, has a deck structure of short-span precast prestressed concrete hollow box beams simply supported on reinforced concrete cross-walls and columns. At two points the superstructure crosses streets by longer-than-normal spans and here the longer spans are made continuous with those on either side.

The entire length of this section lies alongside the existing Hammersmith and City Line railway embankment, which is supported by new independent cantilever retaining walls. A service road at ground level lies partly under the elevated structure and provision is being made for car parking or other uses under the structure.

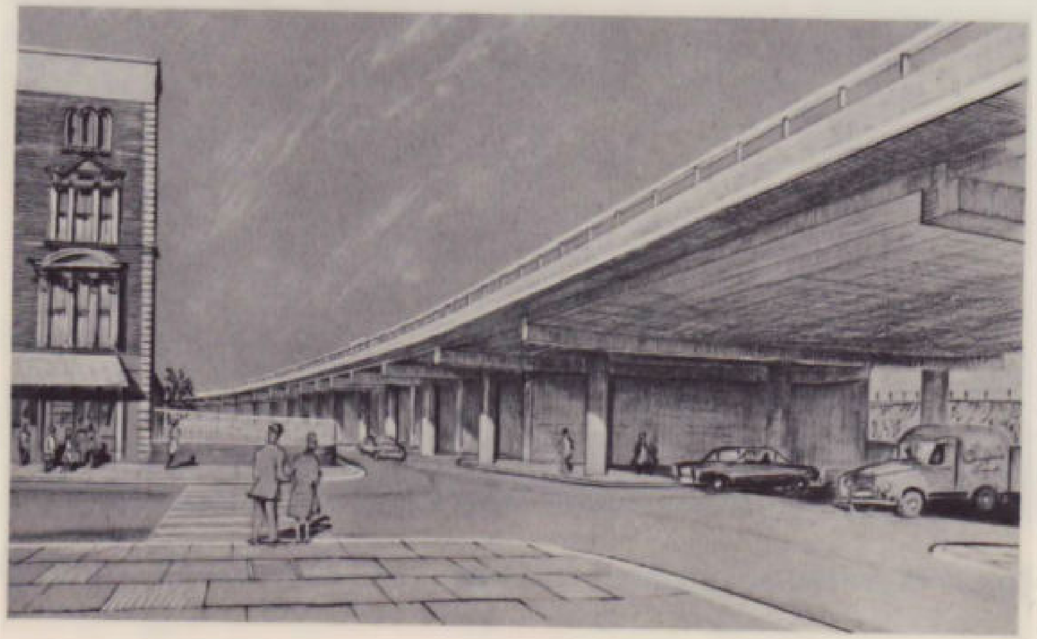


Figure 9: Artist's impression of Section 4 structure.

