The Bailey Bridge and other Alternatives to Rapid Bridging

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Final Year Dissertation by

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many believe the Royal Engineers to be the most impressive unit in the British Army

- George Millar, Rifle Brigade
The Bruneval Raid

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ABSTRACT

The Bailey Bridge, developed in the early 1940's, is the most successful example of rapid bridging and is still widely used today. Originally developed for the British Army, Bailey Bridge applications expanded rapidly into the field of civil engineering taking full advantage of the complete standardization of bridge components resulting in substantial construction time reductions. Both temporary and permanent structures, including towers, gantries, formwork, supporters, etc., may benefit from the use of Bailey Bridge components.

The Bailey Bridge design had been considerably improved by Thos. Storey (Engineers) Ltd in the 1960's making it by far the most versatile and popular of all rapid-construction bridges. The Bailey Bridge inspired engineers to create new and, in some cases, exotic rapid-construction bridges such as the Magnesium Alloy Assault Bridge developed in Canada in which the heaviest component can be hauled without much difficulty by one man. It also inspired the development of an instantly expandable bridge utilizing reinforced plastics, and later, carbon-fibre. Also of interest is a two-part foam bridge that had been developed by USA-CERL for the use of military equipment in the United States Army. Even with the advent of these newer designs, the basic Bailey Bridge design has withstood the tests of time and has remained virtually unchallenged in the field of rapid bridging.

CHAPTER I

Introduction

I. Introduction

Throughout history, bridges have always been required by man for an endless variety of reasons spanning rivers, gorges and other difficult terrain. Each bridge built is unique to the given situation and usually requires careful planning and in-situ construction to achieve the best result. Some applications, however, require fast and easy construction and it is in the military where such an application would most probably arise. Such an application is not confined to the military alone and has found homes in the field of temporary bridge building particularly in reference to emergency situations, such as a vital bridge destroyed by flooding of a river. The easy-to-assemble prefabricated bridge is the resulting product originally demanded by the military to construct bridges in the shortest possible time. The requirement of the bridge appropriate to the military involves a structure which can take the heaviest military loads and be flexible enough to span a number of different widths being erected in only a few hours by a handful of men. Such a bridge did not exist officially until 1941 when Donald Bailey of the now disbanded Experimental Bridging Establishment (EBE) in Christchurch devised the legendary Bailey Bridge.

In war, a commander defending a river line does not usually have the required number of troops on the whole of his front to prevent the enemy from crossing the river. In this situation, the commander would concentrate the troops at the most likely places where crossings could be made and to send patrols in the gaps to inform the others if an attempted crossing is going to be made. A mobile reserve may be needed to suppress the enemy from constructing a bridgehead. Artillery would be placed at the site of the most probable crossing places and observation posts would cover the length of the river as far as deemed possible. Air support would be required to assist in these tasks. The object of the attacker is to conceal from the defender, for as long as possible, the actual site of his main effort. When this can be done no longer, his object is to build up his bridgehead with such rapidity that it can defeat the mobile counter-attack force, which usually contains a high proportion of armour. Once this force can be held, the attacker's object is to expand his bridgehead until he drives back the defenders' observation posts so that they can no longer see the sites at which he hopes to build his bridges. It has been found to be almost impossible to build a bridge under observed fire until the advent of the Bailey Bridge.

Military river crossing equipment, therefore, aims to provide the following:

- The means to ferry men, anti-tank guns and tanks across on a wide front to enable a bridgehead to be built up and expanded.

- The means to construct, in the shortest possible time, bridges to replace the necessarily somewhat slow ferries, to enable the bridgehead to be incorporated into the front.
- The means to replace the field bridges with more permanent structures so that the river forms no obstacle in the lines of communication.

World War II was the first war which has been fought with fully mechanised armies. Not only has the number of vehicles exceeded by far any previously used, but vehicles themselves have also grown enormously in weight. The engineer effort which has been required to keep the army moving has in consequence also grown considerably. The prevailing wheeled vehicle of World War II was the G.S. wagon which weighed about 3 tons. Tanks in World War I weighed up to 35 tons, but all possible moves took place by rail, and road moves needed detailed planning and many special arrangements. By 1946, tank transporters weighed up to 75 tons.

In the years between World War I and World War II, all heavy tanks had gone out of production, and consequent upon a policy of rigid financial economy, there were no modern tanks of weight greater than 5 tons in the army at the beginning of World War II. There were a number of obsolete types weighing about 14 tons and two designs weighing 16 and 23 tons respectively. These in turn were obsolete as soon as they appeared and were in fact the beginning of the armaments race which invariably occurs at the start of any war and which is the anathema of all designers, both of vehicles and of bridges. This race finally ended with the Churchill weighing 40 tons in 1942.

Before the Bailey Bridge, the heaviest floating bridge would carry 24 tons and the heaviest fixed bridge 30 tons with a maximum clear gap by the latter being 130 ft. This means that no assault bridge would be able to carry the Churchill Tank at 40 tons unless it was transported by rail over a permanent railway bridge. There were no less than seven types of military assault bridges before the Bailey Bridge with capacities of 9 tons and over. Each of these had been developed and introduced for a special purpose and there were many cases of overlap. There were also attendant difficulties inherent upon having these seven different types. Manufacture, inspection and storage of the various equipments and the training of troops in their use had all to be multiplied by seven, not to speak of the risk that the wrong equipment might arrive at a given site in operations.

Since 1936, Donald Bailey had an idea that a suitable unit from which to construct a bridge girder would be a flat panel. This panel could be arranged in a variety of ways side by side and storey upon storey, to build a girder of any required length or strength, and would also be a convenient unit for transport. This idea had been put forward several times, but the Ministry of Supply had not been favourable towards the introduction of yet another type of equipment at a time when production was naturally strained to produce even those which existed.

By the end of 1940, the bridging situation had become so serious that Bailey carried his calculations a step further. These calculations showed that a panel of suitable size to make up into a 120 ft. bridge of 45 ton capacity could be made to fit conveniently into a 3-ton lorry and could be carried by six men. The outline design was recognised by the Ministry of Supply as being a great advance on any previous equipment and in December, 1940, authority was given for the construction of a pilot model.

Due to the success of the Bailey bridge in the military, civilian uses were being developed for both temporary and permanent structures. This bridge also gave birth to newer ideas of rapid-construction bridges from magnesium alloy to foam-plastic unit construction bridges. Several types of rapid-construction bridges starting from those developed at the beginning of the century to the 1980s are described in this paper with particular reference to Sir Donald Bailey's design of unit construction bridge.

CHAPTER II

Military Bridging Prior to the Bailey Bridge

II. Military Bridging Prior to the Bailey Bridge

GENERAL DESIGN CONSIDERATIONS

The greatest design consideration in any military assault bridge is *low weight*. Low weight improves speed of erection, reduces transport, and, by savings in steel, reduces production costs. This economy in steel is of particular importance, as maximum production of military equipment is normally required in time of war, when there are so many additional demands for steel. The designer of a military bridge must, therefore, consider very carefully how much weight can be used for each component, besides ensuring that the component is functionally adequate for its purpose.

Although low weight is of such importance in military bridges, a number of weight penalties is normally accepted in the interests of simplicity, flexibility and transport limitations. Elements of girders must often be interchangeable, irrespective of their ultimate position in the bridge, and each must, therefore, be designed for maximum bending moment and maximum shear. Full-strength connections have to be provided at relatively short intervals between the successive girder elements, and, when girders are built up in depth, efficient use cannot be made of the horizontal members lying near the neutral axis.

The following general design considerations summarize the main factors that have contributed towards weight-saving in military bridges before the advent of the Bailey Bridge.

Load Capacity

In 1939 a big step towards lightness was made by adopting a common system of load classification for all military vehicles and bridges. In this system, the load classification of vehicles is related to a series of standardized hypothetical vehicles for which weight, axle and wheel spacings or track dimensions are specified. Bridges are correspondingly classified according to their capacity to carry hypothetical vehicles of a given category at a specified minimum spacing. With this system the live load is obviously much more clearly defined and controlled than is possible in civilian live load specifications, and a very substantial economy in design is obtained.

The majority of bridges are designed for single-way traffic, and the roadway width is limited to give adequate clearance for the widest vehicle existing in this particular load class. The effect of a heavy narrow vehicle causing unequal distribution of loads on main girders is taken into account by multiplying its nominal load class by an appropriate eccentricity factor. The wind loading normally adopted is that caused by a 60 m.p.h. wind.

Impact

Tests have been carried out to determine the dynamic effects of wheeled and tracked loads on elements of military road bridges. As a result, impact factors have been derived which vary according to types of loading and the components affected. Thus, the maximum impact factor is 1.25, and applies to the effects of wheeled vehicles on decking and stringers. A minimum factor of 1.0 is adopted for the main distributing girders of floating bridges where any tendency to increase deflection is directly resisted and damped by greater upward thrusts from the floating pontoons.

Material

Choice of material is affected by such a wide range of factors that no generalization is possible. The combination of qualities most frequently sought after in any material is

- availability
- low weight
- low cost
- high strength
- good weldability
- good fatigue properties
- high ductility
- low transition temperature.

Factors of Safety

Factors of safety are generally lower for military than for civilian applications. This has been made possible by the imposition of a rigorous system of inspection throughout all stages of manufacture, which minimizes the risk of substandard materials or workmanship, and by routine full-scale load tests of all designs to establish actual strength.

Fatigue

Owing to their temporary nature, the number of repetitions of loading on military bridges is generally much less than for their civilian counterparts. However, owing to their low deadweight, the average range of stress is considerably higher, and fatigue life is an important factor to be considered in design.

Brittle Fracture

Attention must be given to the notch brittleness of steel used in military equipments. However, the great majority of the material used is in the form of thin plates and sections, which are less subject to brittle fracture than the heavier sections. Special low-temperature tests have been carried out on various forms of welded joints to establish that there is no risk of brittle fracture occurring at maximum working loads.

Weldability

One of the major attractions in the use of steel is that many specifications are suitable for welding, with good properties in the welded joints. Designers of military equipments were not slow in taking advantage of the resultant saving in weight due to the absence of rivets.

New Forms of Rolled Sections

The wider use of welding led to the introdution of BS 2566 (covering broad-flange beams, heavy-flange T-bars and long-legged T-bars) and universal beams. This contributed to further economies in the design of larger bridges.

Protection Against Corrosion

As the efforts to reduce weight result in lighter and more efficient structures, the necessity of ensuring good protection against corrosion of the thinner steel sections becomes increasingly important. The procedure for the protection of structural steel was as follows:

- clean (acid dip and rinse)
- phosphatize
- chromate rinse
- three-coat paint finish

For certain applications:

- aluminium or zinc spraying, or
- galvanizing, or
- sherardizing

with or without paint finishes.

It has been clearly established that the higher initial cost of a good protective finish is more than offset by the greater effectiveness of the protection in extending the useful life of components before repainting.

BRIDGE DESIGNS

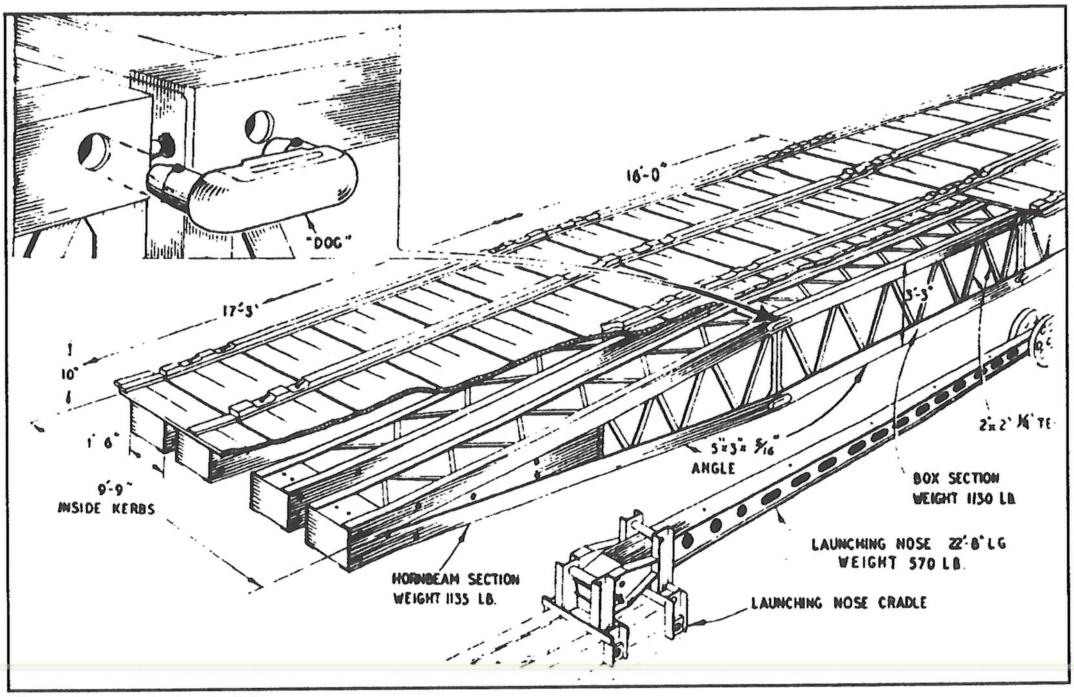
Military bridges fall into two main categories:

1) those consisting of special-purpose equipments designed to fulfil a clearly-defined single role (for example, a military floating bridge may be designed to function only as a floating bridge for a particular load class)

2) those consisting of equipment designed to be flexible for varying load classes and spans

It may be assumed that equipment in the first category are generally lighter and more efficient for their *particular* application than those in the second.

Small Box Girder Bridge



Small box girder bridge

Specifications:

- deck bridge originally designed in 1920s
- strengthened in 1937 to carry single 24-ton loads on a span of 32 ft., or single 12-ton loads on a span of up to 64 ft.
- two principal elements of bridge are rectangular box-truss units and hornbeam sections connected by dowels and "dogs"
- bridge consisted of either 2 or 4 girders side by side, according to the span and load class

- preassembled timber decking panels are laid across the girders to provide a roadway 9 ft. 9 in. in width
- assembled box girders are launched in succession side by side by the cantilever-and-counterweight method, using a launching nose at each end
- launching nose is of plated box construction with lightening holes in the webs
- girders and launching nose of all-welded construction using high-tensile steel with limitations imposed on the carbon, manganese and chromium content to ensure better weldability
- connecting dogs are 3% nickel steel, hardened and tempered
- strengthened again in 1939 to carry 40-ton loads over spans up to 48 ft. at the expense of some increase in weight

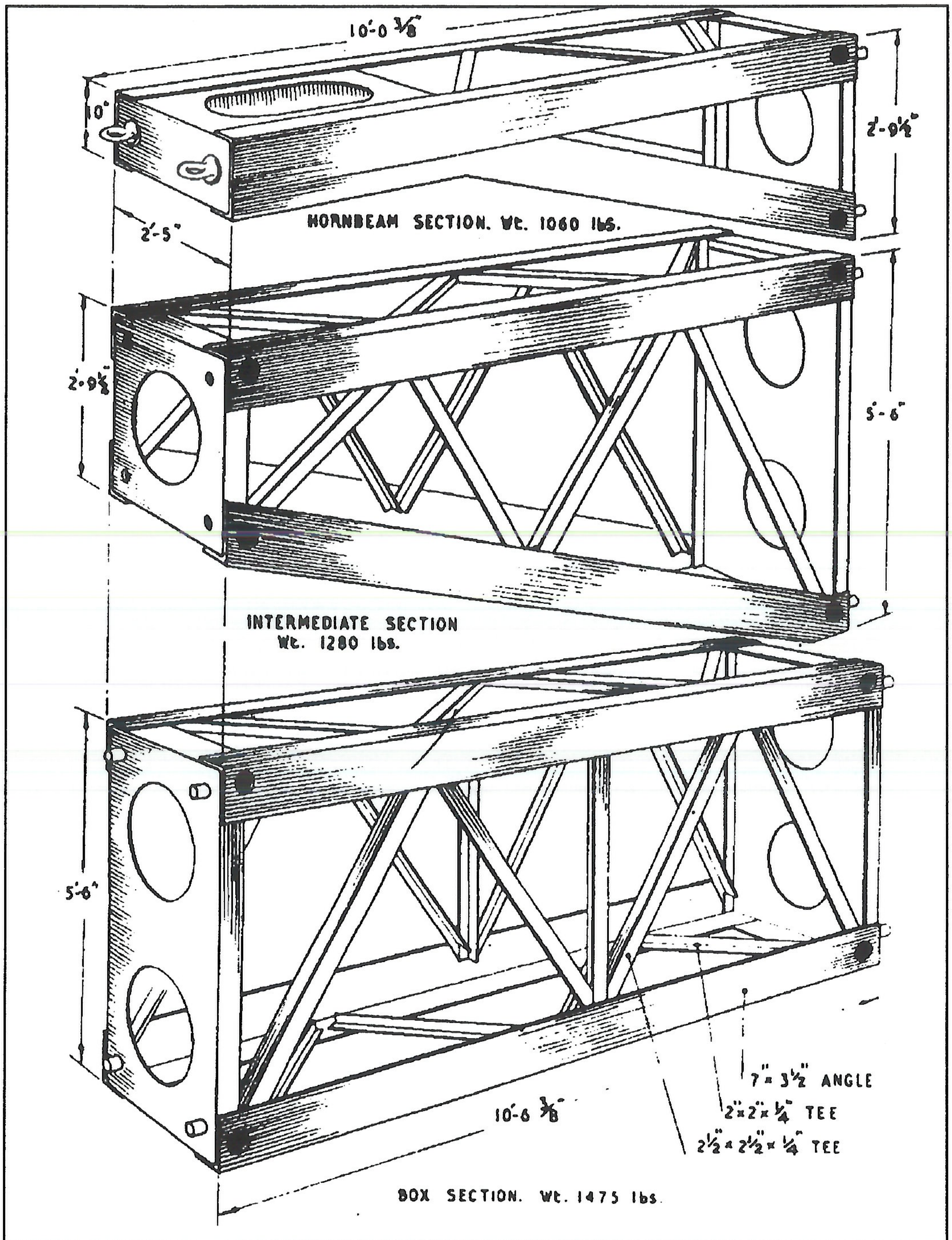
Advantage:

The main advantage of this type of bridge is that the arrangement of multiple box girders dispenses with the need for cross-girders, stringers and sway-bracing, the decking acting also as bracing and being fixed directly to the top chords of the main girders.

Disadvantages:

- each girder must be launched separately
- being a deck bridge, there are sometimes difficulties in providing for adequate clearance under the bridge
- the lateral arrangement of main girders is less efficient than a through bridge in distributing live-load equally between the trusses

Large Box Girder Bridge



Large box girder bridge–girder units

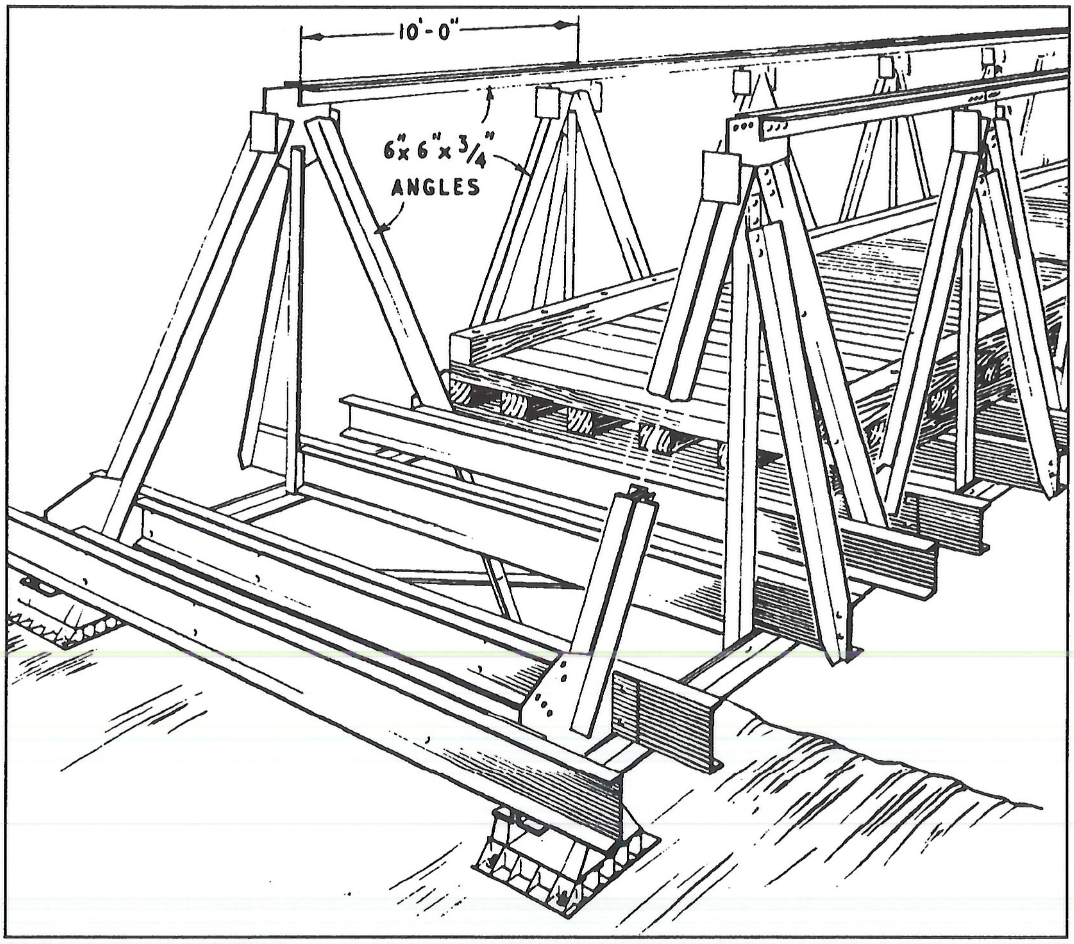
Specifications:

- deck bridge designed in 1936
- designed to carry 24-ton loads on spans up to 130 ft.
- intermediate trapezoidal sections are used in addition to rectangular box sections and hornbeams

Disadvantage:

This bridge is not suitable for cantilever construction, and is normally launched by a derrick, in combination with preventer tackles. This is a tedious operation, and, in consequence, was never very popular with the Army.

