Design and Construction of BRIDGES

Part Ten—Movable Bridges

By Terence Wise

All bridges may be divided into two distinct classes:-
1) fixed bridges, which includes the arch, cantilever and suspension forms, simple or continuous span.
2) opening or moving bridges which are used for maintaining a flow of traffic where two lines of communication cross. For example, a bridge which carries a road or railway over a navigable channel at low level will have to be opened occasionally for the passage of shipping, while in the case of the Manchester Ship Canal a movable bridge carries one canal over another. This month we deal with the various forms this second class of bridge can take.

Bascule Bridges

Bascule means simply a kind of drawbridge (from the French *bacule* meaning see-saw) raised and lowered with a counterpoise, and this type will be familiar to everyone from the most famous example-London's Tower Bridge. Built in 1894, this is one of the largest bascule bridges ever built, with a central span of 200 feet. The footway between the tops of the Gothic towers (now closed) is 142 feet above high water level.

Basically bascule bridges may be said to be those which rotate upon a horizontal axis and they may have one or two counterpoised leaves. The leaves rotate through 75 to 90 degrees and, with the supporting piers being at each side of the waterway, a clear channel for shipping can be made very quickly. This is the main advantage of this type. One disadvantage is that the weight of the leaves is concentrated on the pivots or trunnions, and this can be a problem in large spans. To a great extent the problem is overcome by enlarging the pivots until they are in effect wheels, or by a method such as that used for the Dry Pool Bridge over the River Hull, shown in the accompanying photographs.

*Fig.*1 is a cross section of the Michaelson bascule bridge at Barrow-in-Furness docks, showing the single leaf span in both raised and lowered positions. Carrying the A590 across Barrow docks, this bridge replaced an old wrought iron one of 1886. Including the approach spans, the new bridge has an overall length of 900 feet and a width of 60 feet. The span over the waterway gives an opening of 79 feet six inches and opens 75 degrees to allow for the passage of ocean-going shipping. The leaf span is steel, and the approach spans are precast prestressed concrete beams supported on reinforced concrete portal frames.

FIG1.

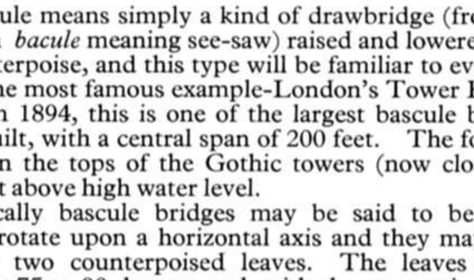
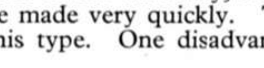


FIG 2.



Rolling Bridges

Rolling Bridges are those where the moving span is carried upon wheels or rollers and travels in a straight line across the waterway. In general the weight of the moving span is supported upon fixed portions of the construction. Not many of this type are built and one of the few examples in Britain may be seen in Newport docks. *Fig.* 2 shows the moving girder of this bridge in closed and open positions. The span is 72 feet and the girder is moved by hydraulic power.

The caissons which are used to close the entrances to graving docks (a dry dock where ships are cleaned and repaired) are sometimes made to travel on rollers across the floor of the dock when they carry a road on their tops and these may be included under the heading of rolling bridges.

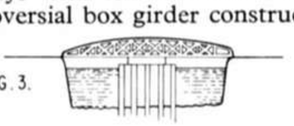
Swing Bridges

This type is normally used for small openings and a typical small swing is illustrated in *Fig.* 3. The movable span rotates on a vertical axis, the weight of the span being carried upon a turntable, and balance is the secret of success here. The ring of the turntable contains a number of conical steel rollers which turn upon radial axles and travel round a circular roller path. An upper inverted roller path travels in the same way upon these rollers and this carries the main girders of the swing span.

In a few examples the navigable channel is spanned by two swinging cantilevers which meet in the middle, or by a single arm which rotates upon a turntable placed to one side of the opening, the swing arm being counterbalanced at the rear. Where a very wide channel has to be bridged the moving span may be divided into two openings, spanned by a double-armed swing bridge upon a central pier. In this case the girder becomes a balanced cantilever with two equal arms, supported upon the central turntable. When the bridge is closed the girder is made so that it fits on to the abutments and is therefore converted into a continuous beam of two spans. The form of girder is thus changed from that of a drooping cantilever to that of a continuous beam with a point of contrary flexure in each span.