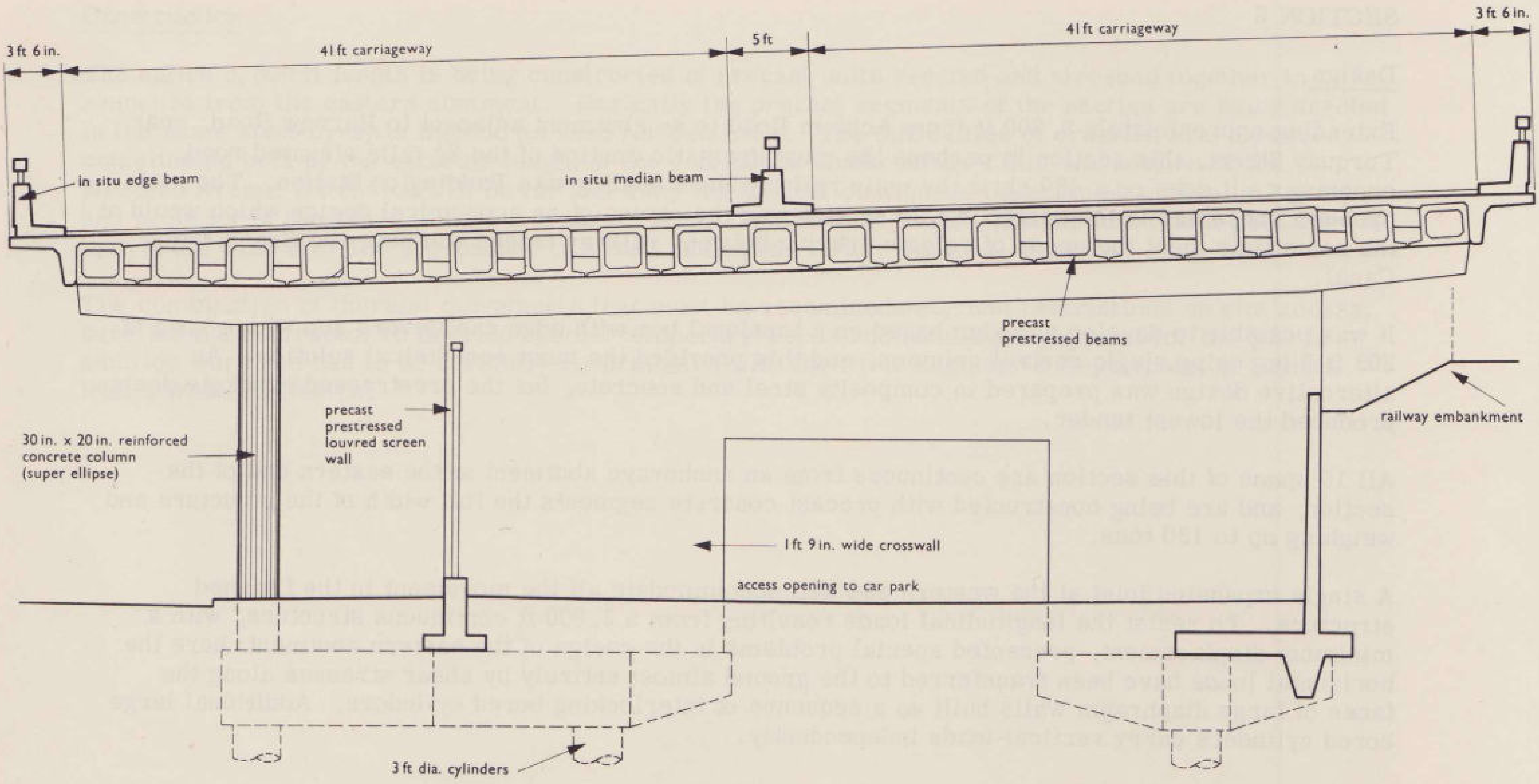


Figure 10: Typical cross-section, Section 4.

SECTION 5

Design

Extending approximately 3, 800 ft from Acklam Road to an abutment adjacent to Harrow Road, near Torquay Street, this section is perhaps the most dramatic portion of the $2\frac{1}{2}$ mile elevated road, crossing as it does on a 45^{o} skew the main railway lines leading into Paddington Station. The main problem presented in the design of this section was the choice of an economical design which would at the same time meet the needs of column spacing between railway tracks and near the Grand Union Canal.

It was possible to develop a design based on a torsional box with edge cantilevers and with a span of 203 ft 8 in. using single central columns, and this provided the most economical solution. An alternative design was prepared in composite steel and concrete, but the prestressed concrete design produced the lowest tender.

All 19 spans of this section are continuous from an anchorage abutment at the eastern end of the section, and are being constructed with precast concrete segments the full width of the structure and weighing up to 130 tons.

A single expansion joint at the western end will accommodate all the movement in the finished structure. To resist the longitudinal loads resulting from a 3, 800 ft continuous structure, with a minimum displacement, presented special problems in the design of the eastern abutment: here the horizontal loads have been transferred to the ground almost entirely by shear stresses along the faces of large diaphragm walls built as a sequence of interlocking bored cylinders. Additional large bored cylinders carry vertical loads independently.

Construction

The entire 3, 800 ft length is being constructed of precast units erected and stressed together in sequence from the eastern abutment. Basically the precast segments of the section are being erected in the same span-by-span method as used for Section 1. The difficulties of erection are, however, complicated both by the extreme length of the continuous construction - this one section of the Western Avenue Extension will be far and away the longest continuous concrete structure in Britain and probably in the world in terms of length from a single anchorage - and the fact that a good part of it is being built over the approaches to a busy mainline railway station.

The combination of thermal movements that must be accommodated, and restrictions on site access, have led the contractor to develop special temporary works and handling equipment for the job: in addition work has had to be carefully co-ordinated with the Civil Engineer's Department of British Rail's Western Region.

Figure 11: Artist's impression of Section 5 alongside Grand Union Canal and crossing Western Region tracks.