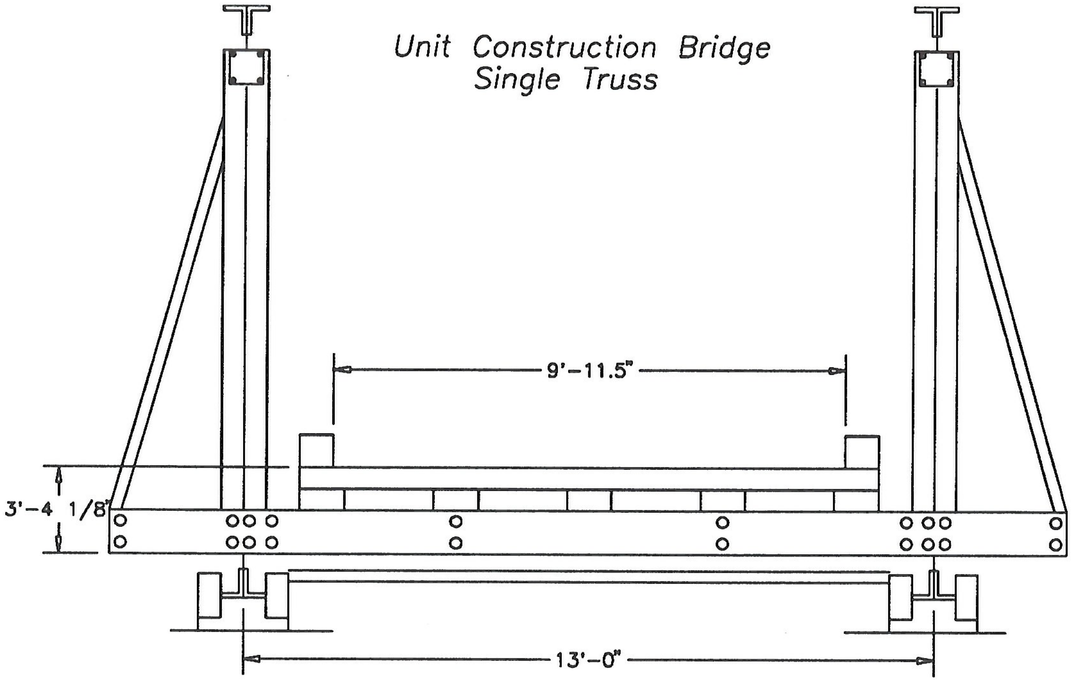
Unit Construction Bridge

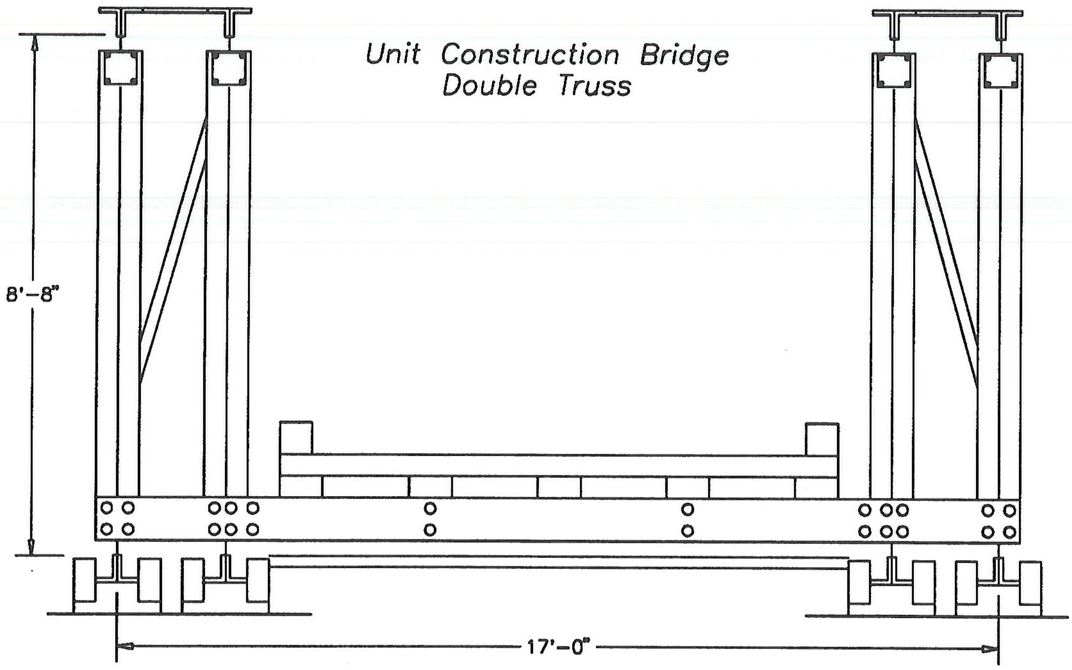


Unit construction bridge

Specifications:

- Warren-girder type through bridge designed by A.M. Hamilton and first produced in 1937
- designed to carry a 10 ft.-wide roadway with loading equivalent to 30-ton tanks at 46-ft. centres
- span may be altered from 40 to 140 ft. in increments of 10 ft.


Unit Construction Bridge
Single Truss
9'–11.5"
3'–4 1/8"
13'–0"


Unit Construction Bridge
Double Truss
8'–8"
17'–0"

- basic element in the truss construction is a 6 × 6 × ¾-in. mild-steel angle, 10 ft. in length, and any given diagonal or chord member consisting of from one to four of these angles, as required
- cross-girders consist of double 12 × 3½-in. mild steel channels

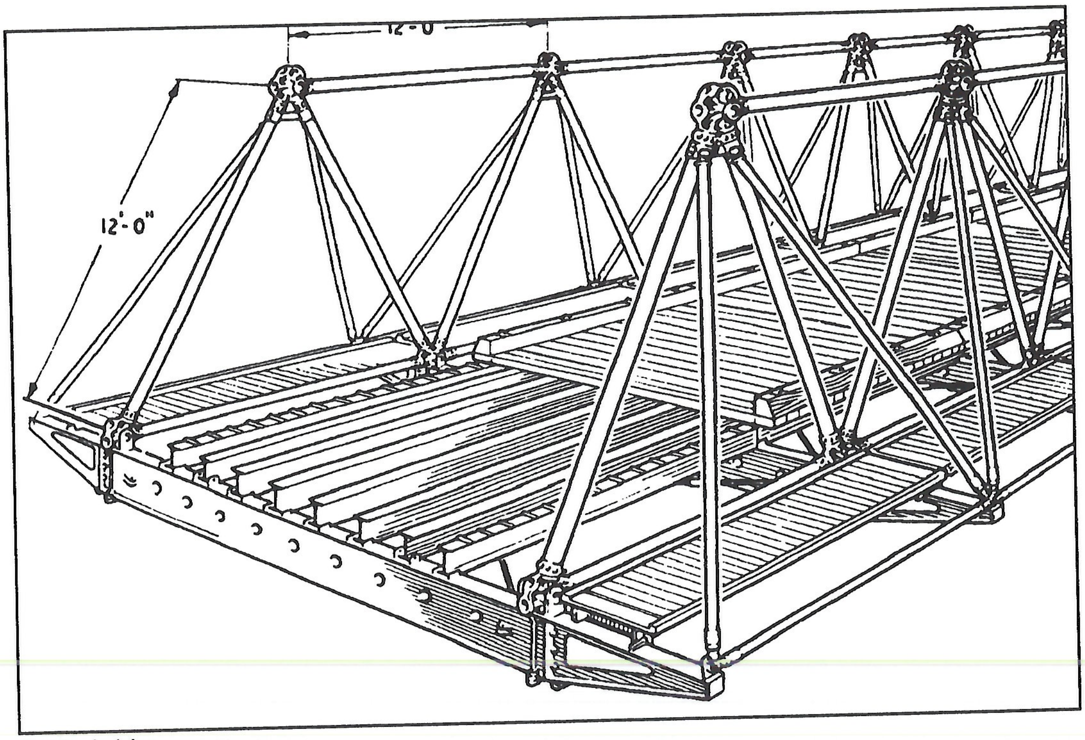
Advantages:

- easy to vary span
- can be strengthened easily by doubling the side girders
- weight relatively low with the use of high strength steel (BS 548) instead of the use of mild steel (BS 15)

Disadvantages:

- all connections are site-bolted with many individual parts to be assembled in-situ
- launched by "derrick and preventer" method and therefore slow to construct (e.g. erection and launching of a 120-ft.-span bridge could take a week or longer)
- not suitable for rapid bridging in the field (from reasons above)

Inglis Bridge

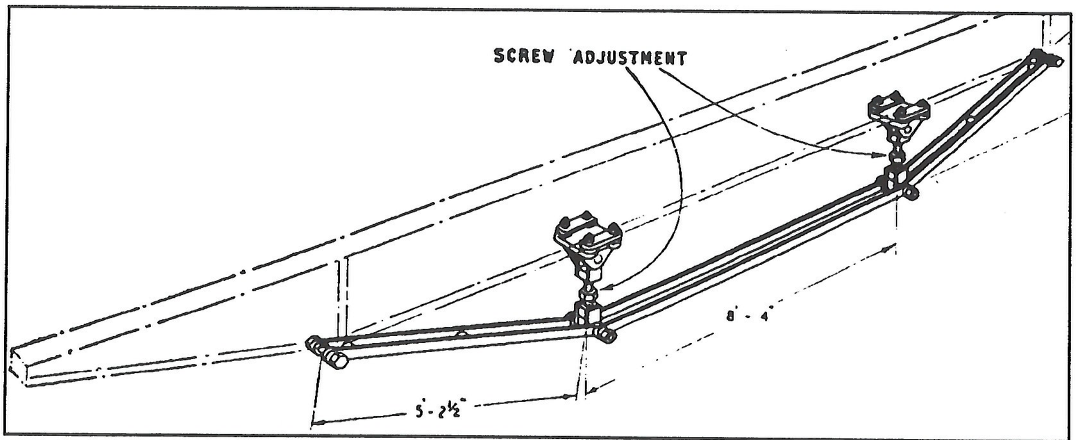


Inglis bridge

Specifications:

- Warren-girder type bridge developed by Prof. C.E. Inglis of Cambridge University
- designed to carry 24-ton loads on spans of up to 140 ft. (12 bays)
- girders made up from single lengths of 4½-in. o.d. steel tubes connected in equilateral triangles of 12-ft. sides forming a girder approximately 10 ft. 9 in. in depth
- connections between ends of tubes in the form of cast-steel junction boxes accommodating recessed slots spaced at angles of 60°

- steel tongues welded to each end of tubes pinned into recesses in junction boxes and locked in position by screwed collars
- provides roadway 11 ft. in width consisting of timber or composite steel-and-timber decking supported on 8 × 4 in. R.S.J. stringers and 15 × 5 in. R.S.J. cross-girders
- sway-bracing of double diagonal 1¼-in. diameter mild-steel rods fitted with turn-buckles for adjustment
- top chords supported by tubular knee bracing members connected to extensions of cross-girders which also support footwalks
- launched either by building out over the gap as a cantilever or, for spans of up to 84 ft., by building on a trolley, and either swinging it over the gap or rolling forward
- "tail" must be constructed to carry a suitable counterweight during erection and launching



Inglis bridge–pre-stressed cross-girder

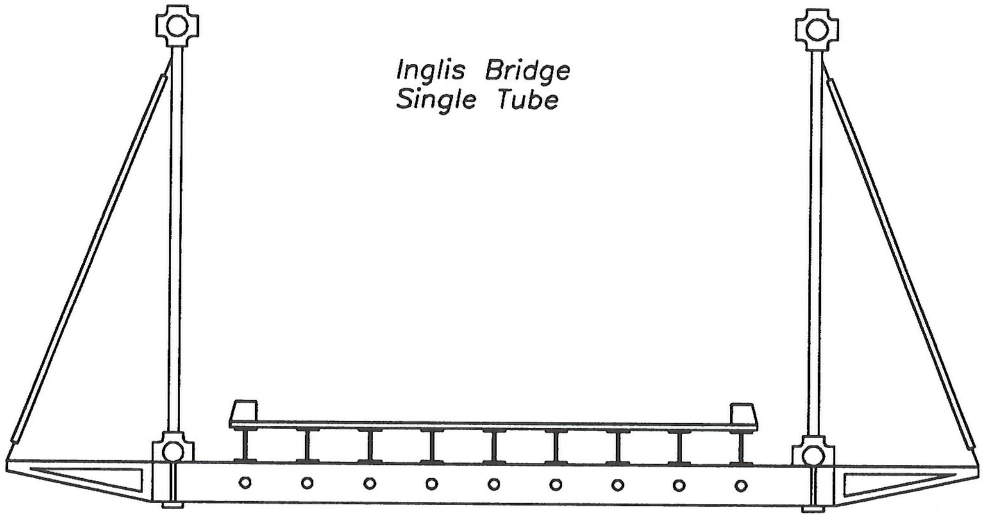
- cross-girders strengthened in 1942 by conversion to trussed beams and pre-stressing enabling bridge to carry 40-ton loads on spans of up to 120 ft.

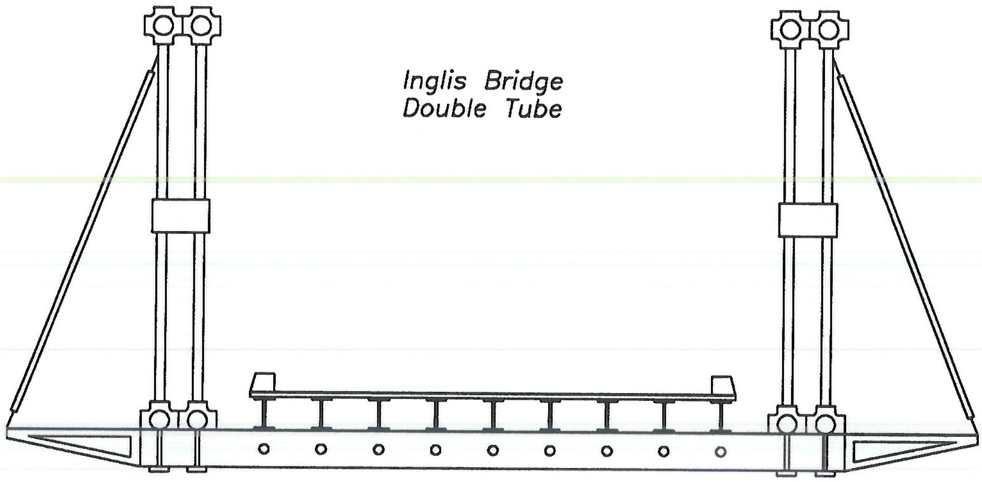
Advantages:

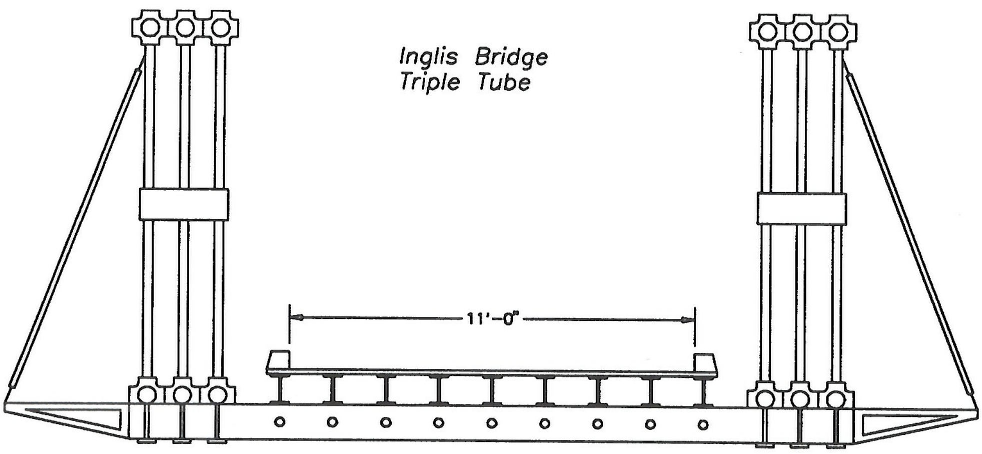
- strength can be increased at design stage by doubling or tripling trusses
- use of pins instead of bolts reduced erection time (e.g. erection of bridge may take only a day, but *unit construction bridge* may take a week)
- use of tubes as simple and standard structural elements which can be transported easily

Disadvantages:

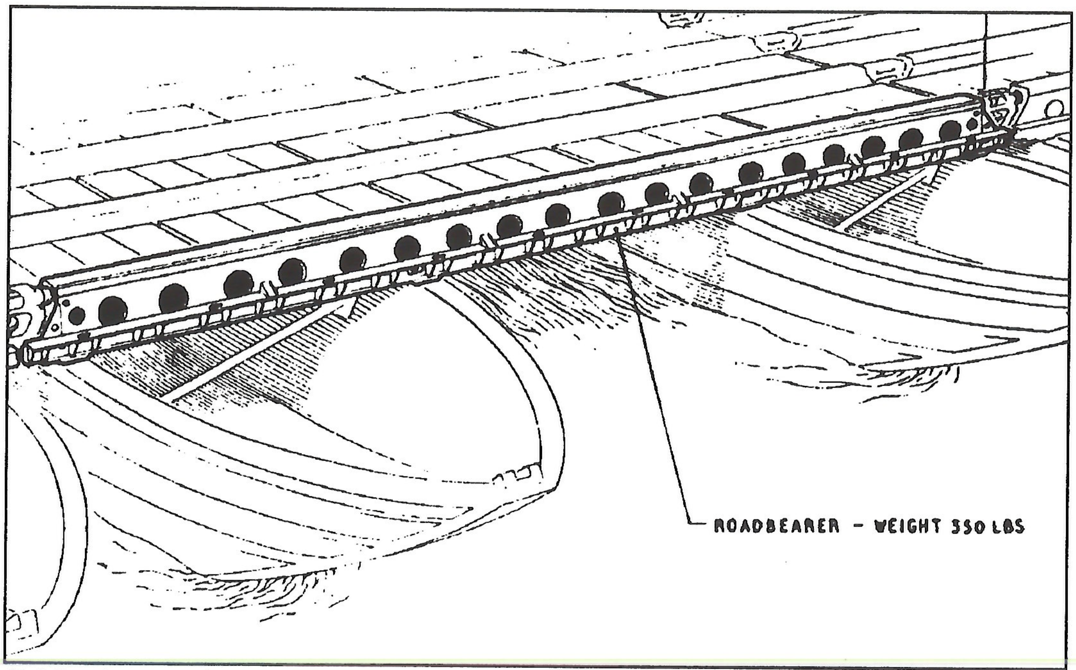
- needs skilled personnel to erect and launch bridge
- bridge must be built twice as long to counteract weight at front end of bridge
- needs relatively flat terrain to build due to bridge being constructed alongside edge of gap and finally being pivoted around to be swung over the gap
- not easily adaptable to take different loads at short notice
- components difficult to assemble and dismantle
- too slow to construct under active enemy fire


Inglis Bridge
Single Tube


Inglis Bridge
Double Tube


Inglis Bridge
Triple Tube
11'-0"

Folding Boat Bridge



Folding boat equipment

- designed in 1939 to carry vehicles up to 9 tons
- buoyancy units consist of open plywood boats, the sides of which can be folded inwards to reduce bulk for transport
- roadway consists of composite steel-and-timber deck panels, these being arranged in three parallel lanes supported by four equally-spaced longitudinal girders or bearers which combines the function of stringers and stiffening girders
- 20-ft. long floating bays each supported by two boats joined together by special connections which allows for limited articulation at the ends of the bearers

Advantage:

This bridge was used operationally in many theatres of war, and speed of erection was such that 120 ft. of bridge could be built at night in well under an hour.

Note:

As soon as the Bailey bridge had established itself as the standard equipment for simply-supported spans, it was quickly adapted to form the superstructure of a floating bridge strong enough to carry the heavier military loads. Advantage was taken of the high strength of the girder panels to distribute loads over much greater lengths of bridge, and thus economize in the number of floating pontoon piers.

CHAPTER III

The Bailey Bridge

III. The Bailey Bridge

SHORT HISTORY OF SIR DONALD BAILEY

Donald Bailey was born on 18 September 1901 in Rotherham, Yorkshire not far from his later home in Sheffield. At the age of 15, his father sent him to The Leys School in Cambridge, a year or more older than the average age of entry. Donald Bailey did not make an impression at Leys School although he liked to experiment with machines and water. Having the foresight of sailing up and down leisurely on the River Cam, he attempted to construct a raft made from a discarded iron bedstead with canvas stretched over it. He also attempted in building an engine which ran on gas, but such experiments ceased before an explosion was imminent. However, he acquired a satisfactory amount of marks to enable him to enrol in university and then had to decide whether Cambridge or Sheffield University appealed to him the greatest. Sheffield's approach to engineering education was far more practical than Cambridge's and this is what appealed to Donald Bailey coupled with the fact that Sheffield was his home and that he had an enormous phobia of hanging around railway stations to wait for connections. Attending a course in civil engineering at Sheffield, Donald Bailey's record at university was far more enlightening including membership to the university's tennis, golf, cricket and hockey club. He took part in wrist-watch repairs and raced motorcycles and automobiles having an immense interest in mechanical objects. He also joined the Abergavenny Rugby Club but did not persevere at this on account of not being able to gain enough weight as his physique was skinny. He eventually managed to obtain a Bachelor of Engineering Degree in the First Division. Donald Bailey's first job was in the Efficiency Department of Rowntrees, the cocoa factory in York. This was followed by an appointment in the Civil Engineering Department of the London Midland & Scottish Railway and then transferred to the Sheffield City Engineering Department where he made his mark during the construction of a new reservoir. He then had ambitions to work abroad but declined as soon as he received an appointment to join the Experimental Bridging Establishment based in Christchurch in the South of England as Civilian Engineer.

EVOLUTION OF THE BAILEY BRIDGE

The Experimental Bridging Establishment (EBE) replaced the military unit at Christchurch in 1925 and consisted of mainly civilian personnel working on an extremely tight budget due to the severe depression of the time. It had virtually no resources and during the time Donald Bailey was appointed to the EBE, consisted of one draughtsman, a few assorted mechanics, odd job men and a 'bridging gang' of about five or six labourers who manhandled heavy equipment and bits of bridge around the adjoining open spaces. The Superintendent was a young man of modest rank in the Royal Engineers and pay was depressingly low of which Bailey earned only £400 per annum which in spite of the equivalent value in today's market was still incredibly low. Projects were not financed in any great way and makeshift ideas formed the basis of the EBE's work and research.

In the year of 1937, Britain started to give some thought to rearming in the face of growing Nazi aggression in Europe and during this finance was given in the testing of new equipment for the military. River crossing strategy was being developed for the conveyance of newer and heavier military equipment to the other side of a river in the least time possible. This research was carried out by the Experimental Bridging Establishment (EBE) of which Donald Bailey was a civil engineer of. It was thought by the generals that, in order to get the first waves of infantry over the water, some form of boat might be required and it was thus that no less than seventeen types of craft both commercial and individual efforts were demonstrated before an assembly of high-ranking officers. These efforts included such contraptions as an ordinary air-filled mattress which floated very well, but did not prove to be watertight. A boat was invented which could be transported in a haversack, but unfortunately, this invention was discarded due to the large amount of time required to assemble the thirty-seven parts at the water's edge. Many other creative inventions were demonstrated until, finally, Mr. Goatley of the Saunders Roe Company produced the official Assault Boat Mark I.