In some other examples the weight of the swinging cantilever is carried on the head of a hydraulic ram, which becomes the central pivot of the turntable, and the whole load is supported by the pressure of the fluid on which the ram rests and turns. An up-to-date example of this type is that in the Cumberland Basin, Bristol. The Ashton Swing Bridge is a 270 foot six inches long balanced cantilever swing bridge, carrying dual 24 foot carriageways with ten foot cantilevered footways. Of the controversial box girder construction, and therefore

FIG. 3.



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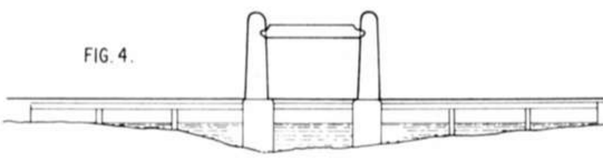

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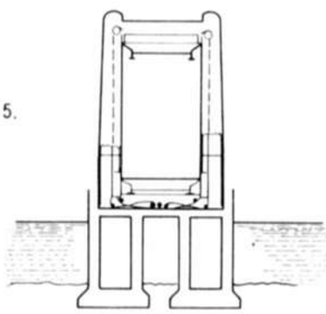

under restricted use at present, the thin plates are 14 feet six inches in depth at the centre and five feet at the ends. The moving weight of 865 tons is carried on a centre bearing of the roller variety which, together with a balance wheel rack and turning rack, is mounted on a reinforced concrete piled foundation. The bridge is electro-hydraulically operated by variable speed gearing driven by motors inside the structure. The usual objection to this type of bridge is that the supporting pier occupies too much space.

Vertical Lift Bridges

Lifting bridges are a less common form of movable bridge, although they do have many advantages and quite a few have been built in America. The weight of the moving span is taken by cables which pass over pulleys at the top of tall towers and are then attached to counter weights. The height of the lifting towers determines the clearance above water level. The moving span is raised in the same manner as a lift with the counter weights doing most of the lifting, and power is

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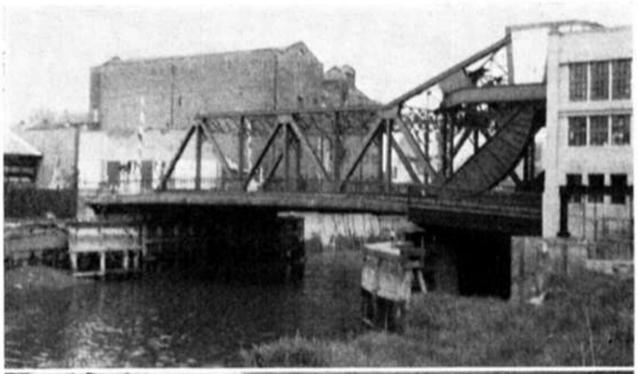
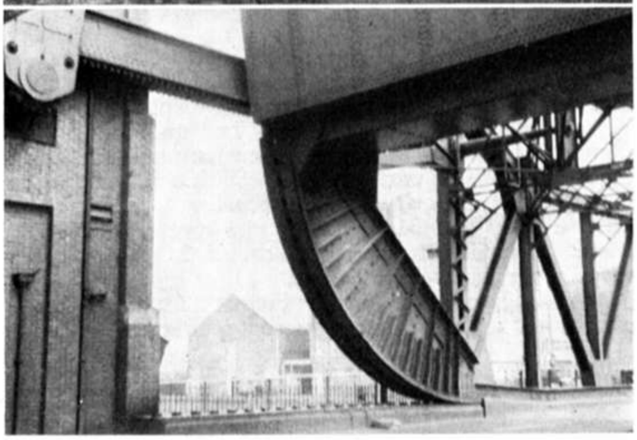