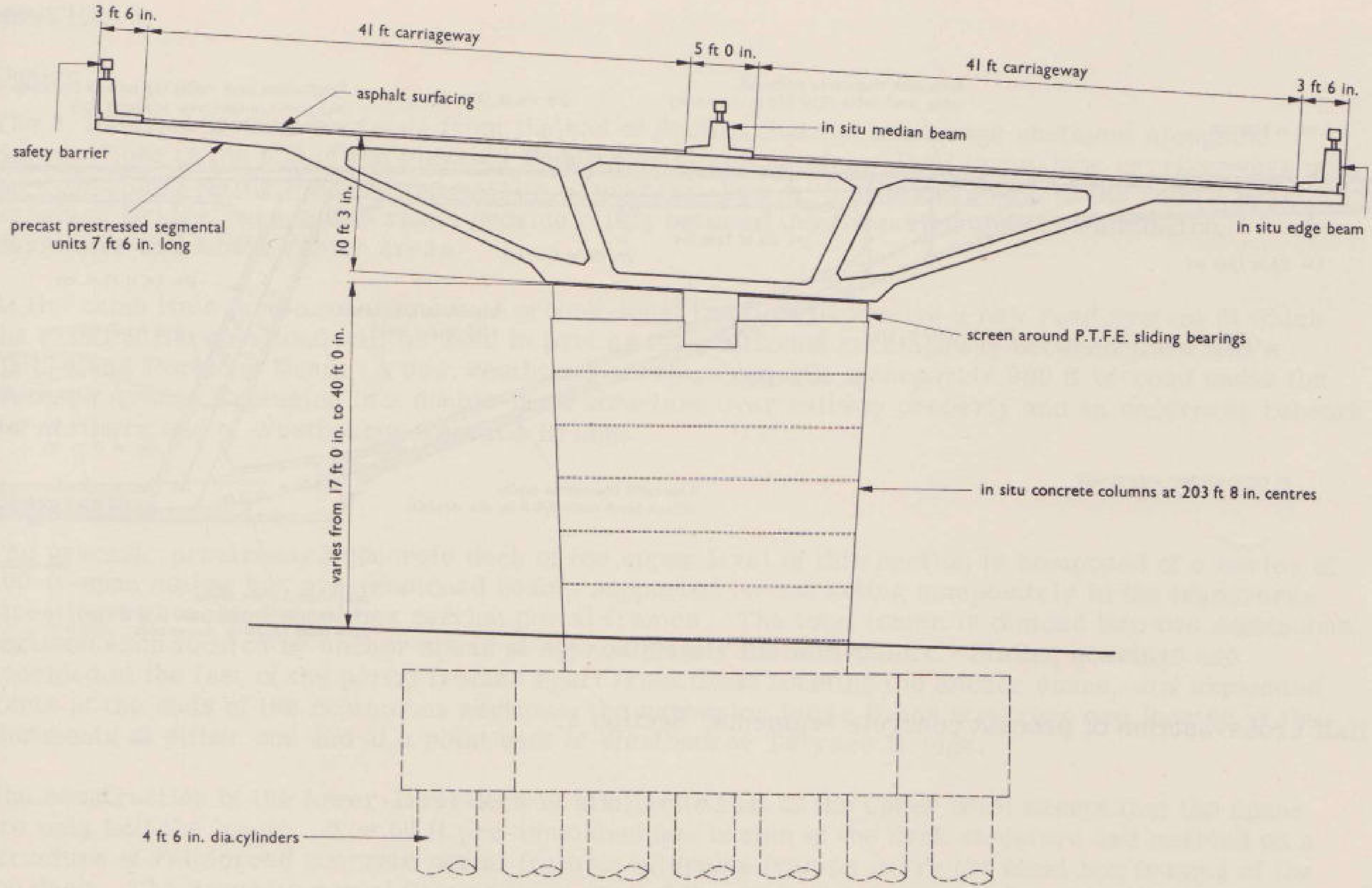


Figure 12: Typical cross-section of elevated structure, Section 5.