Rearmament could not be completed without a new bridge which would be able to support the heavier military loads which were being developed. It was an adaptation of the Inglis Bridge, designed in World War I, which, with a pontoon bridge capable of taking only nine tons, was standard equipment. Most of these, if not all, had been lost in France in 1940. In any case the Inglis Bridge which could take a load up to 26 tons, the requirement of a Matilda tank, was soon outdated. New and much heavier 40-ton tanks like the Churchill were being developed, and with them came a whole new set of criteria for flexible and speedy erection of bridges never before encountered. These criteria had been anticipated by Donald Bailey of the EBE in 1936.

When the Inglis Bridge which had been strengthened and adapted to take heavier loads proved unsatisfactory in late 1940, Donald Bailey noted that 'this caused very considerable alarm and despondency in the War Office circles for it takes a long time, sometimes a very long time, to get a bridge into production.' The Inglis Bridge did not lend itself to the necessary speed of erection demanded by the pace of mobile war; it had to be built twice as long as the distance needed to bridge the gap because it was swung over the gap on a turntable at the point of balance; it was not easily adapted to take different loads at short notice; and not assembled or dismantled without considerable difficulty under active service conditions. It was during this time that Donald Bailey considered the criteria that the new bridge would have to embrace. A bridge was needed in double quick time to carry up to 70-ton loads; to be capable of assembly in different forms so as to be reasonably economic over spans of varying length; to cope with vastly differing loads ranging from the standard army three-ton lorry to tanks of great tonnage and their heavy transporters. Finally it had to have speed of erection and a foolproof design which would enable ordinary soldiers to put it together without mishap. Due to the speed of erection being the key to success, all parts had to be light and easily fastened together and transported to site which demanded that all parts must fit easily into standard army lorries and even aircraft. Bailey did not get very much encouragement by the War Office to develop his idea. The War Office was anxious to update the Inglis Bridge and hence ordered Bailey to concentrate on its update during working hours. Bailey developed his own ideas on his own spare time and it was not until 1941 when his design was adopted by the War Office.

For some years, Bailey had had the idea of constructing a bridge girder out of individual panels, but had never had time to investigate this fully and no calculations had been made. The panel had obvious advantages over the box girder, since the manufacturer only had to worry about accuracy in one plane, and its transport did not also involve the transport of a large volume of air. The advent of the Churchill tank necessitated a complete redesign of all existing equipment in any case, and the time seemed ripe for this to be investigated. The solution to the problem was a matter of extreme urgency.

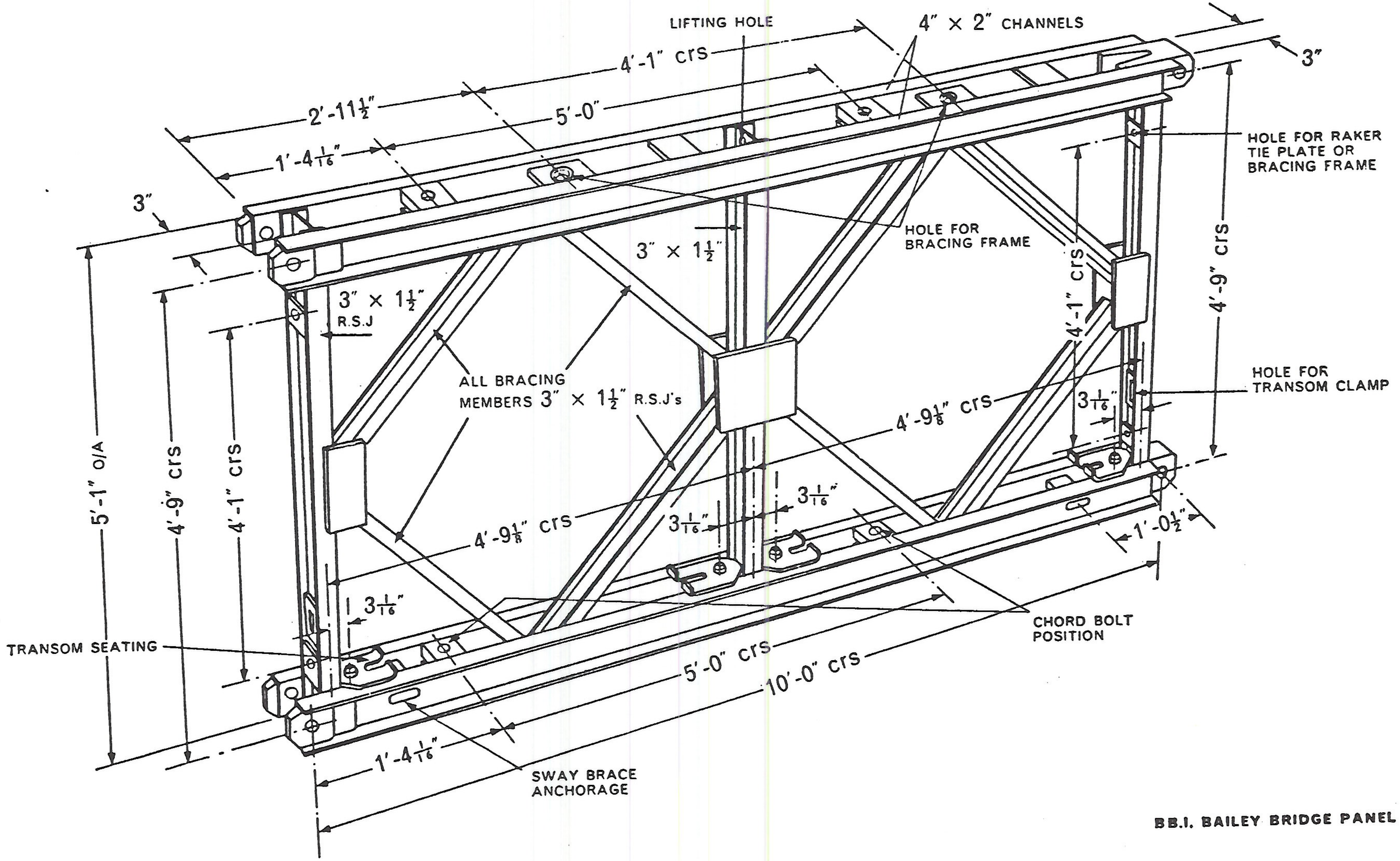
Bailey's idea seemed promising but nothing could be decided until some sizes and weights could be worked out on paper. It became apparent that a panel of a suitable size to fit into a 3-ton lorry could be made which would not be too heavy, and that these panels could be made into a girder to take the Churchill tank over a considerable span. After telephoning the news to London, permission was given to go ahead. Having had considerable experience over the shortcomings of earlier bridging equipment, it was decided from the outset to eliminate as many of them as possible, and the following points were therefore selected as data:

- The girder and deck system to be capable of being strengthened at will, preferably in-situ. This would take care of increases in weight of the tank and of any reasonable transporter.
- All parts to be made of readily available materials, and to be welded; special steels were almost impossible to obtain during the war.
- Parts to be capable of manufacture by almost any engineering firm.
- All parts to fit into a G.S. 3-ton lorry.
- Nothing to be heavier than a six-man load.
- Underside of girders to be kept smooth for rolling on launching rollers.
- A properly designed jacking system to be incorporated, since this operation can cause untold delays in the field.
- Adequate bearings and bankseats to be provided. None of the other equipment bridges had them, and loads were rapidly becoming heavier.
- Close manufacturing tolerances to be avoided. All other bridging equipment had caused difficulties in this respect.

DESIGN OF THE BAILEY BRIDGE

The Bailey Bridge is a prefabricated sectional bridge which is put together from interchangeable parts (not unlike a Meccano set) and can be extended to almost any length or strengthened or added to as required. The bridge consists basically of a series of interchangeable lattice-work panels of electrically arc-welded steel. Bailey's idea was to prefabricate part of a complete girder from top to bottom which would serve for any length of bridge in the form of a panel. This basic unit was five feet by ten feet with two diamond-shaped crossbraces joining a vertical bar in the middle. The panels could be pinned together end to end to form a girder of any required length so long as it retained sufficient strength to deal with a predetermined weight of load. A line of panels forming a complete girder can be accompanied by another line of panels alongside to form a DOUBLE SINGLE design or, with the addition of yet another line of panels, a TRIPLE SINGLE design. The girder may be given extra depth by adding panels vertically. For example, a girder comprised of panels two rows across and three units high would become a DOUBLE TRIPLE design. Only three basic bits were needed to bind the panels together. They were a panel pin, which was secured in position by a steel safety pin, and a strong chord bolt. Two lines of these connected panels, with steel beams laid across between them to carry the roadway, form the simple framework of the bridge. The roadway itself is built of wooden planks, all cut ready to standard size, and these are dropped into position and held down by a curb which is bolted down.

With the older Inglis Bridge, one had to build it more or less parallel to the river or gap and then to a length which would enable it to be swung over on the point of balance. This was a difficult and time-wasting operation because one had to complete the length of bridge needed before it could be put to use as well as building the balancing piece behind it. One also had to find a site with a large enough flat space to allow this to be done. Bailey had his panels assembled on rollers on the home bank, the first part to be put together being of the lightest form possible with the roadway or decking left out. This section is known as the 'launching nose'. The bridge proper was built on to this nose and the whole moved gradually forward on rollers as the panels were assembled. Care had to be taken to have sufficient weight behind to prevent the whole bridge tipping forward into the gap. Eventually the nose reached the rollers previously ferried to the far side. It then only remained to complete the bridge, to push it forward until in position, to remove the nose, and jack the ends down on to their final foundations. In this way, unlike the Inglis Bridge, the Bailey Bridge was actually crossing the gap as it was being built.

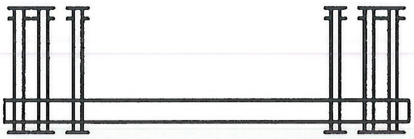


BB.I. BAILEY BRIDGE PANEL

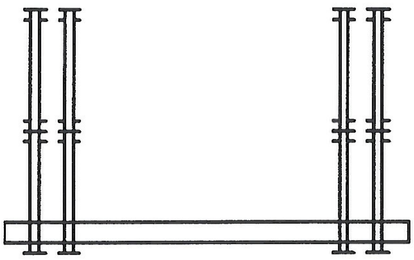
BAILEY BRIDGE PANEL CONFIGURATIONS

Single–Single (SS)

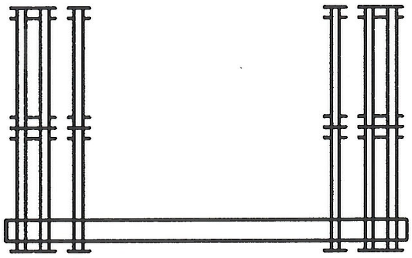
Double–Single (DS)



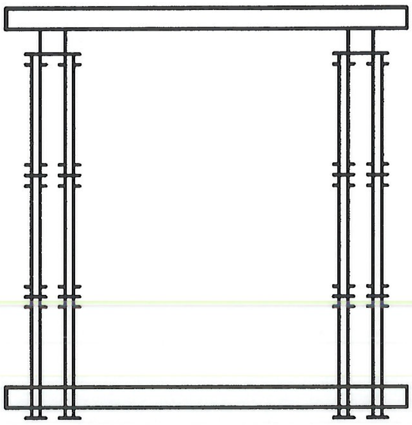
Triple–Single (TS)



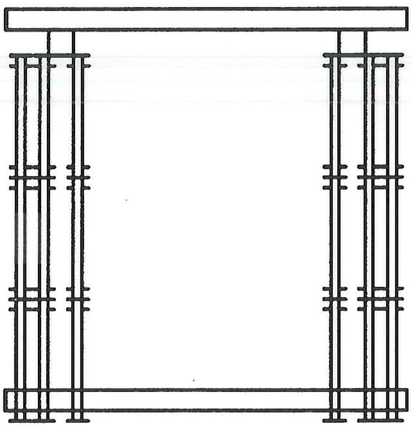
Double–Double (DD)



Triple–Double (TD)



Double–Triple (DT)



Triple–Triple (TT)

BAILEY BRIDGE PROTOTYPE AND TEST

In 1941, the War Office approved the construction of a Bailey bridge prototype to be comprehensively tested. The EBE did not have the facilities to produce the prototype and hence, the contract to construct this prototype was given to Braithwaite & Company. Braithwaite & Company took the greatest interest in the design, and suggested several features to ease manufacture supplying details of their jigs and welding procedures which were subsequently distributed for the benefit of other manufacturers. As they were made, panels were delivered by road, a dozen at a time, which enabled tests to be started on some of the shorter spans at the earliest possible moment. Great care had to be taken at this stage that all necessary fittings were incorporated in the panel and that no subsequent alterations were made which would delay production. The remaining items were designed individually and manufactured in the EBE workshops. Design and production of the pilot model proceeded concurrently and it was in fact ready for test in four and a half months and production was under way in seven months. Owing to the novel nature of the structure, it was decided that all calculations should be checked by more than usually exhaustive tests and further, that such tests should be carried out to destruction. The ultimate breaking point had to be established to allow the parameter of safety for varying loads to be laid down.

The bridge was erected on a flat field, about two feet clear of the ground, so that jacks and safety packing could be arranged underneath. All test loads were applied statically. Jacks with long handles for leverage were placed under the centre of the span to hold the bridge until the load was in place; then they were slacked off. The static load included an extra allowance for stress caused by vehicle impact and other causes. The dead weight was placed against one kerb at an angle of maximum eccentricity. Difficulties arose in finding a solution to placing the test loads on the 12-foot length of bridge. No cranes were available at the EBE and test loads would have to be abnormally high on a relatively small area provided by the bridge. The loading was achieved by driving an old 1917 Mark V tank on to the centre of the bridge. A scissors bridge was then placed as a ramp up the back of the Mark V tank and a timber platform erected at the top of it. On this, two additional tanks were placed, one in front of the other on the top of the Mark V. The Mark V was further filled with pig iron and some tons of heavy scrap were also added to the heap wherever room could be found for them. The testings proved successful and a full-scale bridge was to be built for further testing.

This 70-foot long bridge proved its success when, in 36 minutes, it was completely assembled and ready for traffic. A magazine article written a few years after the end of World War II named it 'one of the most brilliant individual inventions of the war.' It drew attention to the fact that each panel, including all its smaller components, consisted of no more than 17 parts and that the sections could be joined together with comparatively little noise, a vital point when construction was often done within earshot of the enemy. The article stated that 'The best that the Germans could do was to produce a bridge, nothing like as strong or simple, which apart from the numerous main components required 24 nuts and bolts alone for each section.' The bridge was then adopted and the great task of mass production had to be started.

FABRICATION OF THE BAILEY BRIDGE

Donald Bailey and his team at the EBE faced the problem of how to get mass production of all the parts of their bridge when the skilled workers of the nation were already employed in the mass production of everything else needed to meet the demands of a total war effort. The bridge could not be mass produced by the munitions factories, mines, agricultural areas, aviation industries, vehicle assembly lines, nor by the host of those companies already subcontracted to produce the cogs, plugs, washers, and other small mechanical components from pins to ball bearings. Bailey was to use the unskilled sector of the workforce of the nation to produce the parts required for the bridge including women and men too old for active service. A wide assortment of firms were called upon to manufacture the parts of the bridge including firms that make bedsteads, greenhouses, window frames, canoe paddles, combined with paper makers, garages, mail order businesses, confectioners, football pool proprietors, and even restaurateurs to provide the labour of the mass production. Great care had to be taken in the factory in making the parts fit. The four corner holes of the panels were drilled out at one operation by four huge drills which had been mounted on a false baseplate, moved into correct position, and then grouted in. Pins had to fit easily into every hole and the fit had to be perfect. Every part had to be made very accurately as each part had to be reliably interchangeable to a minute fraction of an inch. So each unit of workforce was given precision prototypes of the pieces they were making to copy. Thousands of ordinary people including women turned their hand to every job to release manpower for the forces in the manufacture of panels and other components for the bridge.

By 1943, 650 firms from all over the United Kingdom were involved in the manufacture of the components for the bridge. With so much inexperienced labour it was decided to test all the panels to be certain that they were up to the required standard. Testing centres were set up at which all panels were added one by one to form a continuous girder of 60 feet and tested by a hydraulic ram which could apply any required load. As one panel was added the one at the end was taken off. However when production soared to 25,000 panels a month random testing had to be introduced for a time until special machines were introduced to enable 100 per cent testing to be resumed. It stands as evidence of the efficiency of this operation that less than 300 panels were rejected of the hundreds of thousands made.

From 1942 to 1945 nearly half a million tons of Bailey bridging were made for use in every theatre of war including no less than 700,000 panels which laid end to end would reach from London to Leningrad (St. Petersburg). Another problem arose in which the special steel produced for the Bailey bridge was to be distinguished from the ordinary steel. A broad green line was painted down the middle for the Bailey sections, but unfortunately, this was followed by the welding of the steel becoming cracked. The problem was tracked down to the sulphur in the paint having an adverse effect on the weld, so by simply substituting an oil-bound distemper free of sulphur the trouble was avoided. At least 2,500 Bailey bridges were built in the Italian campaign alone and another 2,000 in northwest Europe and in the Far East. Improved versions of it are still in use all over the world today.

U.S. BAILEY BRIDGING

The Americans faced the same anxieties and problems about their bridging as the British did devising three versions of pontoon and fixed bridges: one to cover the initial assault, one for combat support in which they had a little more time, and finally, when the battle had moved on, one as a line-of-communication bridge which was a more permanent and stronger structure. The last was available in two versions of portable steel bridges modelled on British designs before the Bailey came into existence. The Bailey bridge was different from any American military bridge because most of its structure was above rather than below the roadway it provided. The British supported their bridges with girders aligned just a little below the surface of the decking with the panels rising nearly five feet above when panel storeys had to be added.

In 1942, the Americans placed most of their reliance on the 30-ton Sherman tank. In answer to this, they began perfecting their floating equipage for 30-ton loads including steel treadway bridges which they were using at the time. Even though American sappers stationed in the United Kingdom would have preferred to use the British Bailey bridge, a prominent member of the U.S. Corps of Engineers stated, 'My Tour of duty in England last summer taught me that the British are overly optimistic, not only on the capabilities of their own equipment, but also in their production planning. They are prone to seize admitted advantages and extrapolate unwarranted conclusions with a complete disregard for various disadvantages. Based on my observation, I strongly recommend against complete reliance upon the British to meet all of our bridging requirements.' As a result, the Bailey bridge was restricted to rear locations in the American army for the time being.

The Americans were perfecting the steel treadway bridge but this had reached its effective usefulness at loads of 35 tons. The newer military tanks would entail loads up to 45 tons and hence, the Bailey bridge gained more popularity with the Americans. The Bailey bridge was then to be manufactured in the United States but one major problem showed itself as very prominent. All parts of the Bailey bridge would have to be made completely interchangeable with the British Bailey bridge parts. The difference in production methods in general and the gauges determining the ultra-precision of measurements were not reconciled. Therefore, in 1944, the American Engineers bought nearly a thousand Bailey bridges from their own factories which was more than sufficient to meet their overseas demands, but the American Baileys had to be carefully segregated in Europe to ensure that the parts did not get mixed up with the British originals.

Unlike the United Kingdom, the U.S. Corps of Engineers awarded contracts to only three major firms to build complete sets of Bailey bridges. These were the Detroit Steel Products Company, The Commercial Shearing and Stamping Company of Youngstown, and the American Elevator Company of Louisville. These three firms cooperated among themselves in any improvements of design or production techniques and it was not long when additional firms entered contracts for the building of Bailey bridges. These included the Ceco Steel Products Company of Chicago, The International Steel Company of Evansville, and the Virginia Bridge Company of Roanoke. As some of the sources of material could not produce fast enough to meet the pace of the work, it was found necessary to exchange raw materials and equipment so that all manufacturers could meet their schedules. Many small industries were called on to produce stampings, castings, bolts, pins, wrenches, and other small items. Each American bridge set comprised of 36,607 separate pieces not including many other items such as bolts, rods, and boxes used in packing. This set provided enough material to construct a DOUBLE DOUBLE bridge spanning 150 feet. By the end of the war in Europe nearly 4,000 of these sets were produced in the United States at the rate of about 20 sets per week or over 1,000 sets per year, representing nearly one million tons of material and nearly 4,000 miles of welding.

ASSEMBLY OF SINGLE-SINGLE BAILEY BRIDGE

General

The normal method of constructing and launching single storey bridges is by the cantilever method with a skeleton launching nose of calculated length. The bridge is constructed on rollers, and is rolled forward over the rocking rollers on the home side of the gap until the point of balance of the bridge and launching nose together is reached. The nose will then be over the landing roller on the far bank. When the nose has been lowered on to the landing roller, the whole is pushed forward until the ends of the bridge proper are over the prepared baseplate positions. The bridge is launched completely decked.

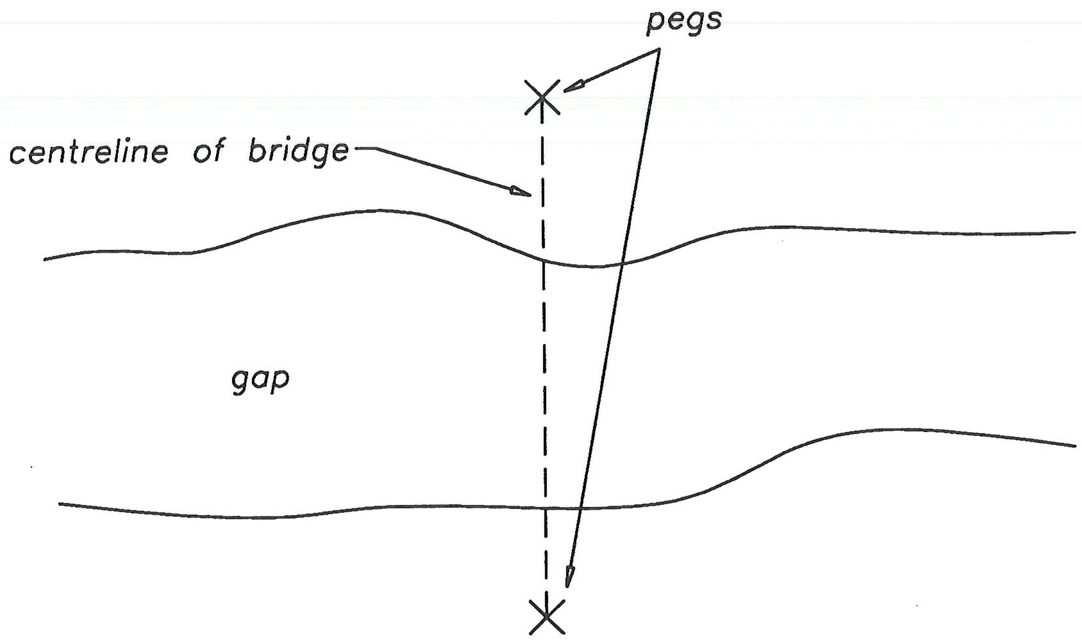
The launching nose is then dismantled on the far bank. Meanwhile on the home bank jacks are fitted under the tail of the bridge, and it is lifted clear of the rollers, which are now removed. The tail of the bridge is then jacked down on to the bearings. The process is repeated at the head of the bridge as soon as the nose is removed and jacking at the tail completed. Finally, ramps are fitted at each end of the bridge.