This column, top, Dry Pool Bridge, Hull. An example of the single leaf bascule. Above, the main pivot for the leaf of Dry Pool Bridge. Below, a single arm bridge at Cumberland Basin, Bristol, which rotates on a turntable placed to one side of the opening. Bottom, the Ashton Swing Bridge, Bristol, pivoted at the centre. The elevated control cabin to the left gives the bridge master a clear view of road and river traffic. This is an example of the cantilever double leaf swing bridge. Opposite page, the high level Tasman bridge in Tasmania during construction (1964). One of the world's longest bridges built in prestressed concrete, it replaced the floating arch bridge, a form of vertical lift bridge, which may be seen in the centre of the picture, with the span raised to allow a ship to pass through. *(Australian Information Bureau photo).*

The Aerospatiale SA 360 helicopter photographed on its maiden flight in June this year.

of "hardware" ranges from supersonic Lightnings and Phantoms to tiny Basset communications aircraft, including Vulcan bombers, Victor tankers, giant VC10 and Belfast transports, the vertical take-off Harrier strike fighter, a fleet of Puma helicopters, maritime Nimrods and "workhorse" Hercules transports.

Super-Jumbo

All 213 of the Boeing 747 "Jumbo jets" ordered so far by 31 airlines are scheduled to have Pratt & Whitney JT9D turbofan engines. However, Boeing has agreed to develop and flight test a prototype 747 powered by four General Electric CF6-50 turbofans of the kind fitted in the Series 30 long-range version of the McDonnell Douglas DC-10 tri-jet airliner. First flight is planned for July 1973, with testing to be completed by the end of the year.

Some US airline experts consider this to be bad news for the makers of the Concorde supersonic transport. They believe that a CF6-engined 747 will be able to fly over routes like London to Sydney, Australia, with only one stop, perhaps with below-deck sleeper cabins for passengers willing to make the long haul. By cutting out other en-route stops, the 747 could offset the present 11-hour advantage which the Concorde offers over standard "Jumbos".

New French Helicopter

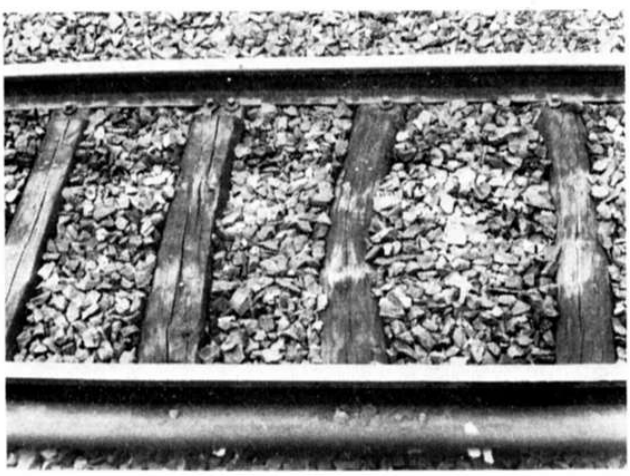
The last picture on this page shows the prototype of Aerospatiale's new SA 360 helicopter, which flew for the first time at Marignane, in the South of France, on 2 June this year. It is a little larger than the well-known Alouette III, with ten seats arranged in three rows. Power plant is a 980 h.p. Turboméca Astazou XVI turboshaft, driving a four-blade rotor of the kind fitted to the Aérospatiale/Westland Gazelle, with plastics blades. The tail rotor is also of the shrouded "fenestron" type used on the Gazelle.

Good streamlining and the lightweight power of turboshaft engines give modern helicopters a performance that makes their predecessors look like tortoises. After less than ten hours of flight testing, the SA 360 had already clocked a level speed of 162 m.p.h. at its maximum loaded weight of 5,500 lb.

BRIDGES *(continued from page 553)*

only needed to overcome the initial inertia and any friction between the guides fixed to the towers which keep the moving span in line. The first vertical lifting bridge was built in 1894 by J. A. L. Waddell at South Halsted Street, Chicago, with a span of 130 feet. The world's longest lift span is over Cape Cod Canal, completed in1935 with a span of 544 feet.