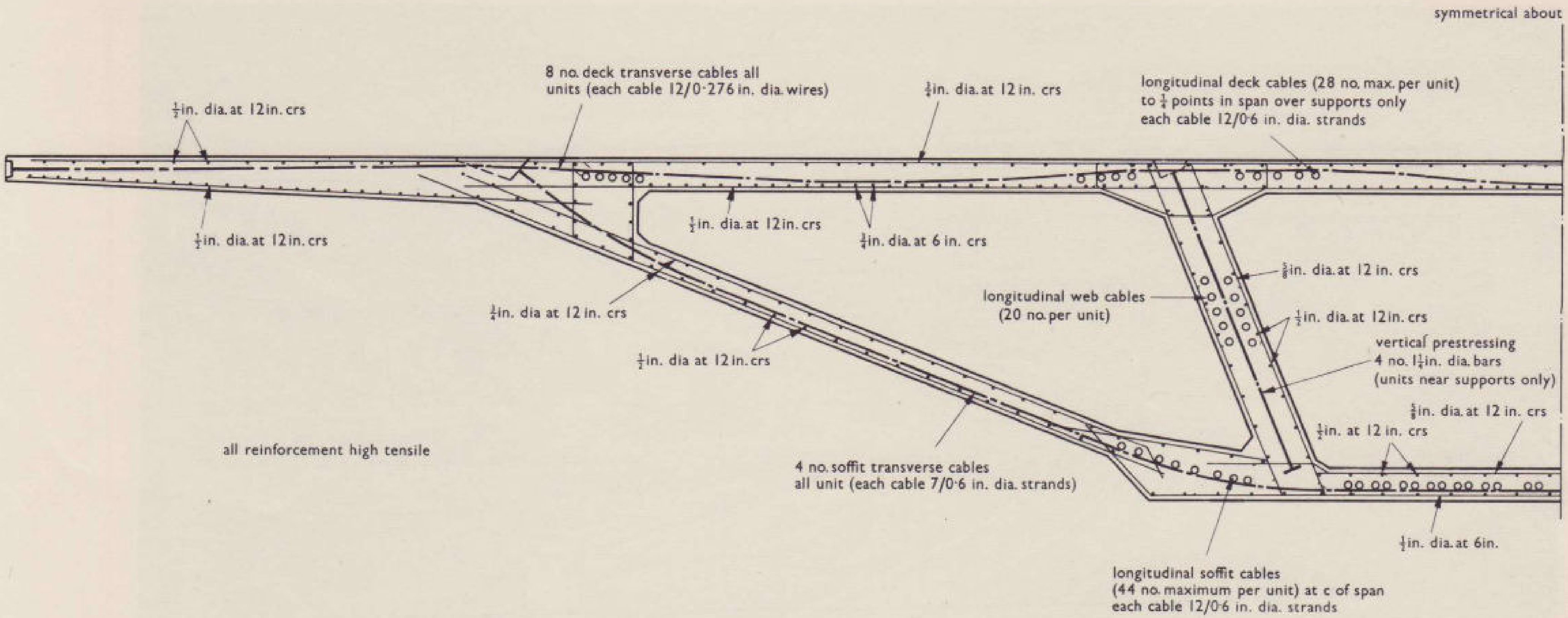


Figure 13: Half cross-section of precast concrete segments, Section 5.

SECTION 6

Design

The 3, 200 ft of Section 6 extends from the end of Section 5 at the anchorage abutment alongside Harrow Road to the end of the elevated Paddington Green section. Dual three-lane carriageways with hard shoulders at the western end narrow to dual two-lane with shoulders east of the ramps near Ranelagh Bridge, where slip roads provide a link between the Extension and the Paddington, Bayswater and Little Venice areas.

At the same time a re-arrangement of ground-level traffic will involve a new road system in which the existing Harrow Road will be used in part as the eastbound carriageway between Lord Hill's Bridge and Porteous Road. A new westbound carriageway will incorporate 900 ft of road under the Western Avenue Extension in a double-deck structure over railway property and an underpass beneath the northern end of Westbourne Terrace Bridge.

Construction

The precast, prestressed concrete deck of the upper level of this section is composed of a series of 100-ft-span hollow box pre-tensioned beams supported on and acting compositely in the transverse direction with welded steel box section portal frames. The total length is divided into two continuous portions each located by anchor spans at approximately the mid-points. Sliding bearings are provided at the feet of the portal frames apart from those forming the anchor spans, and expansion joints at the ends of the continuous sections: the expansion joints in the structure are located at the abutments at either end and at a point east of Westbourne Terrace Bridge.

The construction of the lower-level deck is similar to that of the upper level except that the spans are only half the length. The 50 ft pre-tensioned box beams of the deck structure are carried on a structure of reinforced concrete portal frames: alternate frames carry the steel box frames of the top deck. The concrete portal frames form part of the reconstruction of railway facilities alongside Paddington Goods Station, carried out under an earlier contract.