The general principle in building and launching single storey bridges is that the bridge should be fed forward over the gap as new bays are constructed at the tail. The point of balance is thus kept as nearly as possible on the launching rollers. In practice, there will be a tendency for the tail of the bridge to rise from the construction rollers when too near the point of balance, when this occurs the bridge must be pulled back a few feet.

Launching Nose Assembly

1) Select suitable site. Consider factors such as: narrowness of gap, strength of ground, topography of ground, concealment from enemy, etc.

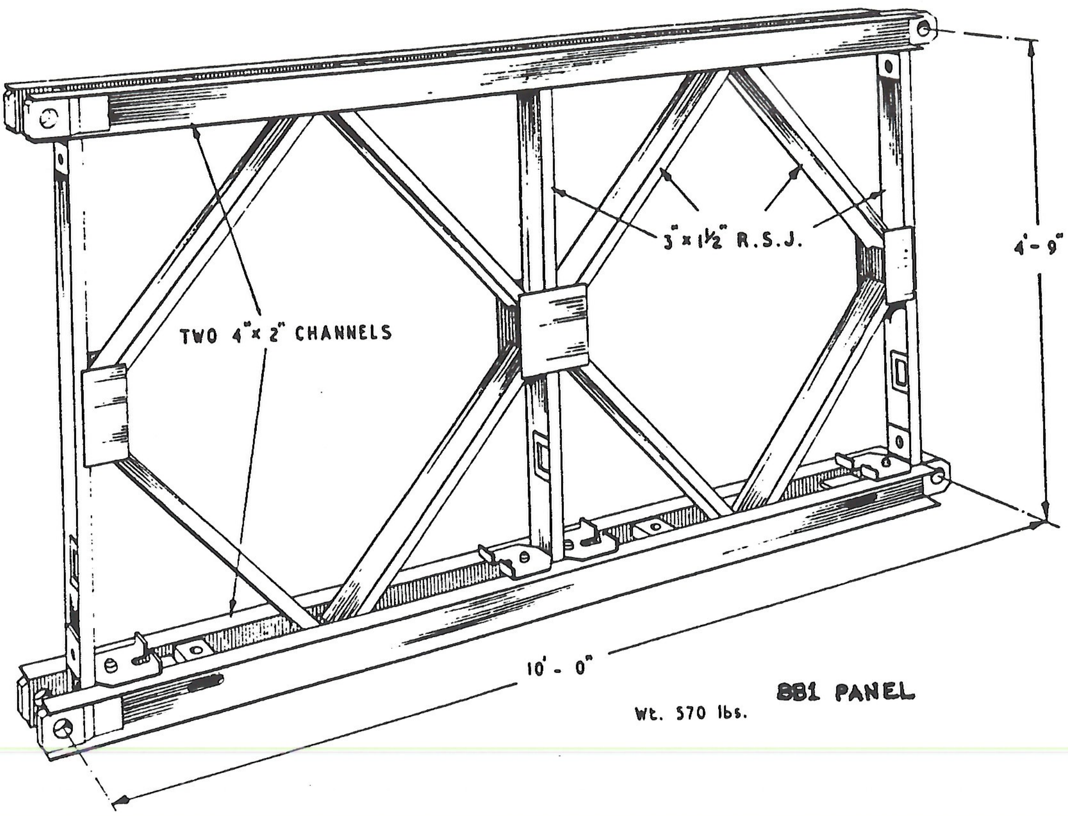
2) Set peg on either side of the gap to be bridged to represent the centre line of the bridge and decide which bank, construction is to be carried out on.



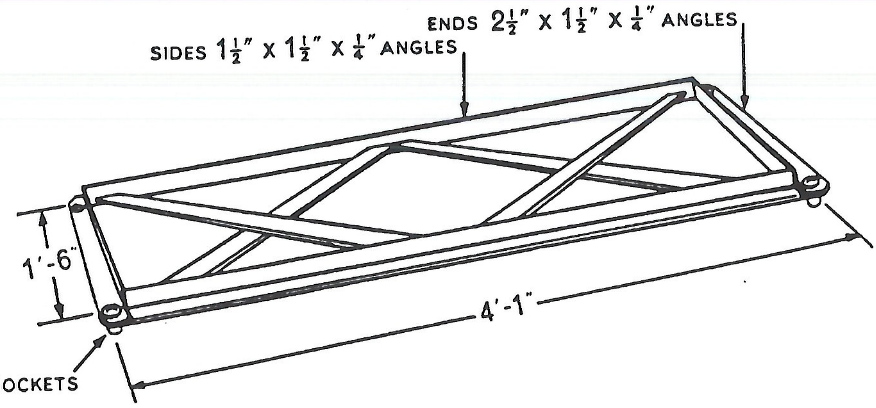
3) An area measuring around 50 ft. in width and the equivalent length of the bridge to be built in length should be cleared and levelled where components for the bridge should be laid out in order.

4) Check for correct quantity of components on site and ensure that all items used for erection purposes are present. For the construction of a single-single bridge, the components needed are shown on the following pages. A Table of Quantities for a Single-Single bridge is shown below.

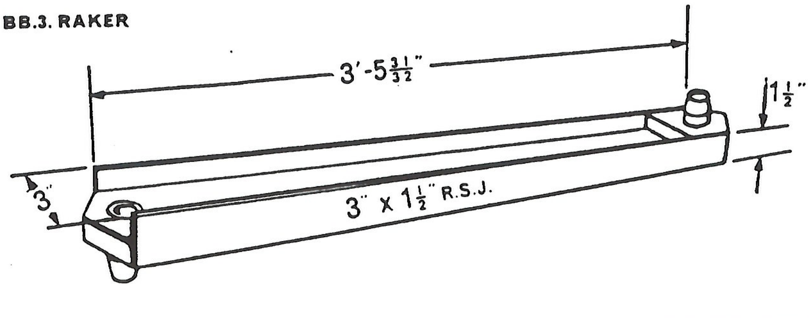
Number of Parts Required per Bay for Single-Single Bridge			
Part	**End bay No. 1**	**Intermediate bay**	**End bay No. 2**
Base plates	2	-	2
Bearings	2	-	2
Bearers, footwalk	4	4	6
Bolts, bracing	4	4	8
Bolts, chord	-	-	-
Bolts. riband	8	8	8
Braces, sway	2	2	2
Chesses	13	13	13
Clamps, transom	4	4	4
Frames, bracing	-	-	-
Panels	2	2	2
Pins, panel	4	4	8
Posts, end, male	2	-	-
Posts, end, female	-	-	2
Posts, footwalk	4	4	6
Footwalks	2	2	2
Rakers	2	2	4
Ribands	2	2	2
Split pins	4	4	8
Stringers, button	2	2	2
Stringers, plain	3	3	3
Tieplates	-	-	-
Transoms	2	2	3
Overhead bracing support	-	-	-



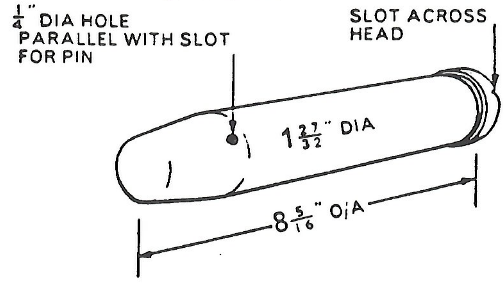
BB.2. BRACING FRAME



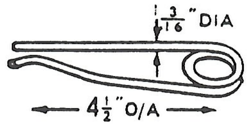
BB.3. RAKER

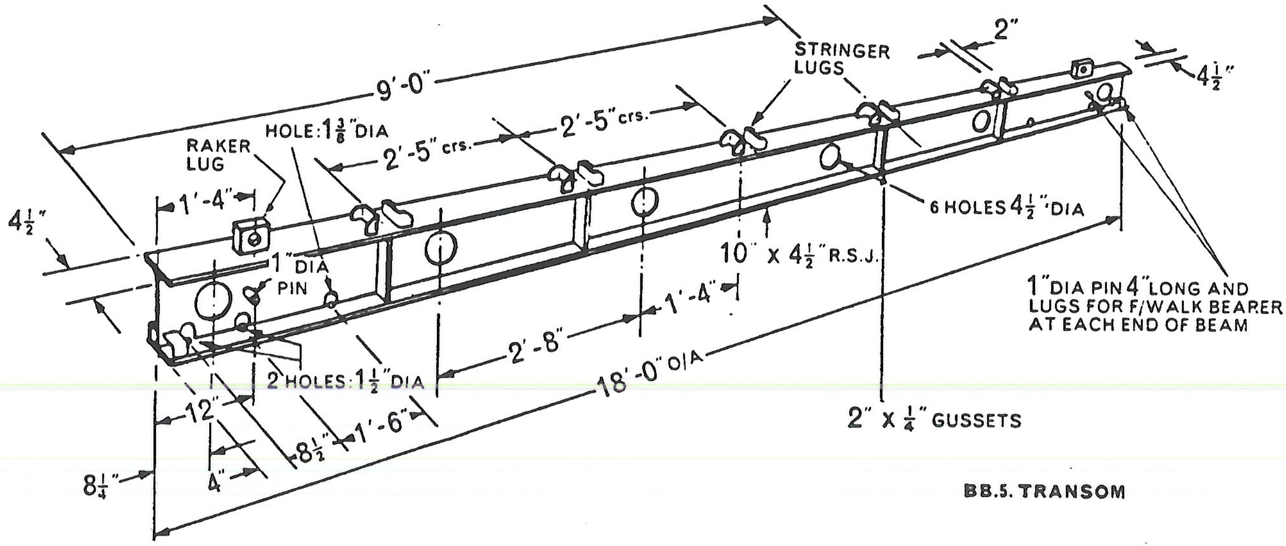


BB.4. PANEL PIN

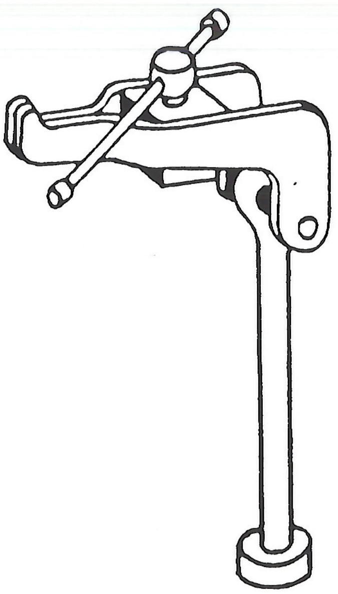


BB.4.A. SAFETY PIN

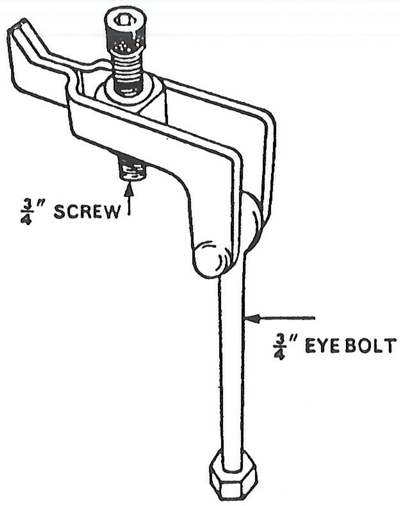




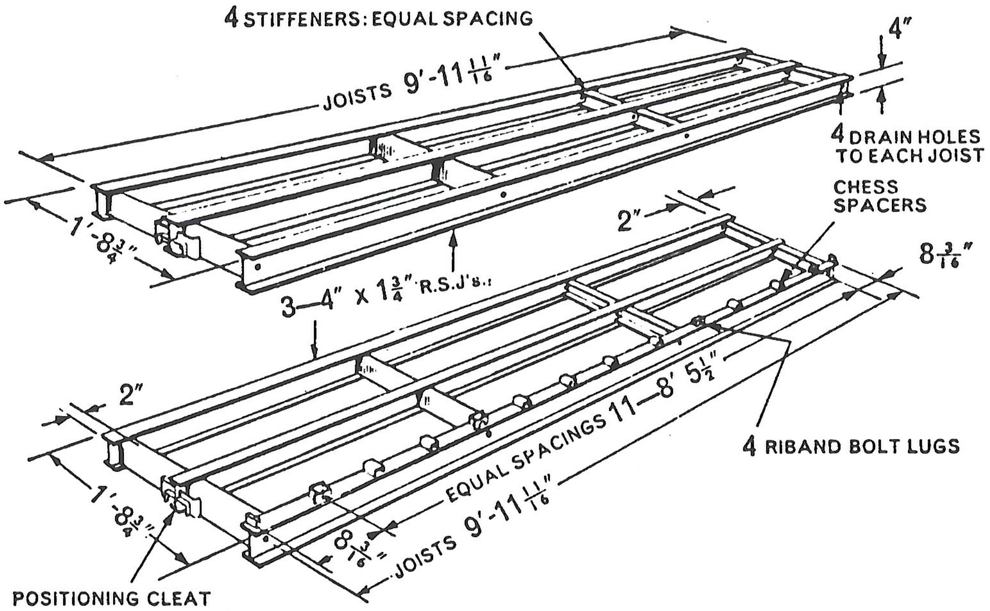
BB.5. TRANSOM



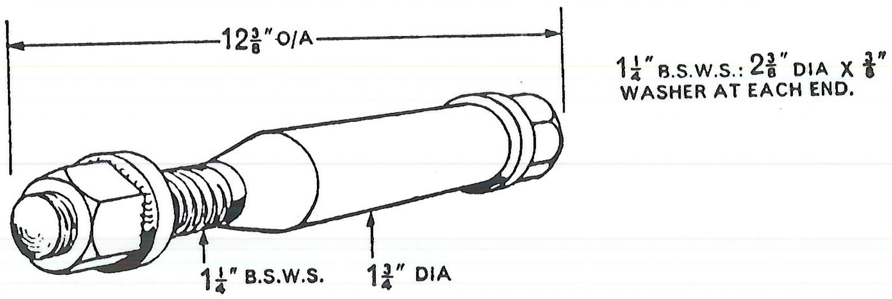
BB.6. TRANSOM CLAMP



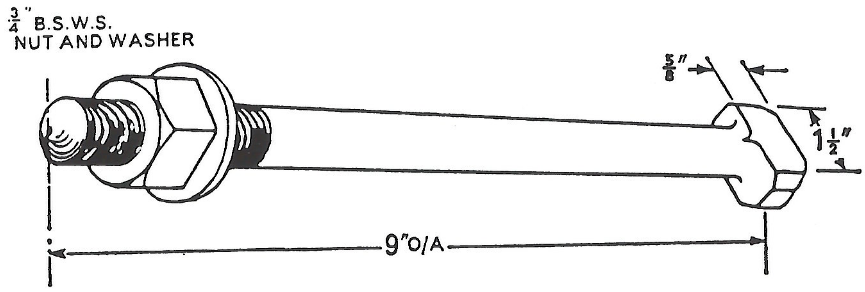
BB.573. TRANSOM CLAMP



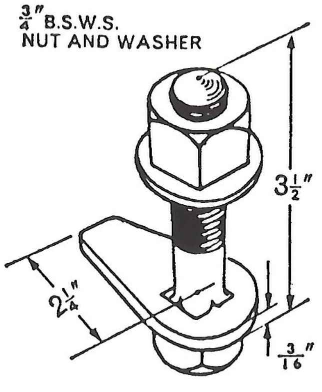
BB.7. PLAIN STRINGER **BB.8. BUTTON STRINGER**