One of the most modern lifting bridges is that built over the River Swale at Kingsferry, carrying the A249 to the Isle of Sheppey. It cost £1.2 million and has a lifting span of 90 feet with a vertical clearance of 95 feet. An important feature of this bridge is the lifting mechanism which is located in the piers at each end of the lifting span with the winch motors synchronised electrically. There is no mechanical linkage. This is a revolutionary step forward (lifting bridges normally have machinery on the lifting span itself)which enabled the engineers to save a great deal of weight in the bridge and tower construction, and consequently to reduce the size of the towers and piers. *Fig.* 4 shows the bridge and approach viaducts: *Fig.* 5 a cross section of one of the towers and the lifting span.



The piece of railway track at the left was photographed by John Coulson while on a visit to Northern France. This example of French permanent way between Calais and Lille startles the British eye used to ruler-straight wood or concrete sleepers at home. These sleepers at Hazebrouck are little more than squared off branches with the rails bolted down in an almost casual fashion. Despite this, all the French lines the Editor has travelled on have been notably smooth.

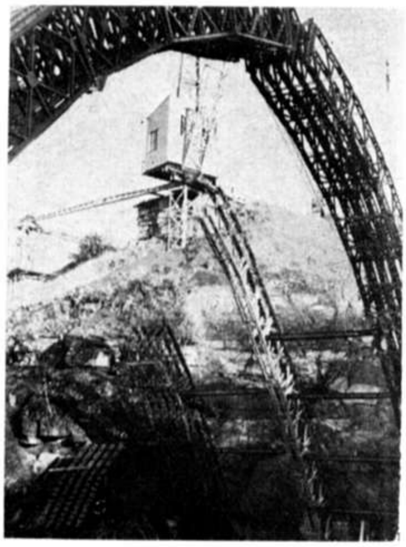
Transporter Bridges

Another form of lifting bridge, this type is best described by the alternative term—aerial ferry. The design consists of an overhead bridge supported by tall towers with a moving cradle slung from the bridge. A platform is then slung from the cradle so that it is aligned with the sides of the opening to be spanned and the loaded platform is then conveyed across the gap by the movable cradle. This style of bridge is mostly used to cross wide or very busy rivers or harbours where any other form of bridge might obstruct the traffic, or where the cost of other forms of bridge, with long approach viaducts, makes the cost prohibitive. The first bridge of this type in Europe was built at Rouen in France with a span of 466 feet: there is another at Marseilles with a span of 541 feet. In Britain there are examples over the Mersey and the Manchester Ship Canal, both with spans of a 1000 feet, and at Middlesborough. The latter was built in 1911 and was a great engineering marvel in its time. Carrying 10 vehicles and 600 people it is still one of the largest of its kind in the world.

Design and Construction of BRIDGES Part II-Bailey Bridges

By

Terence Wise



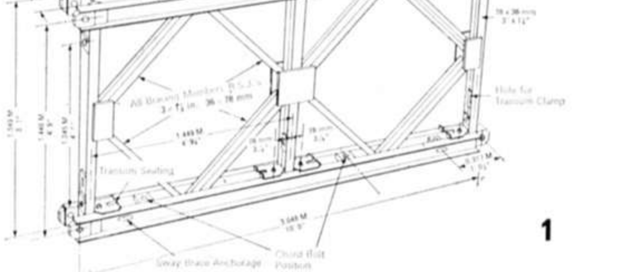
Bailey components being used as falsework for an in-situ concrete arch during a project in Scotland.

THE Bailey Bridge was invented by Sir Donald Bailey and may be briefly described as a bridge made up from steel parts, easily transported in standard three ton trucks, all capable of being erected by man-power alone and all of which are jig manufactured to precise tolerances so that they fit perfectly. All parts are interchangeable and because of this can be built up rapidly into all types of structures to meet varying requirements of span and load.

This system of bridge building proved of great value to the British and American armies in World War Two and soon became a standard method of bridge construction. Nowadays Bailey equipment is used throughout the world for all types of engineering structures, including piers, towers, access ramps, gantries and falsework and shoring for other forms of construction.

The original Bailey bridge was designed as a simple through bridge, i.e. the deck being carried between two main girders which spanned the gap. These two main load-carrying girders are composed of a number of steel lattice panels, each ten feet long by five feet one inch high, pinned together with alloy steel pins. (The pin holes are very tight connections and when panels are connected end to end the effect of local stresses can be ignored.) This Bailey panel is the basic component and the manner in which panels are grouped together decides the load the structure will bear. It has been found that the normal beam theory applies to structures made up of this panel, for the diamond shaped bracing in the panel is such that it acts as a composite plate beam, the upper and lower chords being the flanges and the vertical and diagonal components the plate web.