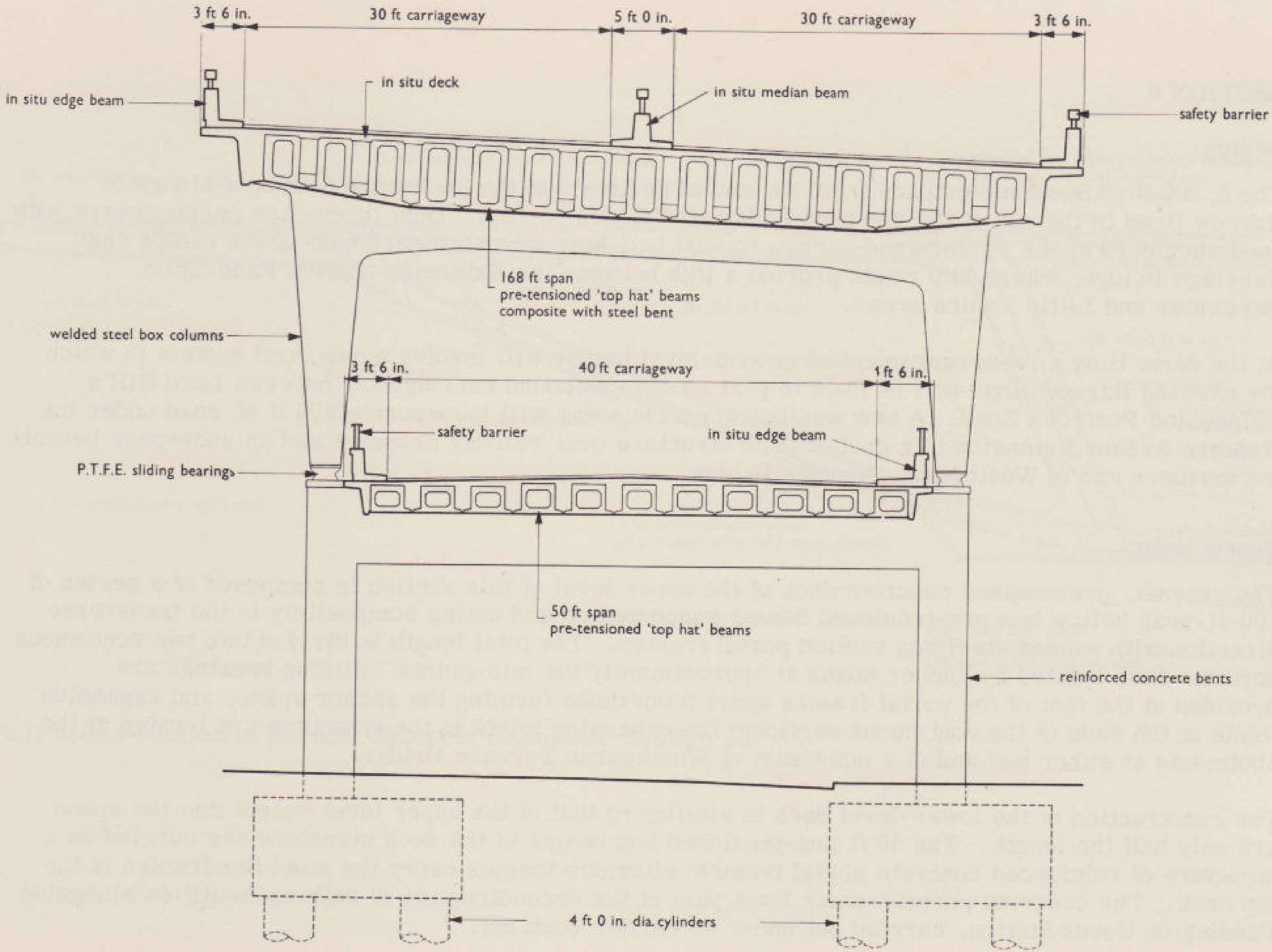


Figure 14: Typical cross-section of double-deck structure, Section 6.

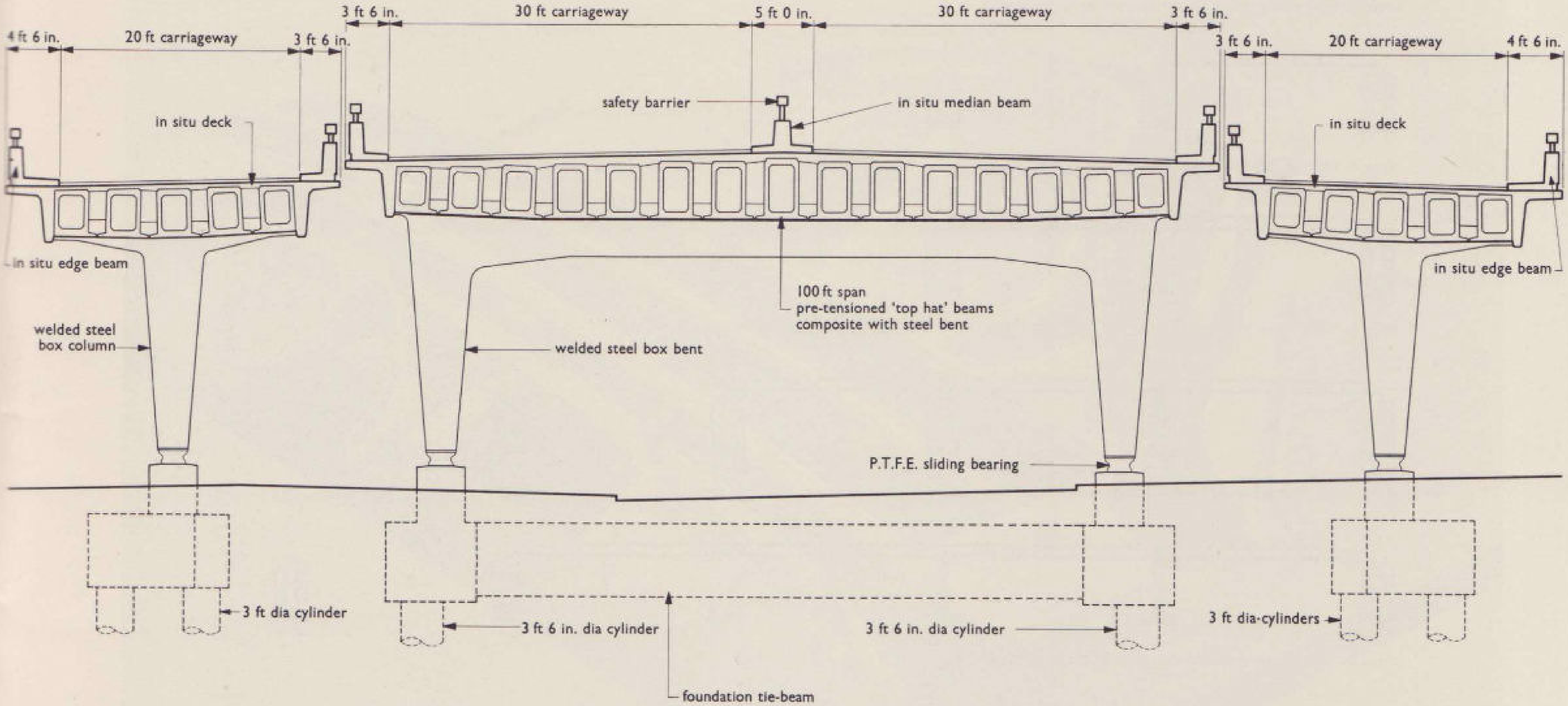


Figure 15: Typical cross-section, Section 6 dual two-lane structure with slip roads.