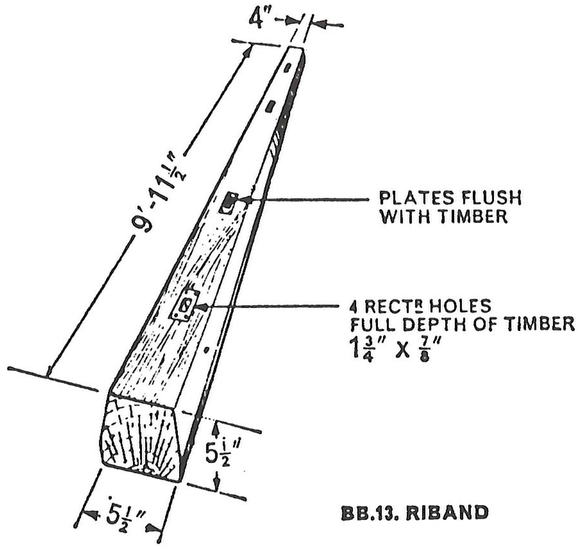
BB.9. CHORD BOLT



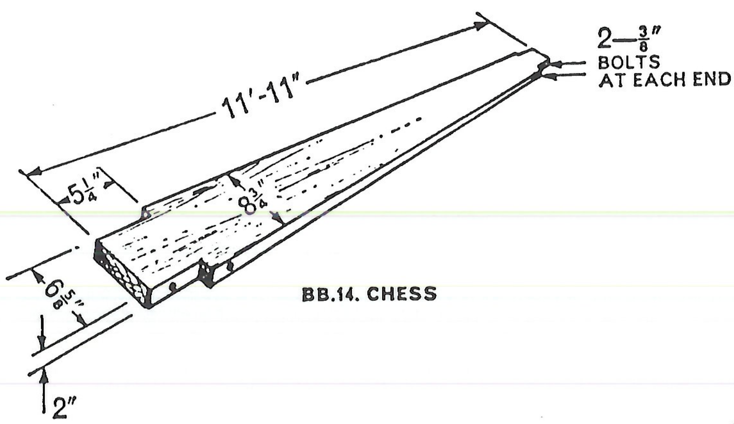
BB.10. RIBAND BOLT NO. 1



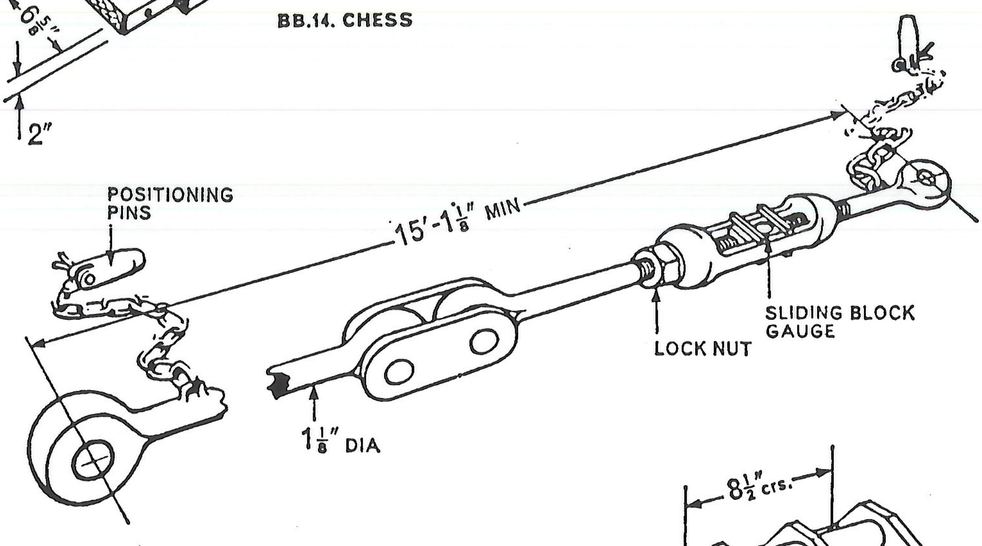
BB.11. BRACING BOLT



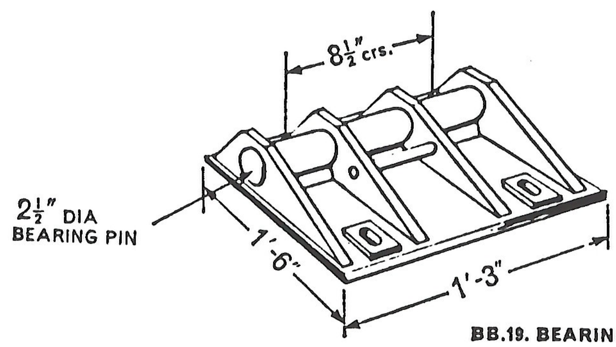
BB.13. RIBAND



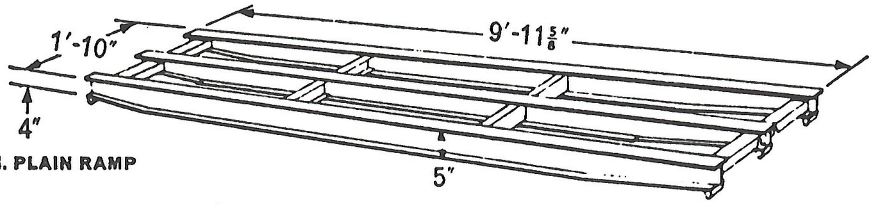
BB.14. CHESS



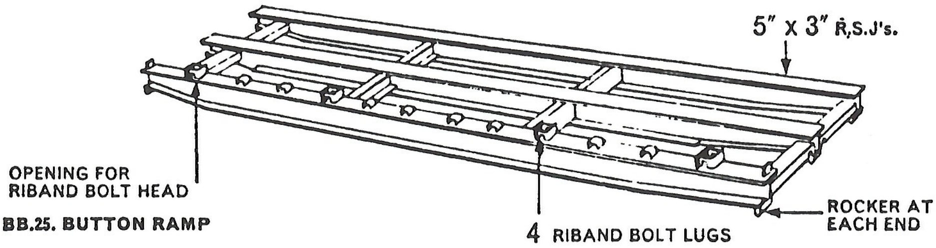
BB.15. SWAYBRACE



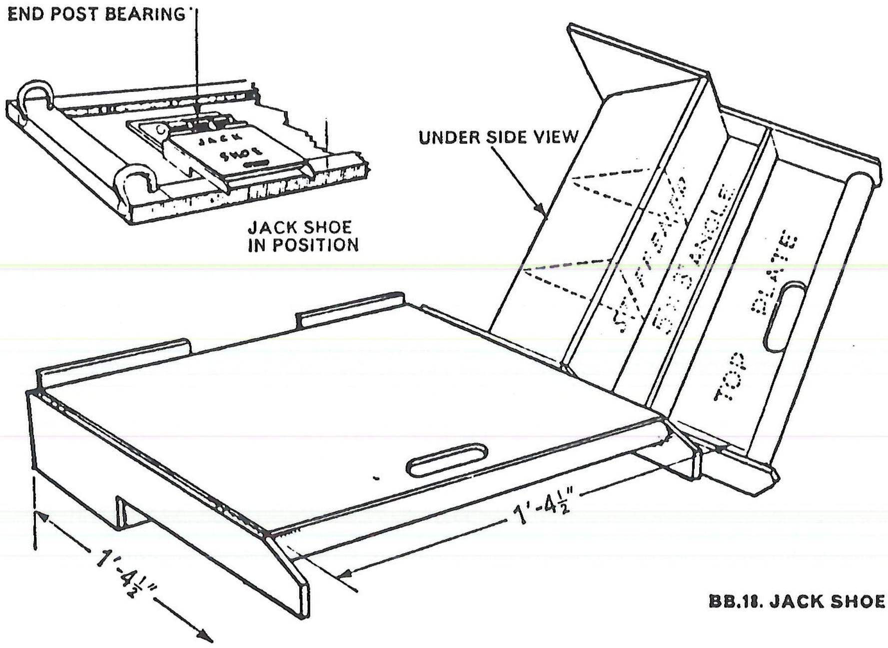
BB.19. BEARING



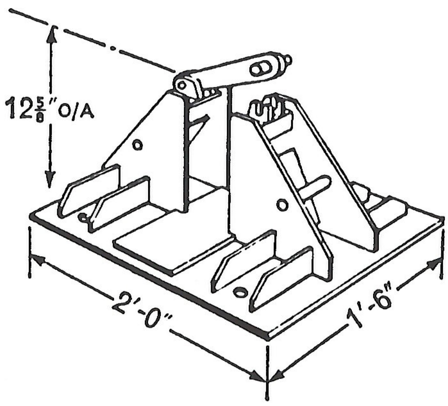
BB.24. PLAIN RAMP



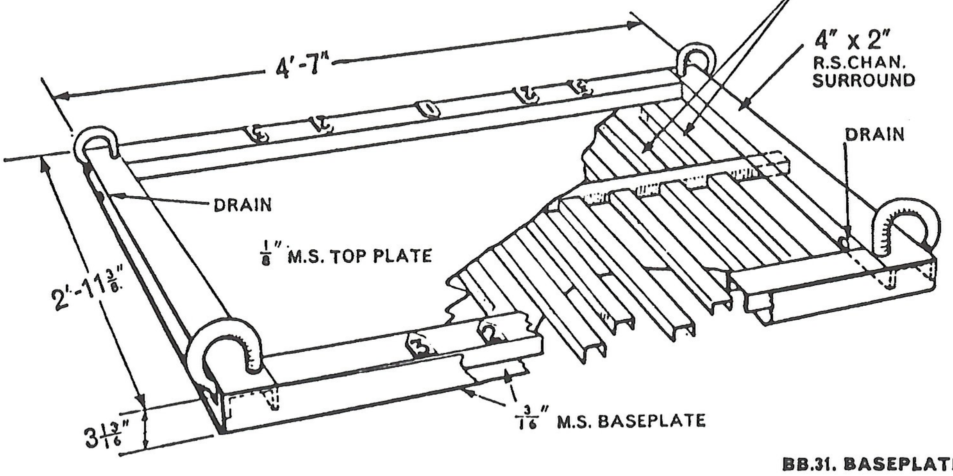
BB.25. BUTTON RAMP



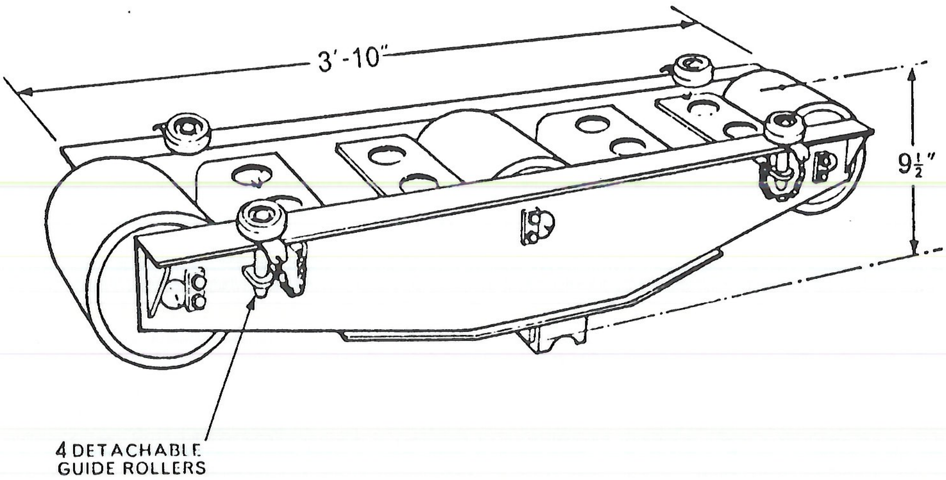
BB.18. JACK SHOE



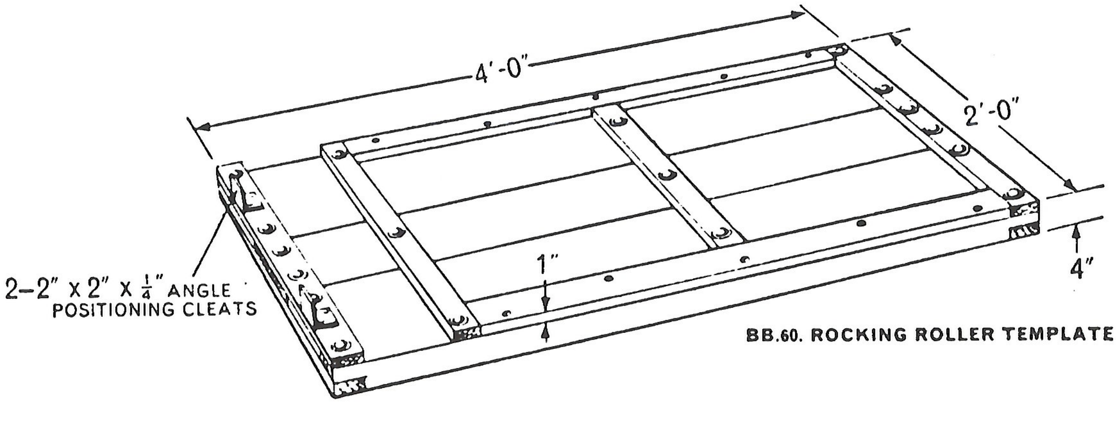
BB.23. RAMP PEDESTAL



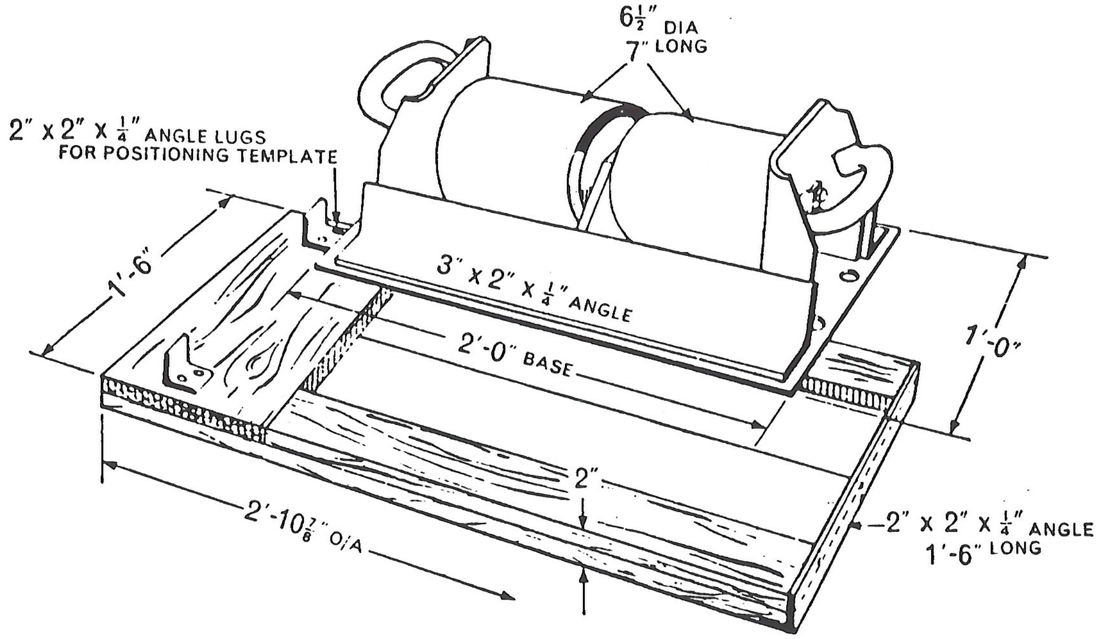
BB.31. BASEPLATE



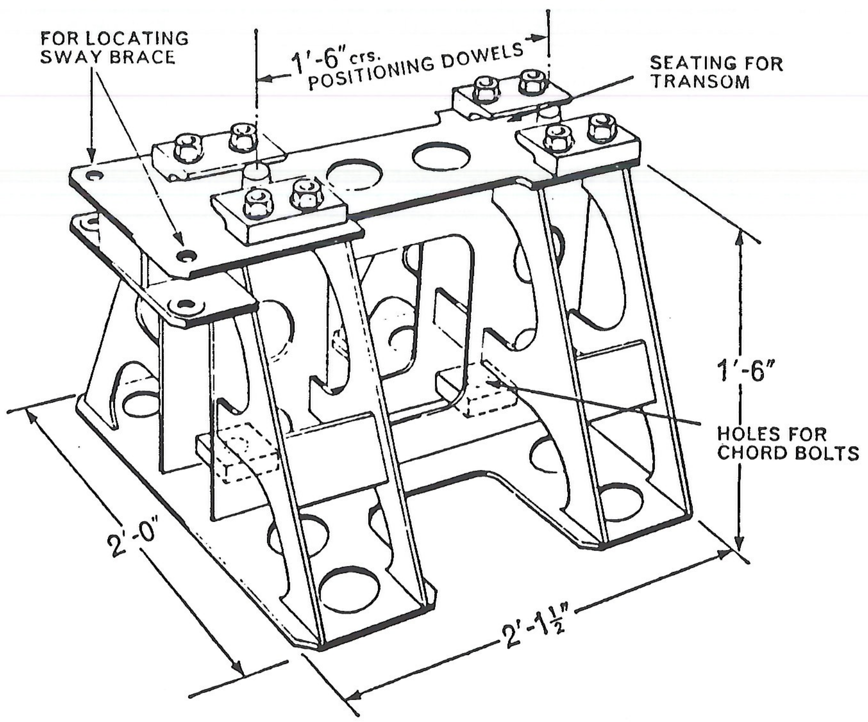
BB.59. ROCKING ROLLER



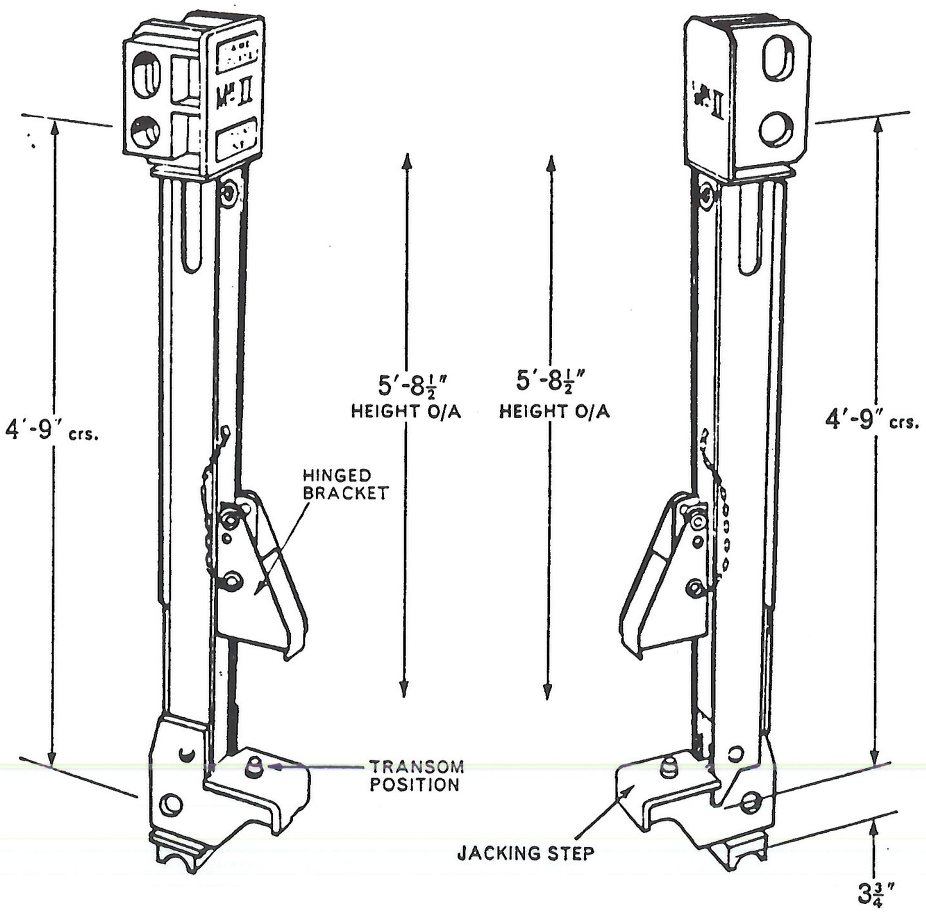
BB.60. ROCKING ROLLER TEMPLATE



BB.58. PLAIN ROLLER BB.54. PLAIN ROLLER TEMPLATE

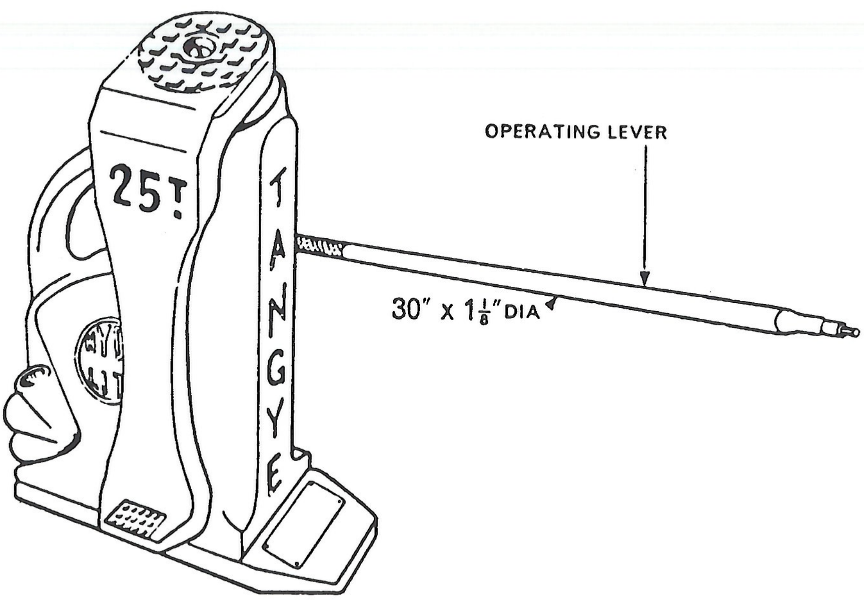


BB.73. OVERHEAD BRACING SUPPORT

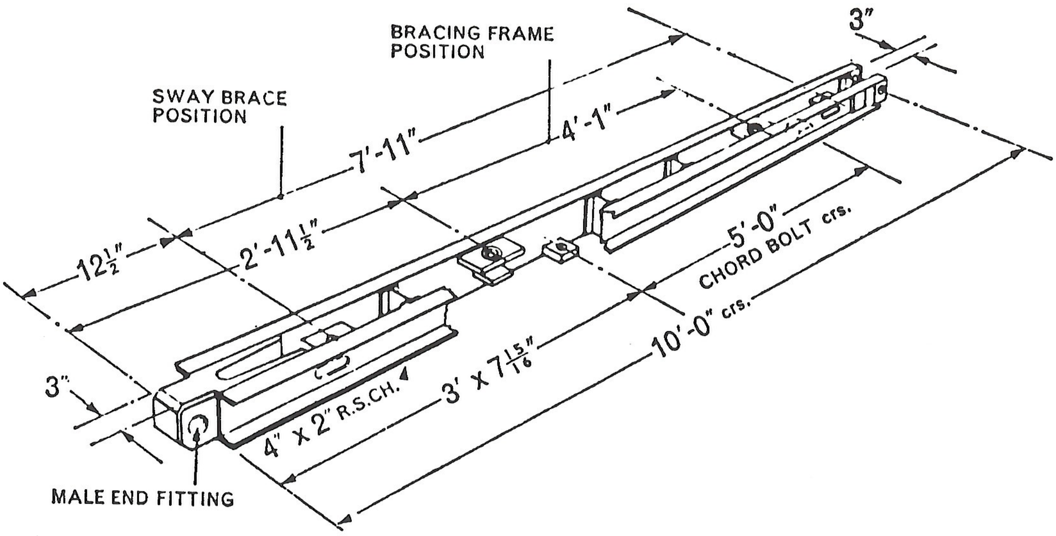


BB.62. FEMALE END POST

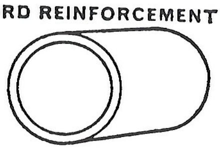
BB.63. MALE END POST



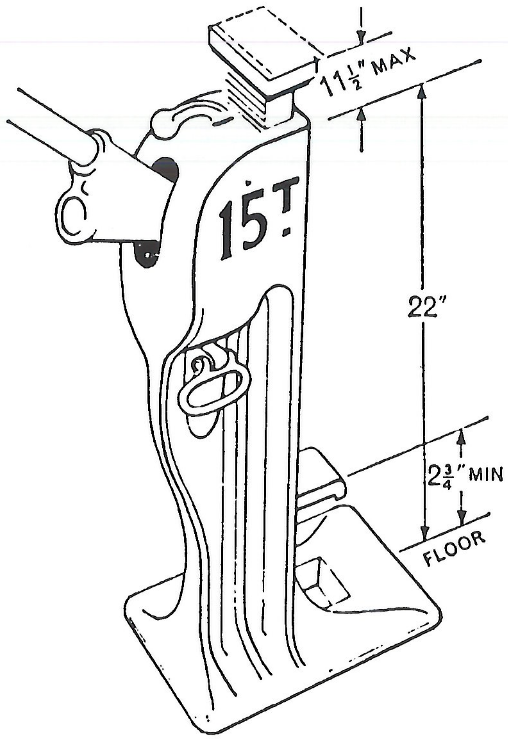
TSBB.505. HYDRAULIC JACK



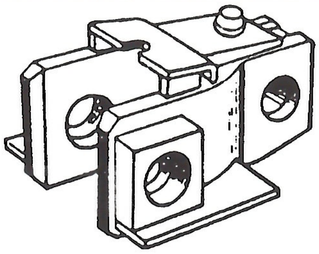
BB.150. CHORD REINFORCEMENT



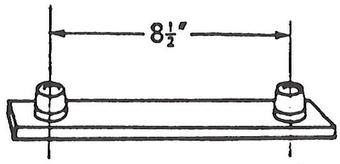
BB.151. CHORD BOLT COLLAR



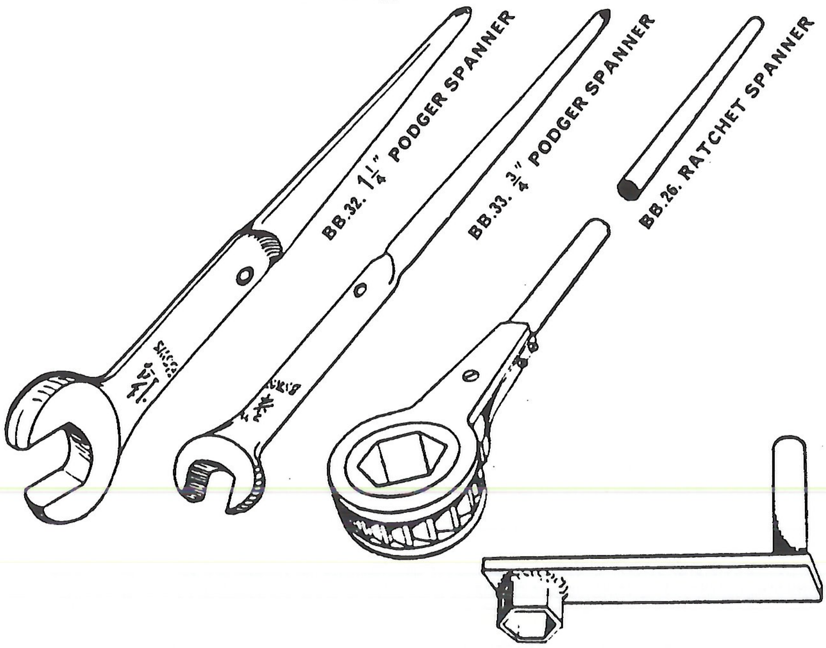
EN.1046. RATCHET JACK



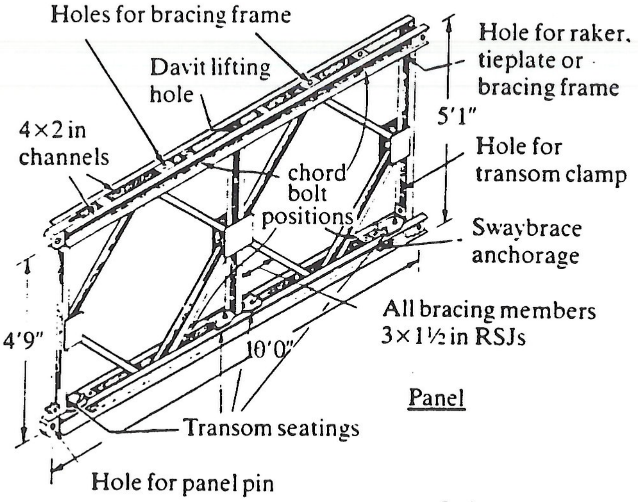
BB.65. LAUNCHING LINK MK 2



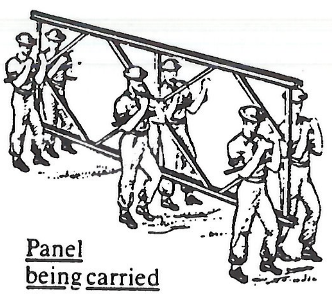
BB.29. TIEPLATE



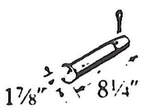
BB.34. ¾" CRANKED BOX SPANNER



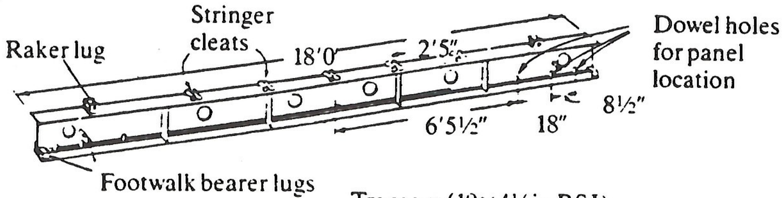
Panel



Panel being carried



Panel pin



Transom (10×4½in RSJ)

5) On prepared site, extend the bridge centreline backwards by driving pegs at approximately 30 ft. intervals. Mark out two lines parallel to the centreline, one either side, distant from it 6 ft. 5½ in. These denote the position of the bridge girders, and on these lines all rollers and baseplates are set.