The strength of these main girders or trusses can be varied by adding extra panels alongside the first and/or adding storeys above them. Road bearers, called transoms, are then laid across the bottom chords of the panels, connecting them and at the same time spacing them at the correct distance throughout the length of the bridge. These bear the subsidiary steelwork for the bridge deck. Various bracing pieces and the decking sections complete the bridge.



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Simple beam bridges of this type are normally built on rollers and pushed out across the gap to be spanned as each set of panels is assembled. A false "nose" is constructed of Bailey panels, added to the front of the structure, and this allows the beam bridge to be "launched" across the gap with the "nose" acting as a cantilever. Spans of up to 260 feet have been achieved by this method.

There are two types of decking: timber for temporary structures and a steel deck for permanent work. The latter is designed to be covered by asphalt or similar road-making materials. The roadway of a Bailey bridge is two feet four inches above ground level and therefore ramps are needed at each end, unless the baseplates are set below the ground. Ramp sections can carry axle loads of up to 15 tons when supported at each end, i.e. over their 10 feet length. Heavier loads can be taken if the ramp section is supported midway. However, the majority of vehicles cannot easily negotiate gradients of over one-in-ten, so a 20 foot ramp is required. This is constructed from two 10 foot ramp sections, supported in the middle by a transom.

Footways are normally fitted outside the main girders. These can have wooden or steel decks in two standard widths, three feet or four feet six inches, all designed to carry a load of 100 lbs p.s.i. They are supported on cantilever brackets which fit on the ends of the roadway transoms. Handrails are also supplied, three feet six inches high.

There has been considerable expansion in the range of parts since the early days and all types of bridge can be constructed from the basic Bailey components now available. The main parts used are shown in the figures and are described briefly below. The high tensile steel used has an ultimate tensile strength of 35-40 tons p.s.i., the mild steel a minimum yield of 15-25 tons p.s.i.

Bailey Panel (*Fig.* 1). High tensile steel, welded construction. The two chord members are interconnected by vertical and diagonal bracing. Panels are joined to each other end to end by engaging the lugs and jaws and inserting locking pins.

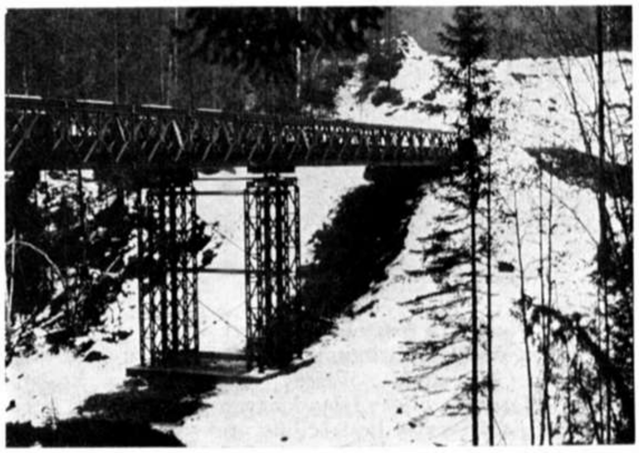
Bracing Frame (*Fig.* 2). Mild steel panel of welded angle and bar construction, used to brace the tops of the panels.

Raker (*Fig.* 3). High tensile steel joist which connects the top of one end of the transom to the top of an end vertical member of the panel. It is the main stabilising member of the bridge assembly.

Transom High tensile steel joist which forms the cross girder between the two main girders, thus bearing the bridge deck.

Stringer (*Fig.* 4). Three mild steel joists welded together to form a frame. It forms the longitudinal bearer for the roadway of the bridge and fits over lugs on the transom.