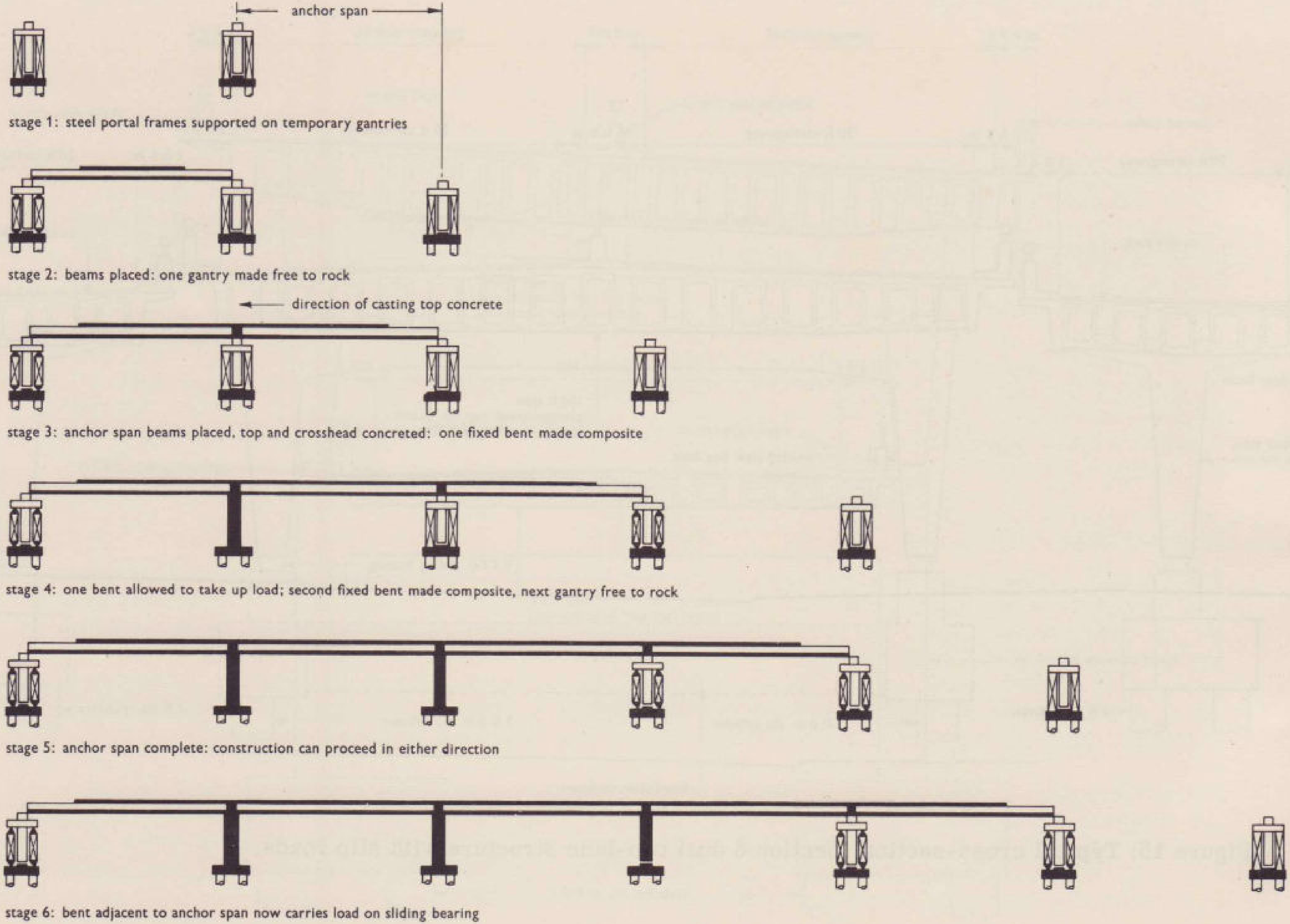


Figure 16: Construction sequence for Section 6.