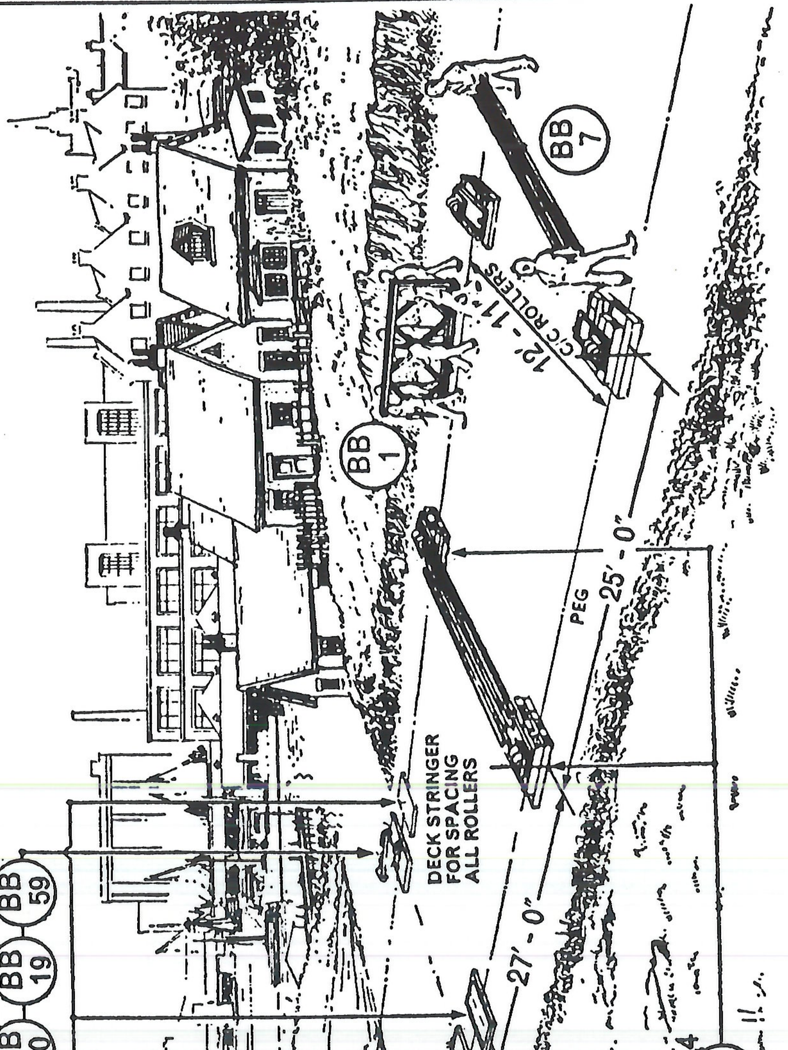
6) Lay down *baseplates* and check that the line through them is at right-angles to the centreline.

7) Place *launching rollers* (either *plain* or *rocking*) approximately 3 ft. 6 in. in front of the baseplates nearer the gap to be bridged.

8) Places remaining *plain rollers* (with *templates*) at approximately 25 ft. intervals behind the baseplates.

9) Ensure that each pair of rollers is correctly lined across transversely and is at right-angles to the centreline and also ensure that the rollers are firmly bedded down, with no tendency to overturn. *This step should be checked thoroughly.*

10) Check roller positions by laying a transom across each pair in turn. The inner hole in the bottom flange at each end should be on the centre of the roller.


BB 7
C/C ROLLERS
12' - 11½"
BB 1
25' - 0"
PEG
DECK STRINGER FOR SPACING ALL ROLLERS
27' - 0"
3' - 6"
80' - 0" SPAN
C/C BASE PLATES
BB 60
BB 19
BB 59
BB 58
BB 54
BB 31

11) Place a *Bailey panel* on each of the two launching rollers with the female jaws towards the gap.

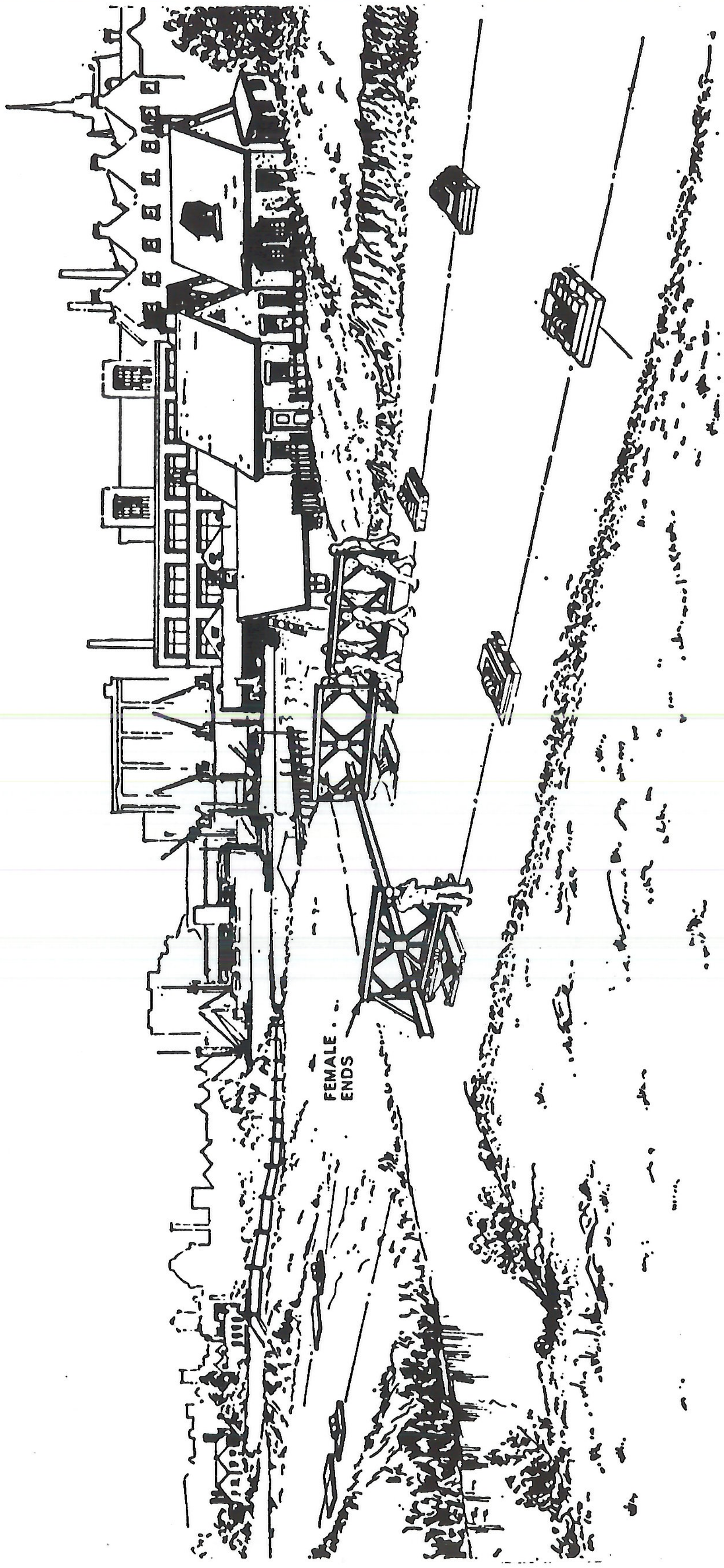
12) Thread a *transom* through these two panels so that it locates in the panel seatings nearest the gap.

13) Secure the transom with *transom clamps*.

14) Fit two *rakers* by attaching them with *bracing bolts* in which the bottom end is connected to the block on top of the transom and the top end is secured in the hole in the panel just below the top chord.

15) Tighten bolts with spanner.

This completes Bay 1 of Launching Nose.

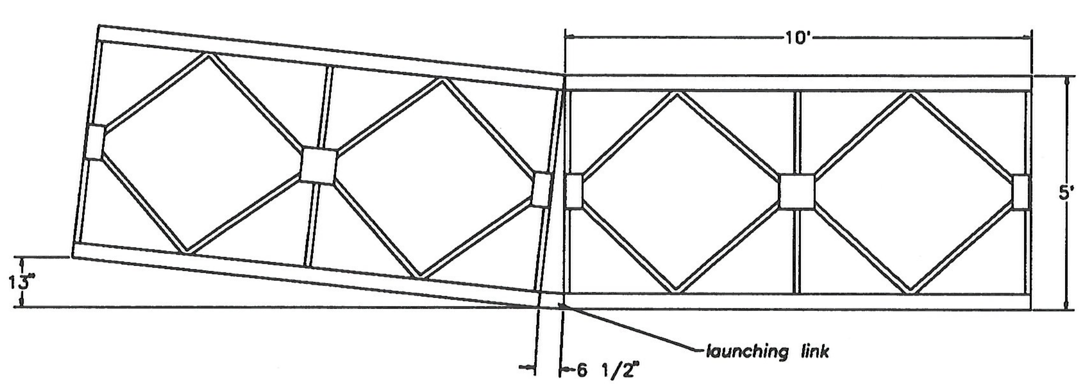

FEMALE
ENDS

16) Start building Bay 2 of launching nose by pinning on two more panels with *panel pins*. If these new panels are standing flat on the ground and the first panels are canted on the rollers, the bottom pins can be left out for the time being. As bridge increases in length, the bottom pins can be inserted easily.

17) Feed a transom in to the most forward seatings and clamp in position.

18) At this stage, it is appropriate to decide if the use of *launching links* is relevant. These are inserted between the bottom chords of panels to offset the sag at the end of the bridge when it is pushed over to the far bank. Depending how many launching links are used and where they are inserted, a suitable difference in height can be achieved with the aid of *bridge sag tables*.

Effect of Launching Link to compensate for end sag



19) The number of bays in the launching nose should be calculated:

a) Length of launching nose is equal to half the number of bays in the bridge plus one extra bay.

b) For single-storey bridges:

Maximum length of single-single nose	= 6 bays
Maximum length of double-single nose	= 4 bays

For double and triple-storey bridges:

Maximum length of single-single nose	= 6 bays
Maximum length of double-single nose	= 3 bays

Any further bays required must be double-double.

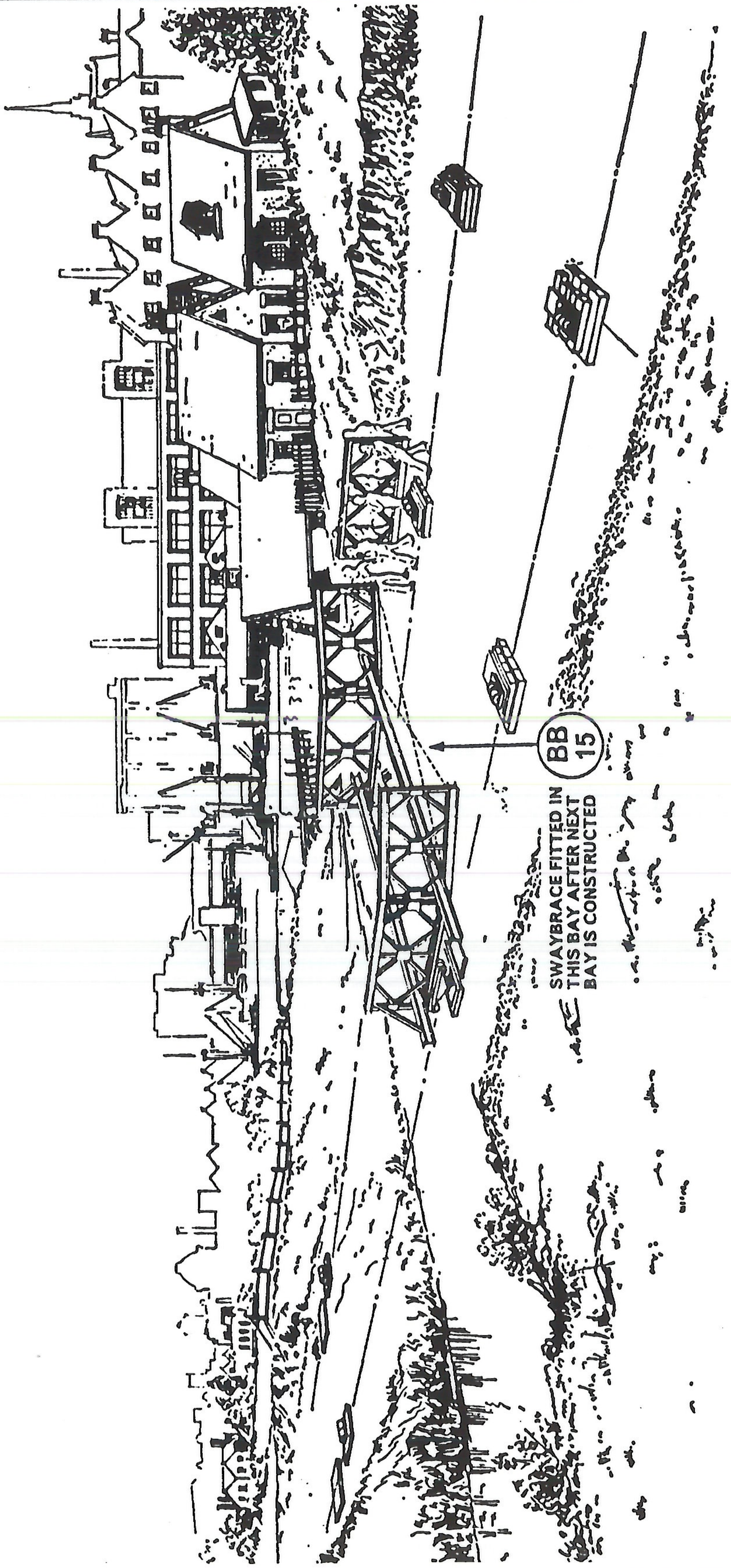
c) Launching links must not be fitted more than four bays back in the single-single portion of the nose.

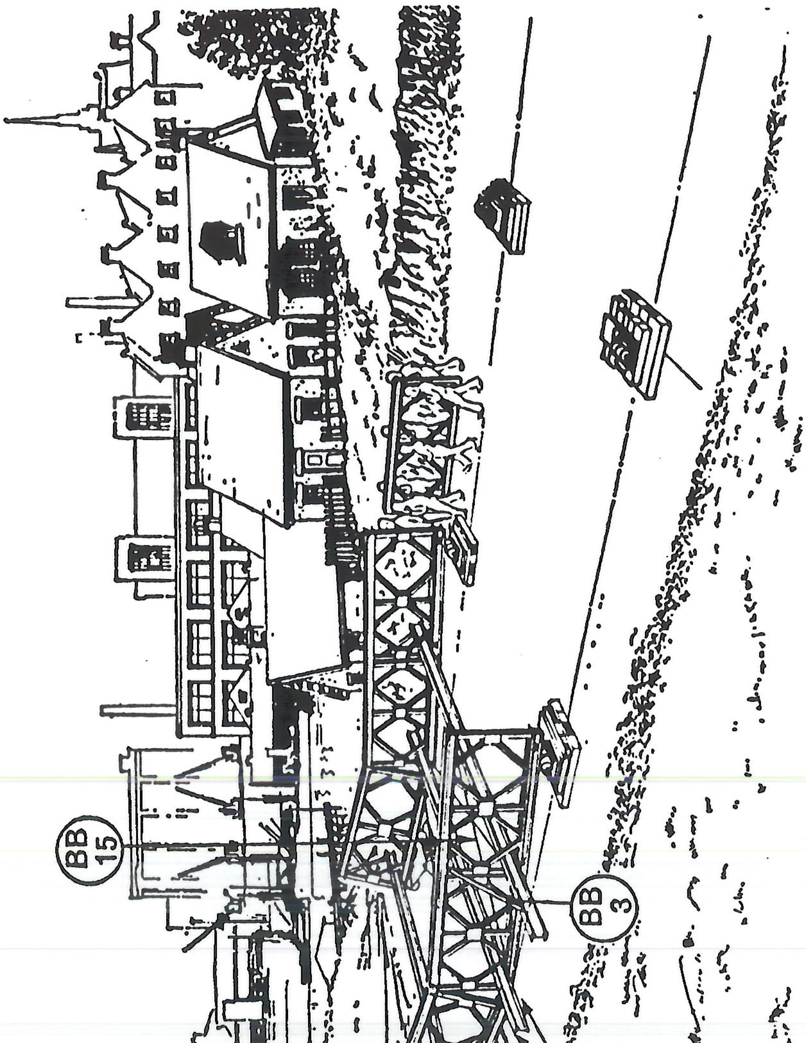
d) When the bridge reaches the point of balance during launching, the whole weight of the bridge plus the nose is carried on the launching rollers. The foundation for the launching rollers must be provided to take this weight.

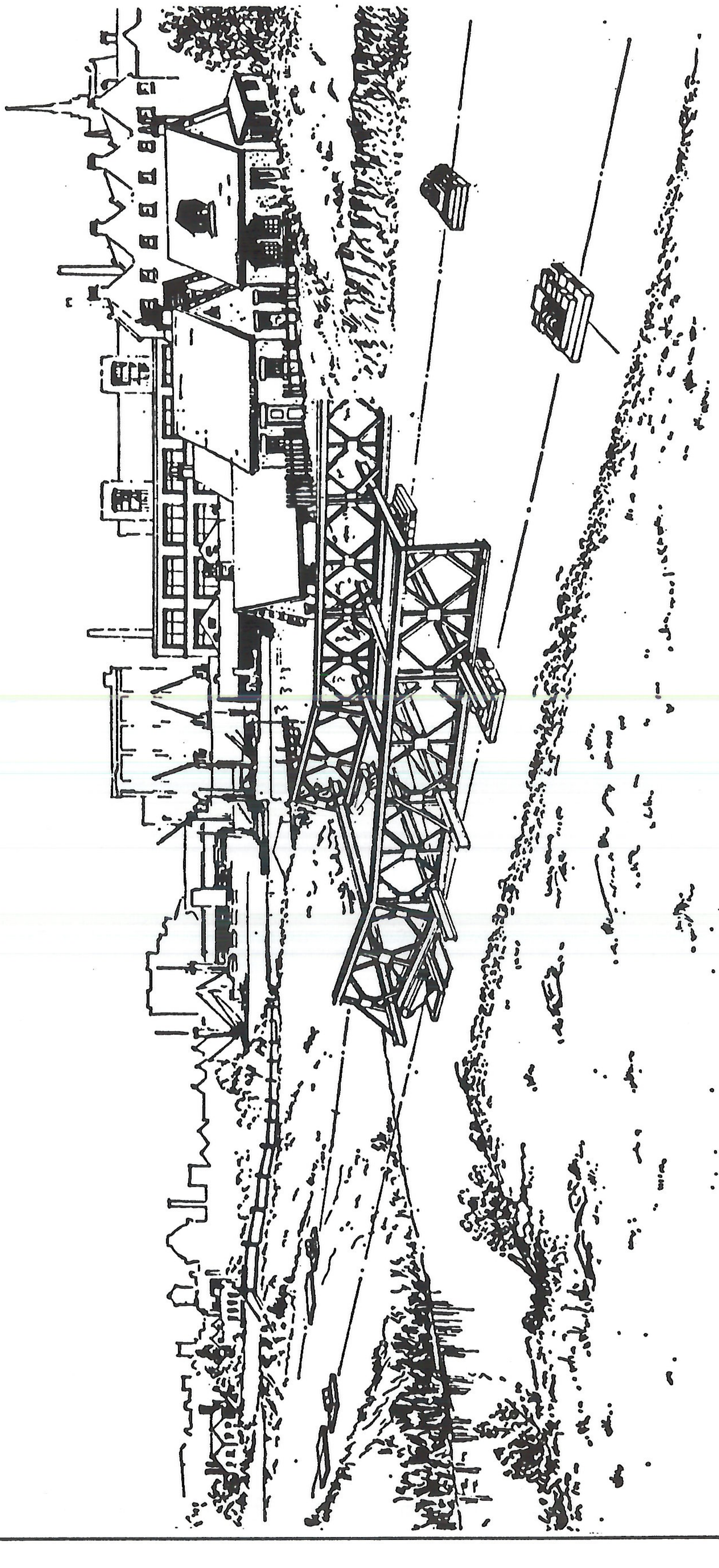
20) Pin on two more panels to form Bay 3 of nose and fit transom and raker as in Bay 1.

21) Insert and tighten *swaybrace* in Bay 2.

22) Pin on two more panels to form Bay 4 and fit transom (but no rakers). Swaybraces to this bay must not be fitted and tightened until next bay (either of bridge or nose) has been constructed.


BB
15
SWAYBRACE FITTED IN
THIS BAY AFTER NEXT
BAY IS CONSTRUCTED


BB 15
BB 3
TEMP. PACKS REMOVED

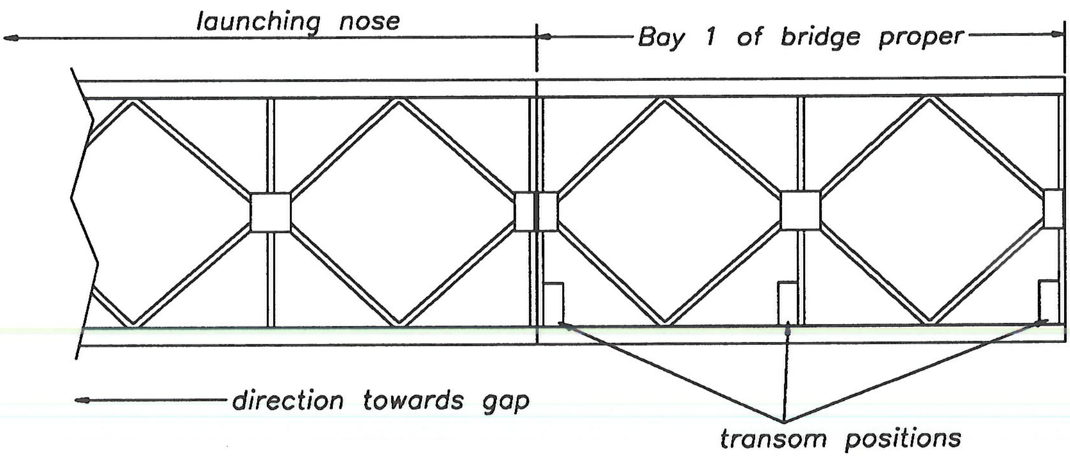


Assembly of Bridge Proper

1) For Bay 1:

   a) Pin two panels to rear of launching nose.

   b) Fit three transoms as shown below and secure with transom clamps.



   c) Fit rakers to the front and rear transoms.

   d) Tighten raker bracing bolts.