Baseplate To spread the load of the bridge evenly over



A 150 foot double/single reinforced Bailey Bridge with two supporting Bailey Piers.

an area of ground. Only four baseplates are required whatever the type of bridge—one at each end of each main girder. Of welded heavy gauge steel, the centre part forms a sunken "tray" to receive the bearings. *Ramp* Three joists of high tensile steel built up into a frame similar to the stringer but of heavier construction. *Rocking Roller* (*Fig*. 5). For launching the beam bridge this part consists of three rollers in an assembly with half round bearings at its bottom centre. These bearings fit over the bridge bearings on which the roller assembly is then free to rock. The four side rollers act as guides for the trusses. The maximum number of rollers for launching all normal spans is four, two either side under the first and second panels. Maximum load for a roller is 21 tons.

The original and simplest form of Bailey bridge mentioned earlier consists of a single truss of panels along each side of the deck and can be strengthened, or the number of decks increased, by adding other panels parallel to or on top of the first. However, one truss two storeys high is not used as this would be unstable, and the usual combinations are double or triple trusses for single double and triple decks. For example, a triple/double deck bridge has its main girders composed of panels arranged in three trusses side by side and two storeys high.

This type of bridge has a roadway 10 feet nine inches wide. Larger transoms can be used to create roadway widths of 12 feet six inches or 13 feet nine inches with the corresponding increase in the number of stringers to support the wider roadway. Where a roadway greater than 13 feet nine inches is required the only method with Bailey equipment is to build a deck type bridge in which the transoms and decking parts are carried on top of the trusses forming the main girders. The width is then only governed by the length of the transom and these are available up to 20 feet. Greater widths can, of course, be obtained by building another bridge with its transoms linked to the first.

Continuous girder and broken span bridges can be constructed from the standard parts with the addition of two small pieces of equipment. Suspension bridges may be built by first erecting Bailey towers (exactly the same technique as for a beam bridge but erected vertically) then passing steel wire cables over them and so to the anchorages. Half the span is then built on each bank and launched outwards, the outer ends being supported by trolleys on the cables. The two halves are pinned together and the trolleys are then used to help fix the suspenders. This type of bridge enables the span to be increased to 400 feet without supports.

A lifting bridge can be built with a normal Bailey span and two Bailey towers at each end of the span. Running gear is required to raise the span up the towers and concrete foundations are necessary for the towers and the ends of the span. Single and double bascule, swing and retractable or roller bridges have also been designed and operated successfully with Bailey components.

In recent years new techniques have been developed for the building of arch bridges (*Fig*. 6) and under-stressed bridges (*Fig*. 7). Both types may be constructed from standard Bailey components and are particularly useful as falsework during the construction of reinforced concrete bridges. Single spans of 730 feet have been built with the under-stressed design, capable of carrying loads of up to 1500 tons.

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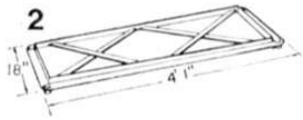

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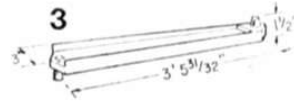

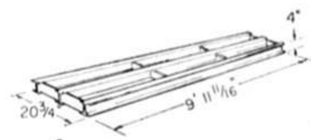

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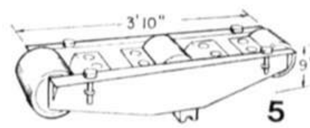

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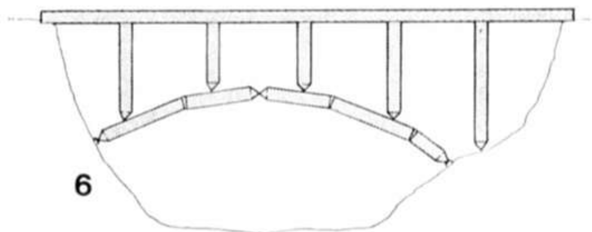

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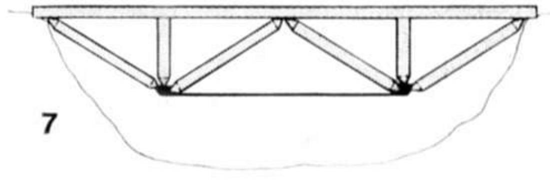

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Three quarters of a mile of dual carriageway in Bangladesh built with Bailey Bridging on Uniflote flotation. The bridge has an elevated span allowing 22 ft. clear above water level and a 100 ft. gap with inclined spans either side.