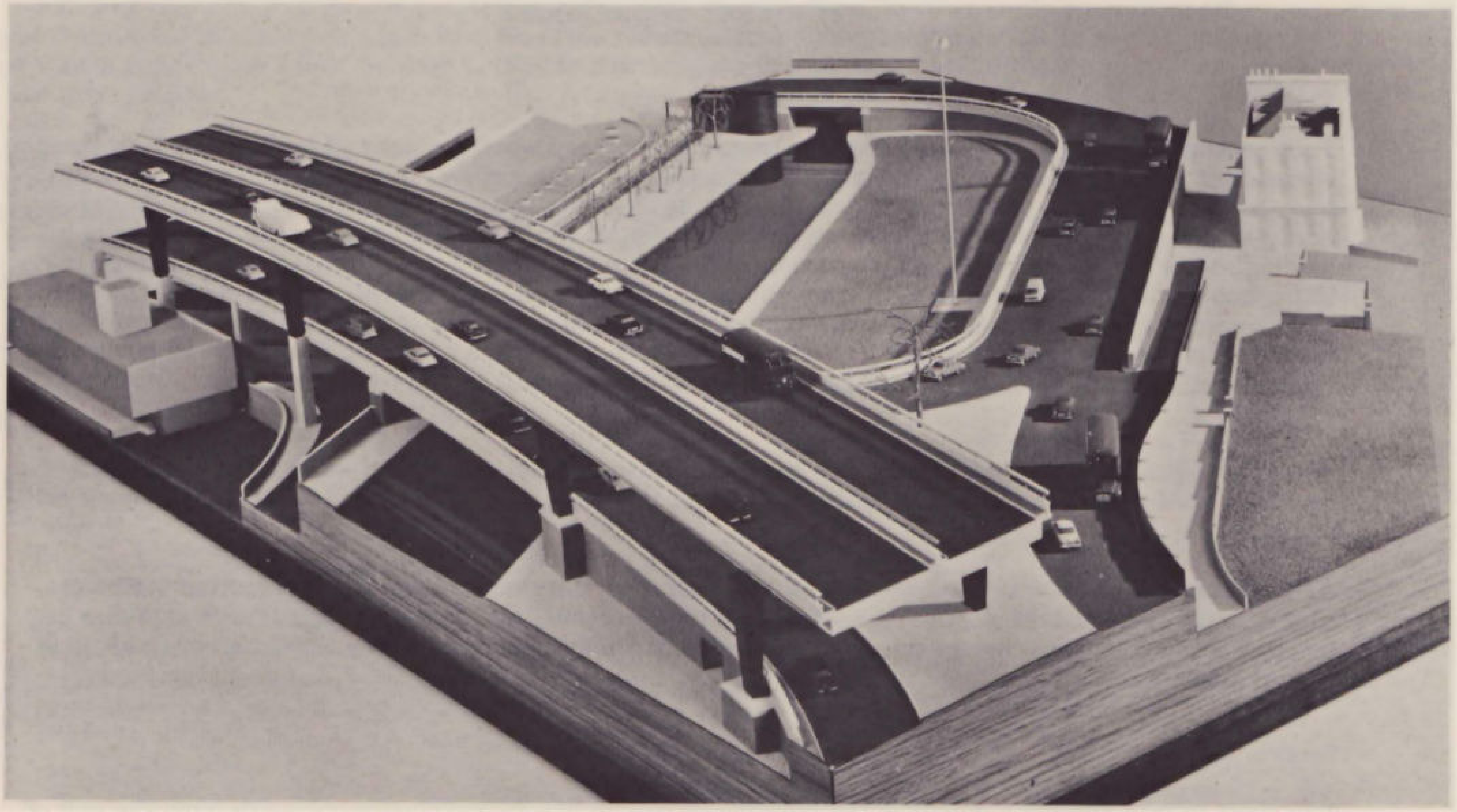


Figure 17: Model of Section 6 at crossing of Paddington Arm, Grand Union Canal.

THE WEST CROSS ROUTE

Section 2

This section, about 3, 300 ft long, extends from the southern access ramps of the Section 1 elevated roundabout to a point just north of Holland Park Avenue. The work in this section comprises a dual four-lane carriageway parallel to and to the east of the West London line of British Rail. At the northern end the 44 ft wide carriageways split and reduce to the 24 ft wide slip road carriageways leading to the elevated roundabout. Eventually the main carriageways will continue northwards to Willesden Junction where the West Cross and North Cross routes will meet. At the southern end the carriageways also split to accommodate the future elevated extension of the West Cross Route south towards Clapham Junction. At the Holland Park Avenue interchange the slip roads are 36 ft wide for the present: when the motorway is extended southward these will be narrowed to normal slip-road width.

The roadworks consist of rigid concrete paving between concrete retaining walls which also serve as boundary walls between the road and the railway on the west, and housing and other development on the east.

As the level of the railway is above that of the road over the central length of the section but below carriageway level at both north and south ends, the west-side wall has a changing function along its length. A new two-span bridge has been built by London Transport to carry the Hammersmith Line over the new road.

Section 3

The work in this section comprises the building of two 36 ft wide carriageways south from the end of Section 2 and the construction of a diamond-shaped ground-level interchange at the roundabout at the junction of Holland Park Avenue, Uxbridge Road and Holland Road. The western arms of the roundabout to be built here are carried over the West London Line on two new bridges of in situ reinforced and precast pre-tensioned concrete construction, the span being 35 ft in each case and the abutments averaging 145 ft in length. These new bridges are on each side of the existing three-span cast iron bridge.