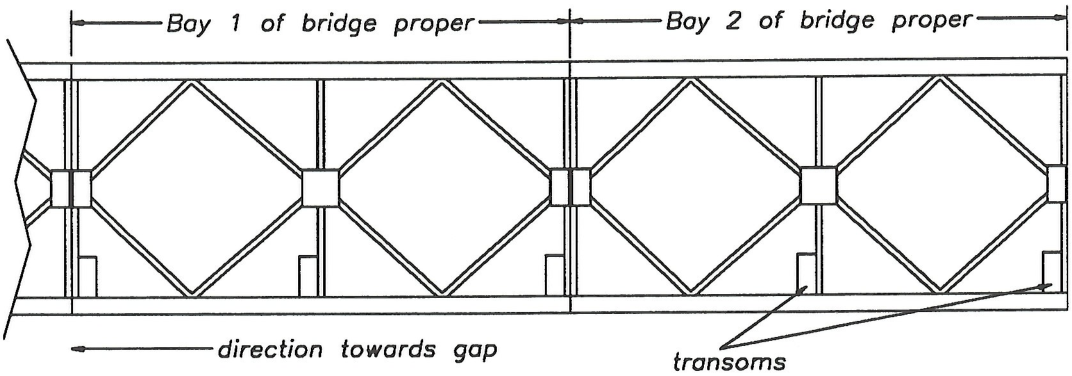
   e) Fit two swaybraces, long arms towards the gap and tighten.

   f) Do not attempt to fit decking in this bay.

2) For Bay 2:

   a) Pin on two more panels.

   b) Fit two transoms as shown below and secure with transom clamps.



c) Fit rakers to the rear transom and tighten bolts.

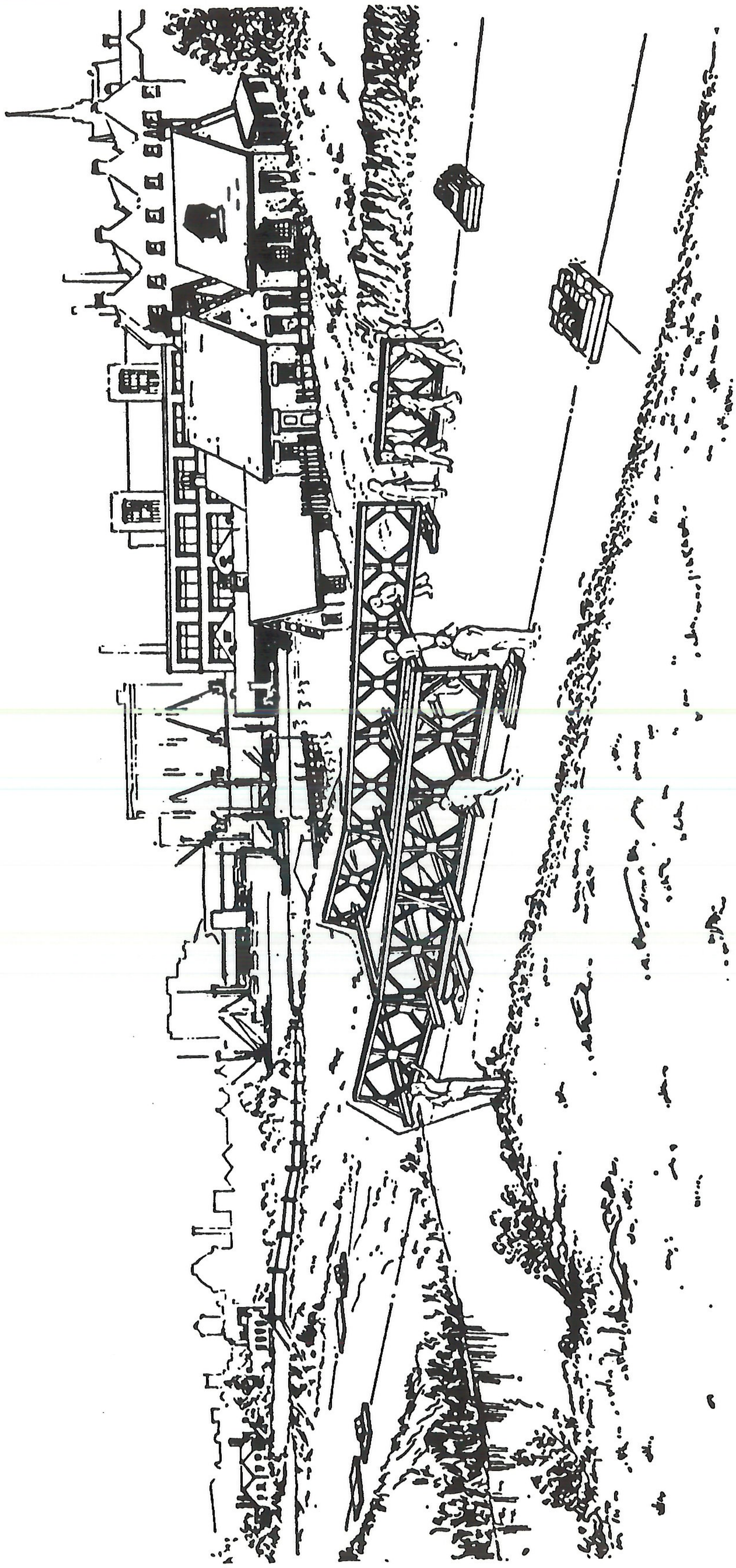
d) Fit swaybraces and tighten. Never tighten swaybraces until rakers are fitted and tightened.

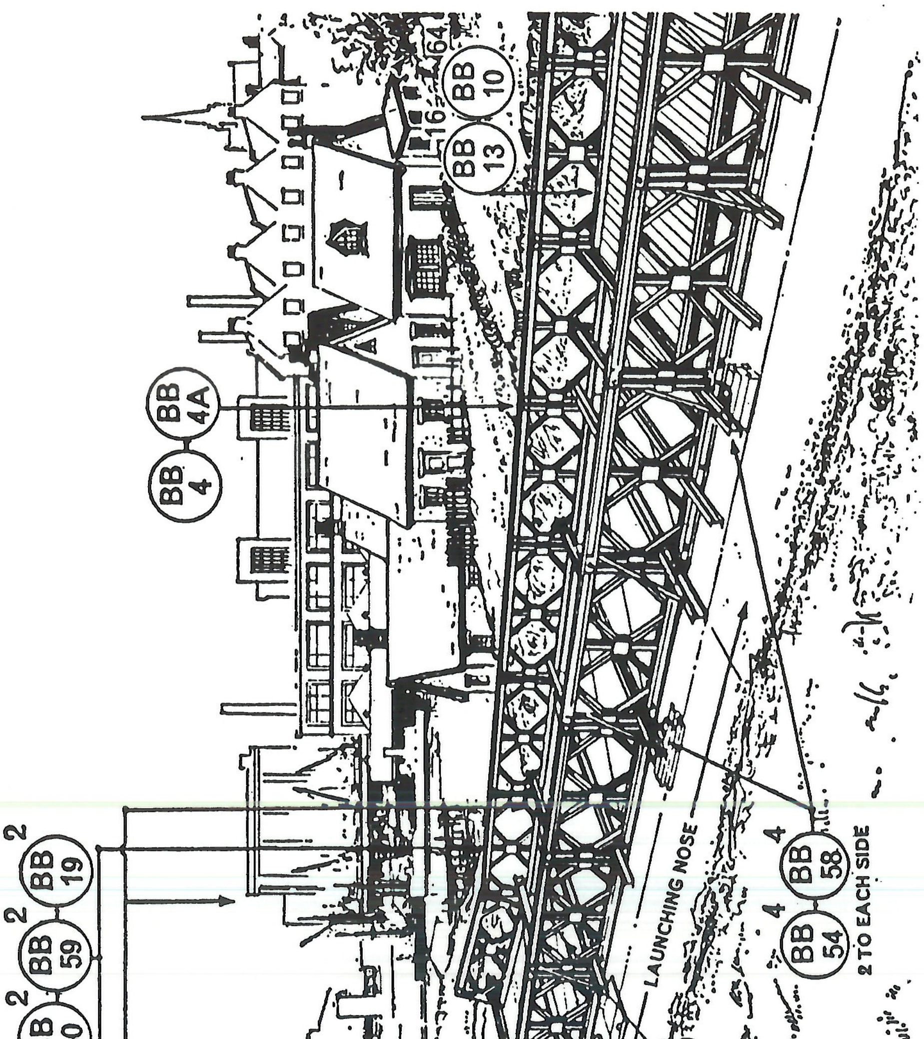
3) For Bay 3 and all subsequent bays, repeat construction as described for Bay 2 until the bridge is the required length.

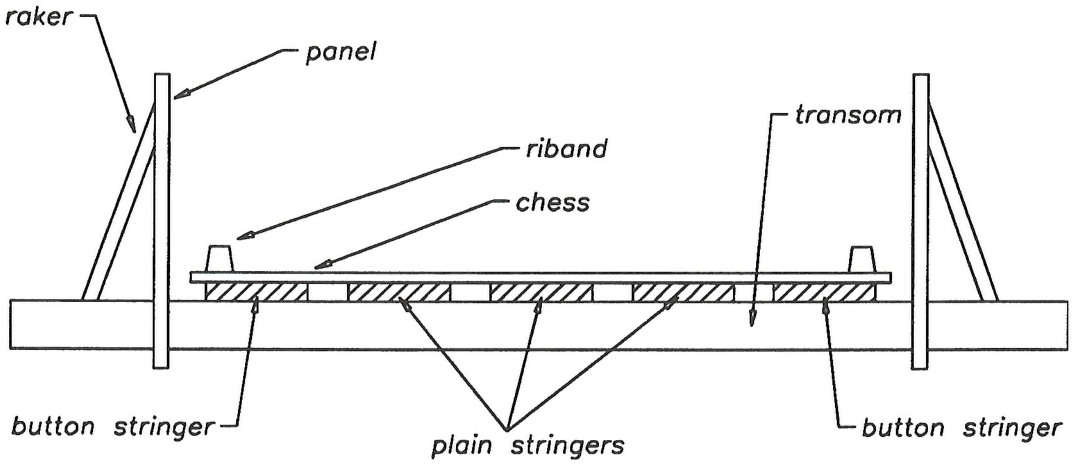
4) Lay five *stringers* along the length of each bay. The outermost stringers should be of the 'button' type and the three innermost should be of the 'plain' type.

5) Lay thirteen *chesses* (decking planks) across the stringers for each bay.

6) Place a *riband* along each side of the bay over the ends of the chesses and secure using *riband bolts.*




LAUNCHING NOSE
MARK II
2 TO EACH SIDE
DECKING
TIMBER CHESS
TIMBER RIBAND
PLAIN STRINGER
BUTTON STRINGER
TSBB 573



Launching the Bridge

1) The bridge may now be launched (by pushing) with the aid of the rollers to the far side of the gap.

2) As soon as the tail end has passed the construction rollers, pin *female end posts* to the end of each truss.

3) Continue launching until the bearings under the end posts are directly above the bridge bearings, upon which they are to seat.

4) Insert temporary packing under the last panel at either side of the bridge.

5) Place *jack shoe* on the *baseplates* so that they straddle the *bearings*.

6) Stand *ratchet jacks* on the jack shoes, so that the toes of the jacks engage under the transom brackets of the end posts.

7) Jack up the end of the bridge until the launching rollers may be removed.

8) Jack down the end of the bridge and remove temporary packing until the end posts are properly seated on the bearings.

9) Dismantle the launching nose on the far bank and loosen swaybraces in Bay 1 of the bridge.

10) Pin *male end posts* to the end of each truss.

11) Open the swinging gates on the end posts and maintain them in the open position with the chained pin provided.

12) Remove the transom and rakers from the female end of Bay 1 of the bridge.

13) Refit this transom across the end posts and lock into position by closing the swinging gates and fitting the chained pins.

14) Refit and tighten rakers on transom and end posts.

15) Retighten swaybraces in Bay 1 of the bridge.

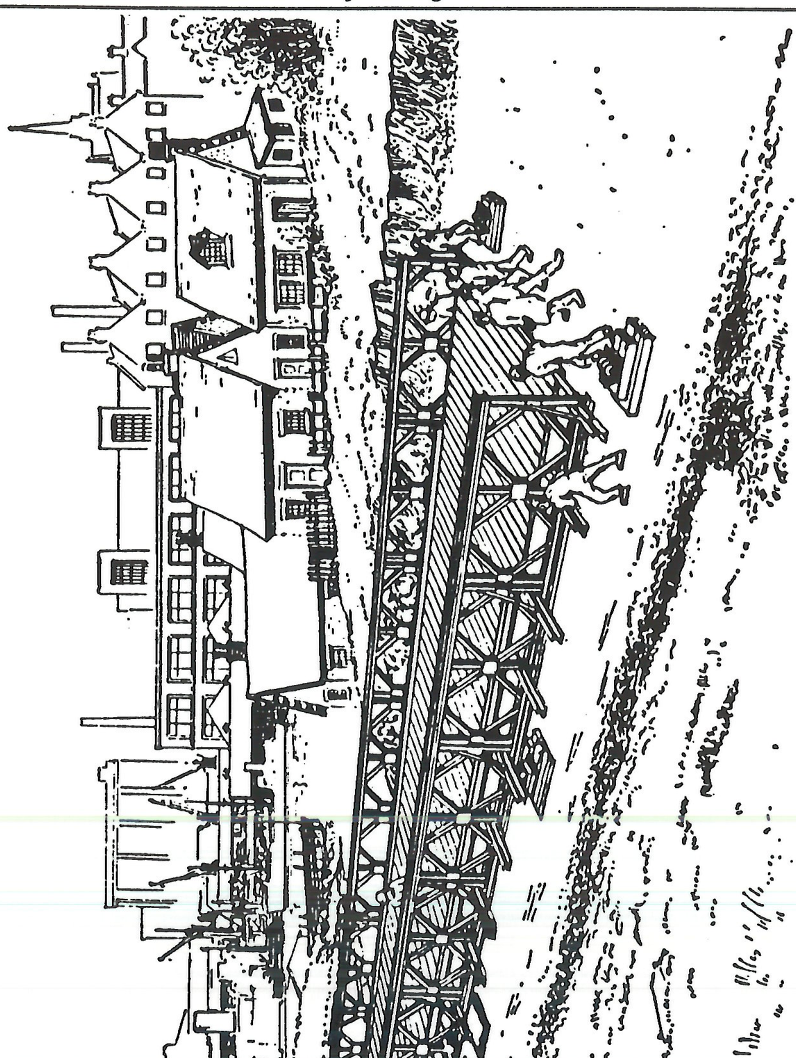
16) Repeat jacking process on this end of the bridge and lower the bridge onto its bearings.

17) Decking may now be laid in Bay 1 of the bridge.

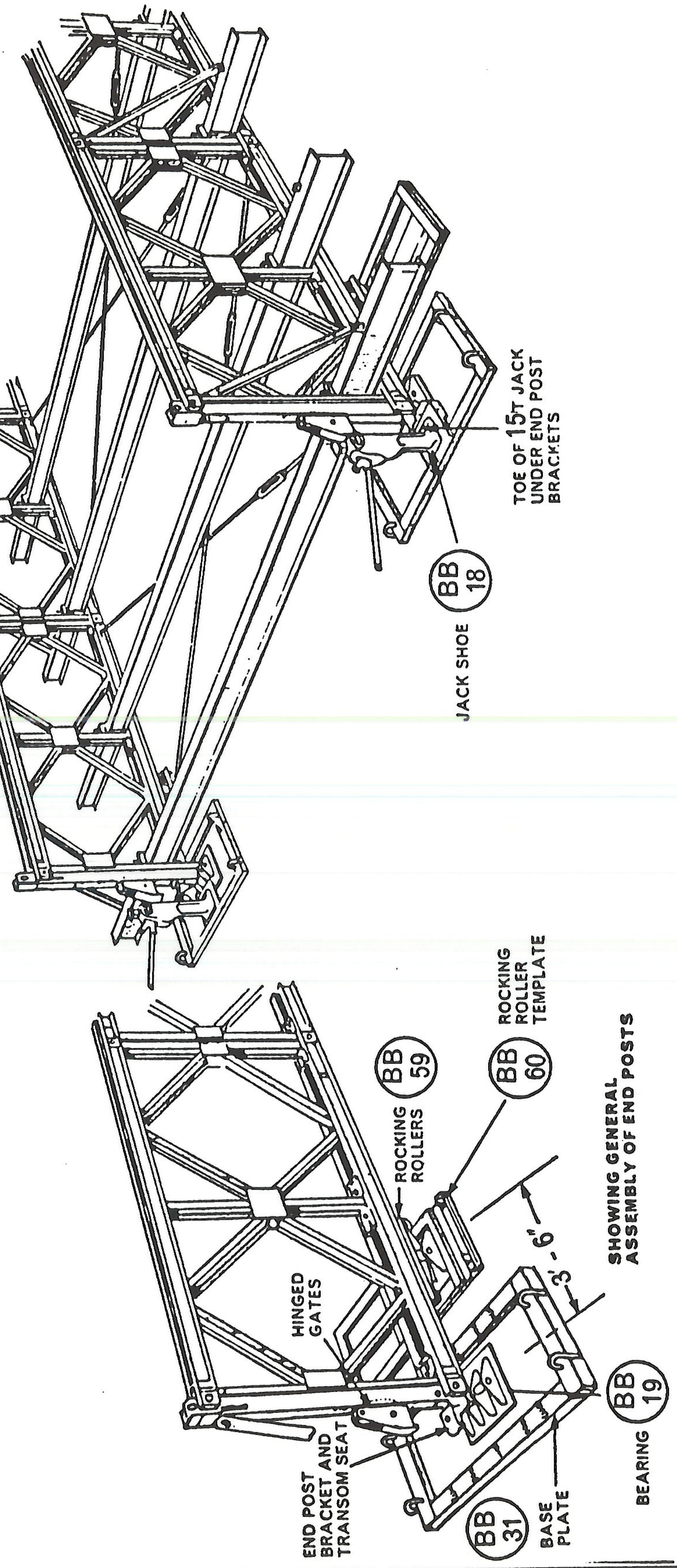
18) Check that every pin and bolt has been correctly placed and tightened.

19) Approach ramps can now be fitted.

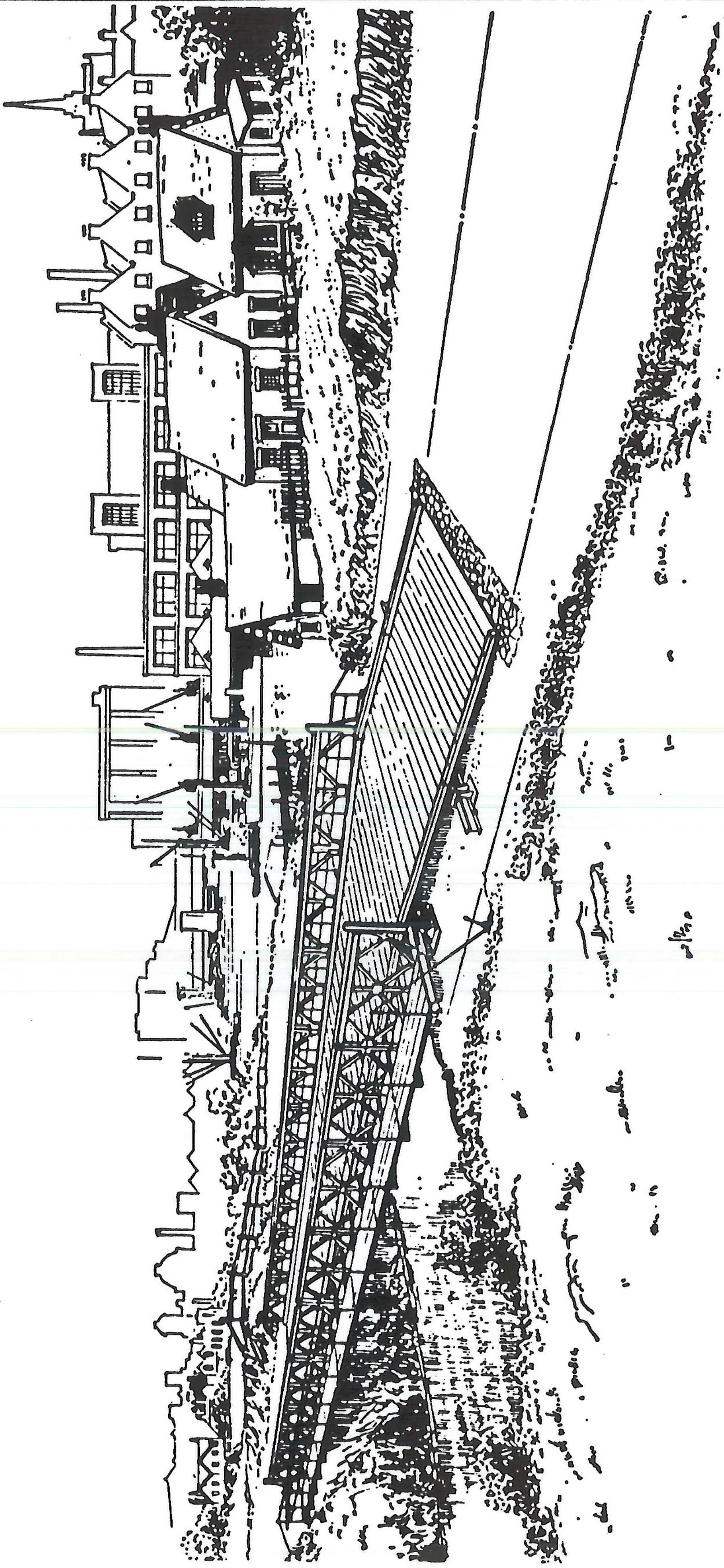
20) Footwalks can be fitted as an option.


LAUNCHING NOSE

NOTE: DURING ASSEMBLY OF BRIDGE AT NO TIME SHOULD BOTH ENDS OF BRIDGE BE SUPPORTED ON "LIFTING JACKS". NO LIFTING MUST TAKE PLACE FROM UNDER TRANSOMS OTHER THAN AT END POST BRACKET POSITIONS.