Four pedestrian subways are included in the contract together with associated approach ramps and stairs. One of these passes through the disused west span of the existing cast iron bridge. A footbridge will be constructed over Uxbridge Road and Shepherd's Bush Green adjoining London Transport's Shepherd's Bush station, and provision will be made on the footbridge for mechanical passenger conveyors at each end.

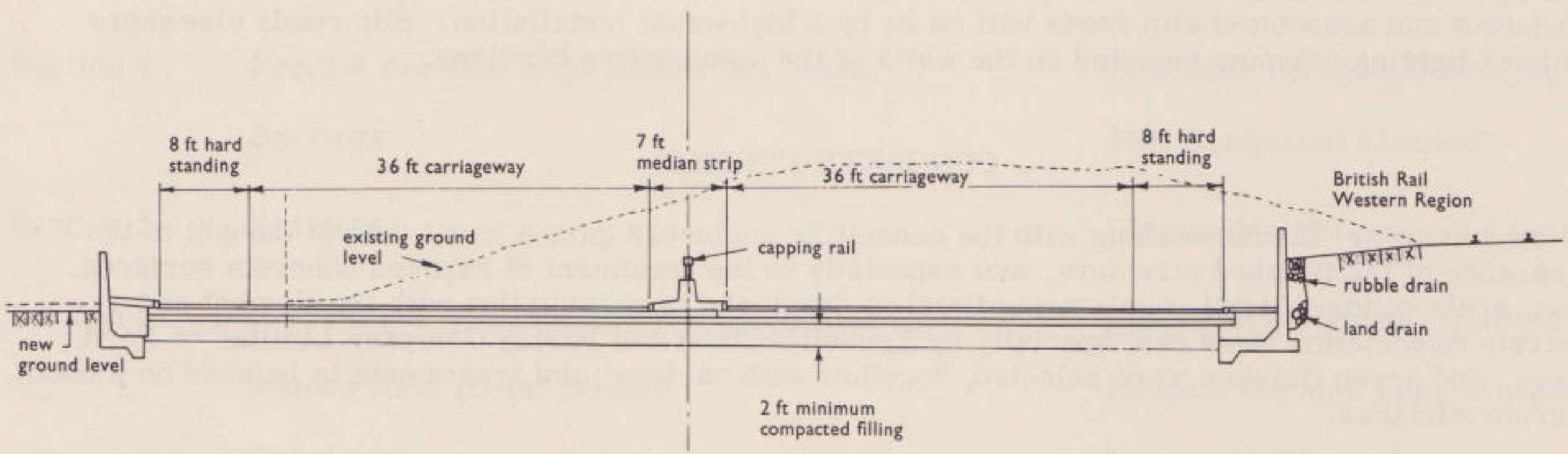


Figure 18: Typical cross-section of West Cross Route (Section 2).

SERVICES, BARRIERS AND LIGHTING

Road heating will be provided on gradients of 1 in 25 or more and for the carriageways of the elevated roundabout. Elsewhere the road surfaces will be conventionally de-iced.

Provision is made along the structures to carry a water main and hydrants. Provision is also made for carriageway lighting and traffic gantries with direction and surveillance signs.

Considerable thought was given to the design of the safety barrier to be incorporated in the central reservation and at the outer edges of the structure. The design adopted by the consulting engineers consists of a concrete upstand 2 ft high in the central reservation and 2 ft 6 in. high on the edges, faced with a resin-based material on the traffic side and surmounted by a steel rail.

Lighting of the dual carriageways, both two and three lane, of the elevated road will be by 40 ft high steel lighting columns mounted on top of the concrete wall of the median safety barrier. The elevated roundabout and associated slip roads will be lit by a high-mast installation. Slip roads elsewhere will have lighting columns mounted on the walls of the outer safety barriers.

CONCRETE FINISHES

The consultant architects working with the consulting engineers gave a great deal of thought to the appearance of the finished structure, and especially to the treatment of exposed concrete surfaces. Large-scale concrete trial panels using finishes developed in consultation with the Cement and Concrete Association were cast specially by Kendell's Stone and Paving Company Limited of Ford, Sussex, and seven finishes were selected, together with various joint treatments to be used on smooth concrete surfaces.

PRINCIPAL SUB-CONTRACTORS AND SUPPLIERS

General	Piled foundations	McKinney Foundations Limited Economic Foundations Limited
	Prestressing tendons for on-site post-tensioning	Somerset Wire Company Limited
	Prestressing tendons for pre-tensioned box beams	British Ropes Limited
Section 1	Precast segmental range units	St Albans Concrete Limited
	Bearings	André Rubber Company Limited
Section 4	Precast pre-tensioned hollow box beams	Dow-Mac (Products) Limited
	Bearings	PSC Equipment Limited
Section 5	Bearings	Glacier Metal Company Limited
Section 6	Precast pre-tensioned hollow box beams	Dow-Mac (Products) Limited
	Welded steel portal frames	Redpath Dorman Long Limited
	Bearings	Metalastik Limited