SHOWING GENERAL ASSEMBLY OF END POSTS



ASSEMBLY OF DOUBLE-SINGLE BRIDGE

Nose: Construct as before.

Bridge Proper

1) On completion of the nose, the first two panels of the inner trusses are connected with the last bay of the nose.

2) Feed a transom through in front of the centre upright of the panel.

3) Add the first panel of the second truss by lifting it over the centre transom and holding it in position with the transom clamps. At the same time fix the eye of the long arm of the swaybrace to the front connecting positions on each panel.

4) Feed the second transom through in front of the rear vertical and a third transom behind the front vertical. A raker is positioned on the second transom and the short arm of the swaybrace is fixed to the rear connecting position of the panel. In the meantime, the *bracing frame* has been hoisted into place and is fixed.

5) Put on the outer and inner panels of the next bay.

6) Fit long arm of swaybrace in front recess of panels of Bay 2. Position the outer panels of Bay 3, and at the same time fit the first transom in front of the rear upright of Bay 2.

7) As soon as the transom is fitted in Bay 2, the raker is put in position between it and the panel.

8) Position the inner panels of Bay 3 and connect long arm of swaybrace in front recesses.

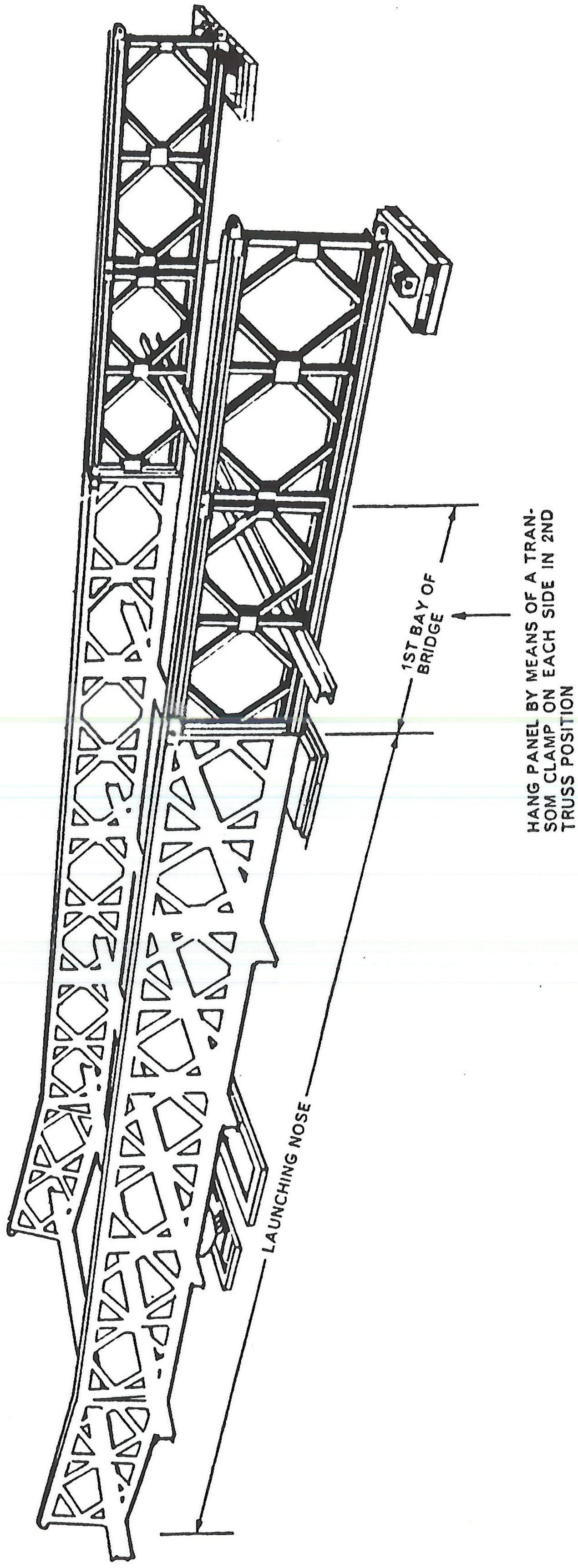
9) Position the bracing frames of Bay 2 and fix short arm of swaybrace in rear recess.

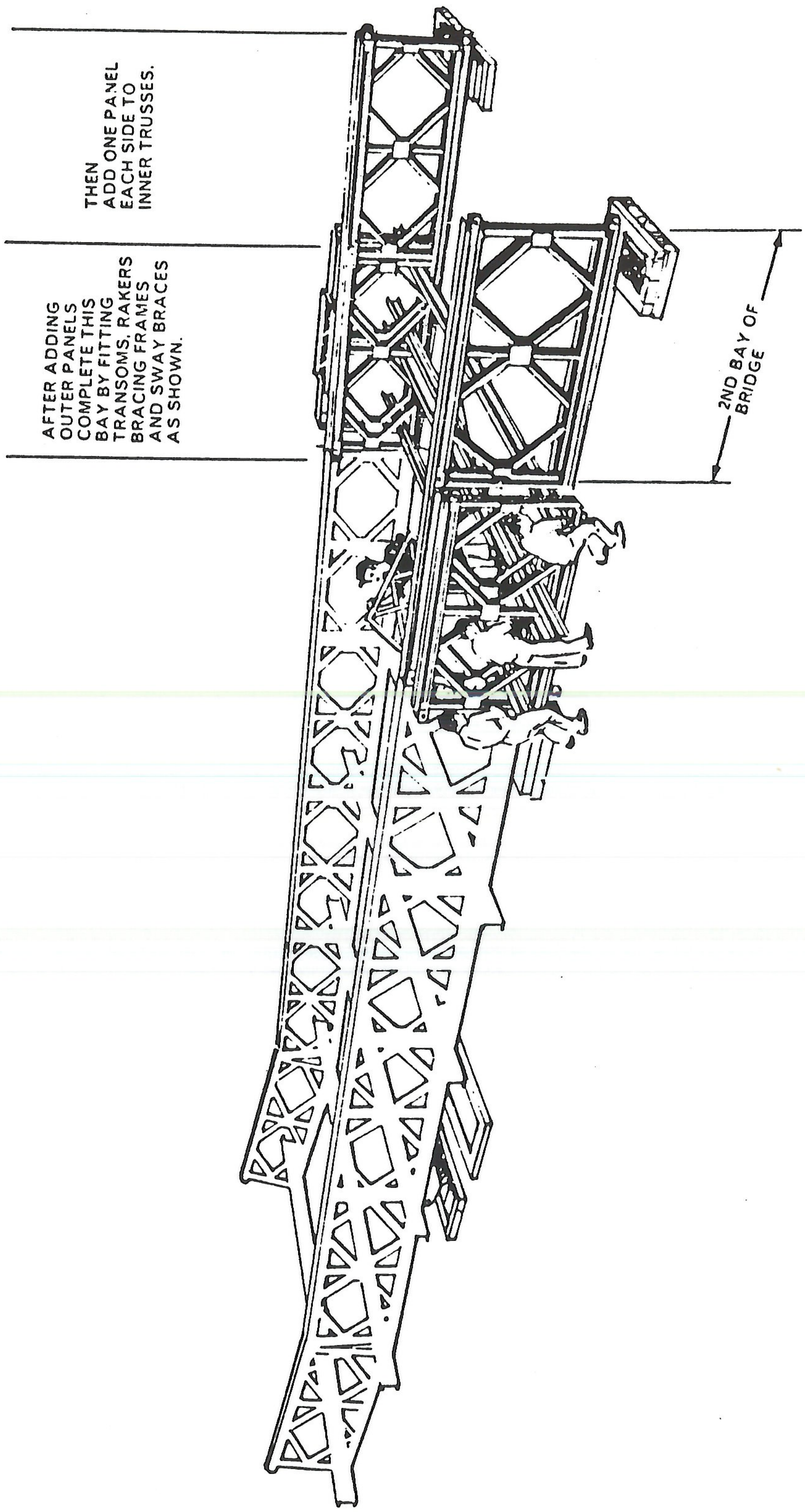
10) Position the centre transom of Bay 2, fastening the clamps loosely.

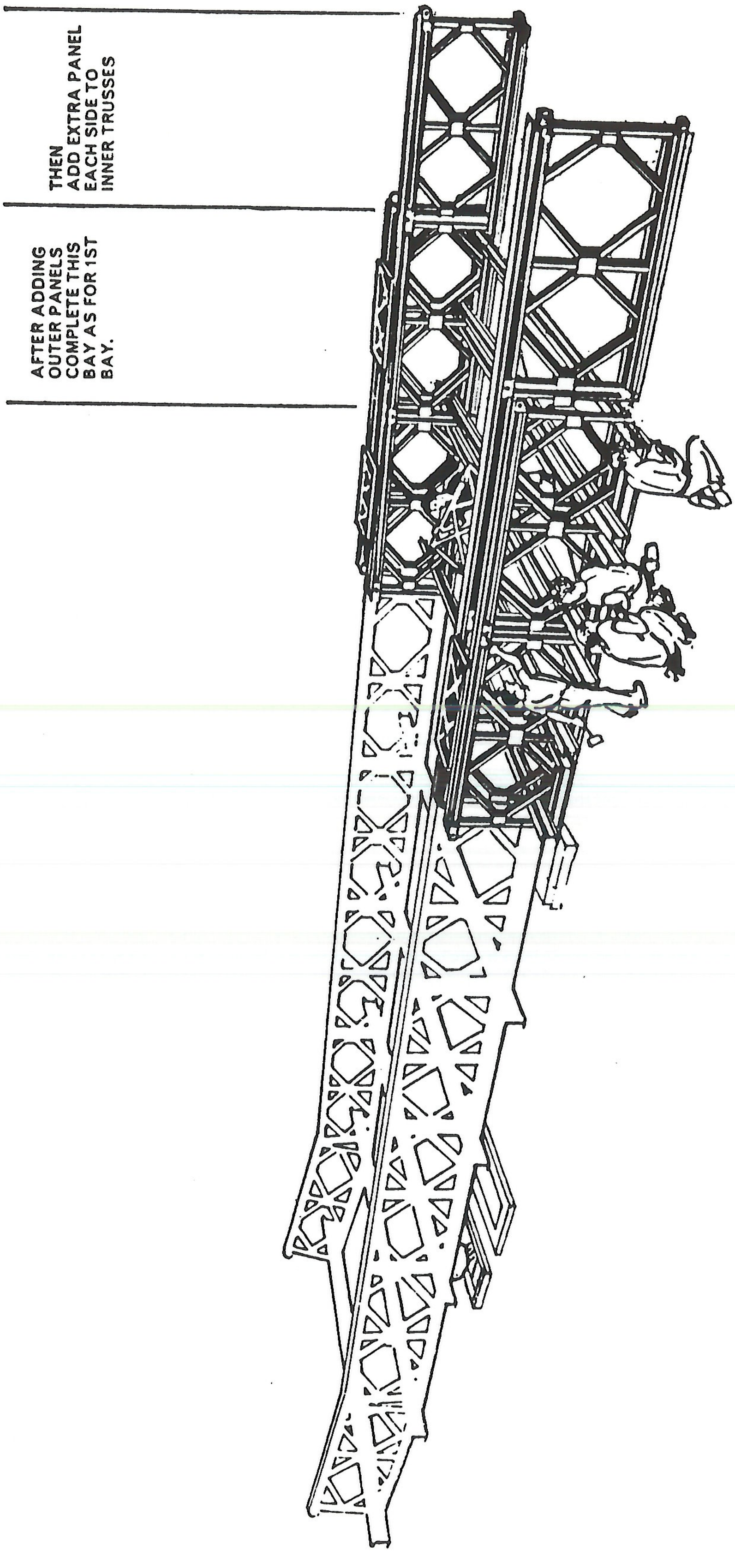
11) Tighten up the swaybrace of Bay 2.

12) Tighten transom clamps.

13) Lay stringers and decking as described before.


1ST BAY OF
BRIDGE
HANG PANEL BY MEANS OF A TRAN-
SOM CLAMP ON EACH SIDE IN 2ND
TRUSS POSITION
LAUNCHING NOSE


THEN
ADD ONE PANEL
EACH SIDE TO
INNER TRUSSES.
AFTER ADDING
OUTER PANELS
COMPLETE THIS
BAY BY FITTING
TRANSOMS, RAKERS
BRACING FRAMES
AND SWAY BRACES
AS SHOWN.
2ND BAY OF
BRIDGE


THEN
ADD EXTRA PANEL
EACH SIDE TO
INNER TRUSSES
AFTER ADDING
OUTER PANELS
COMPLETE THIS
BAY AS FOR 1ST
BAY.

ASSEMBLY OF TRIPLE-SINGLE BRIDGE

Nose: Construct as for double-single bridge.

Bridge Proper

1) Bring up and connect the first two panels of the inner trusses to the launching nose.
2) Place a transom through these panels in front of the centre vertical and connect the long arm of the swaybrace to the front end of the inner panels.
3) Bring up two panels for the second truss and connect them with the centre transom with transom clamps.
4) Position the panels of the second truss in bay 2.
5) Add the first two panels of the third truss in Bay 1, attaching them by the clamps to the centre transom.
6) Pass a second transom through all three trusses of Bay 1 in front of the rear upright, and position the raker on each side of bridge to the rear vertical. Position a third transom behind the front verticals.
7) Connect the short arm of the swaybrace with the rear position, and fix the bracing frame in Bay 1.
8) Position the *tie plates* in the top raker hole of the front upright of the second and third trusses of Bay 1.

9) Tighten transom clamps and swaybrace.

10) Position panels for the inner truss of Bay 2 and connect swaybrace to front recesses.

11) Position panels for the second truss of Bay 3.

12) Position panels for the third truss of Bay 2.

13) Place transoms in front of rear and centre uprights of Bay 2.

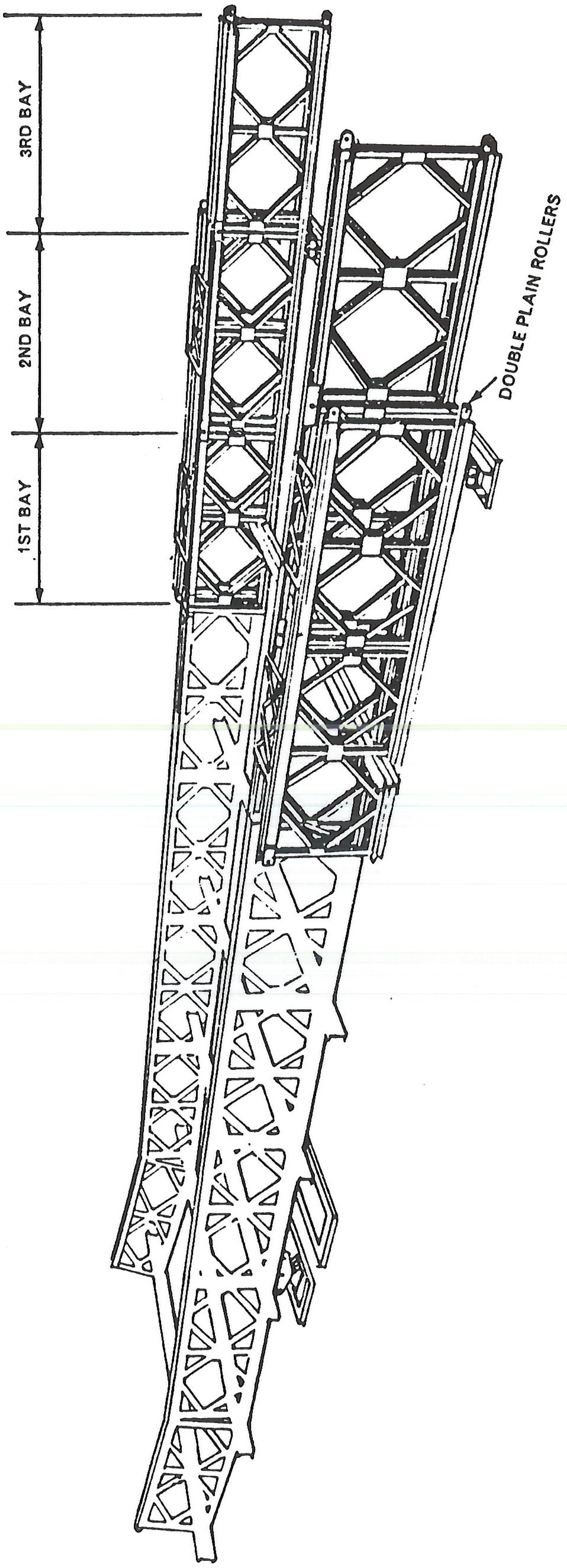
14) Position the raker to the rear transom of Bay 2.

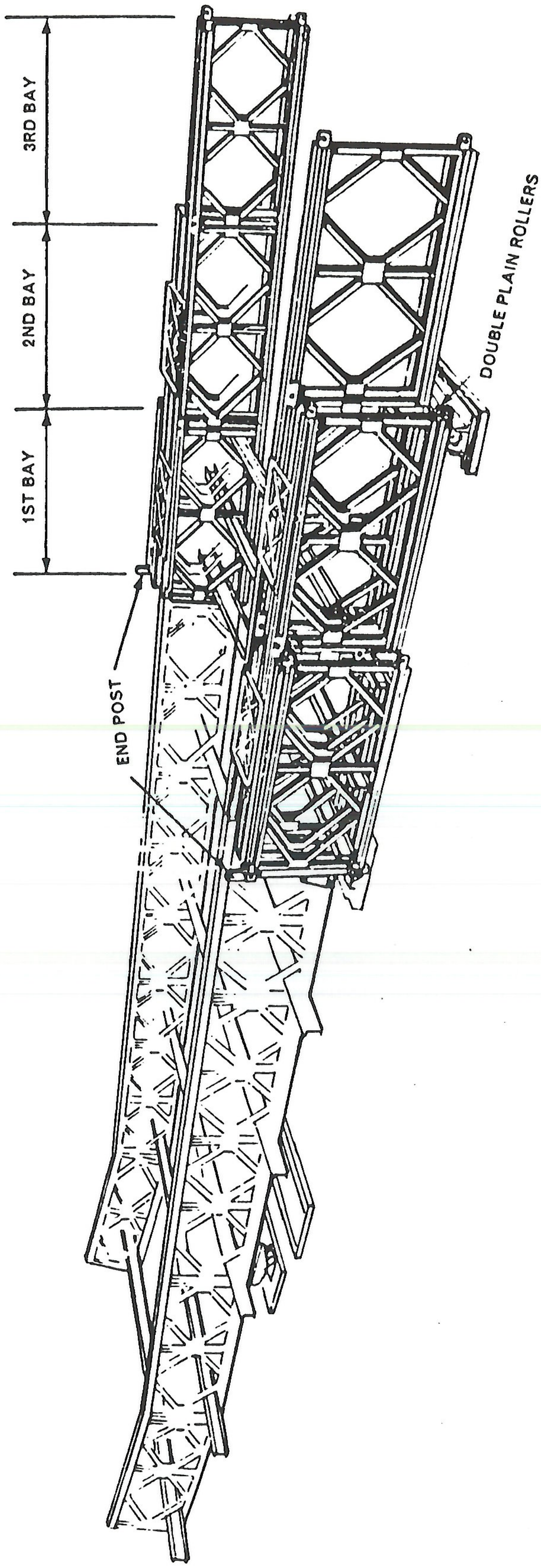
15) Connect swaybrace, bracing frames and tie plates of Bay 2.

16) Tighten transom clamps and swaybraces.

17) Continue process until required number of bays is met.

18) Lay stringers and decking.


3RD BAY
2ND BAY
1ST BAY
DOUBLE PLAIN ROLLERS


3RD BAY
2ND BAY
1ST BAY
END POST
DOUBLE PLAIN ROLLERS

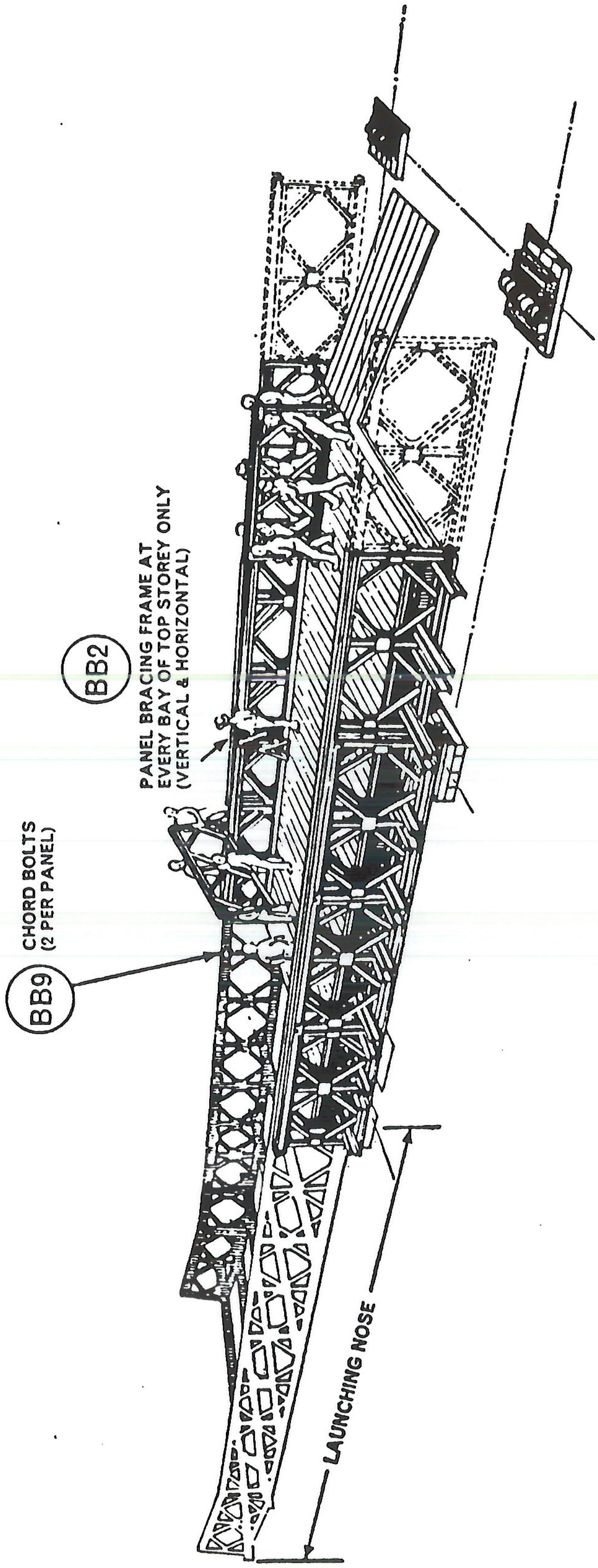
DOUBLE-STOREY BRIDGES

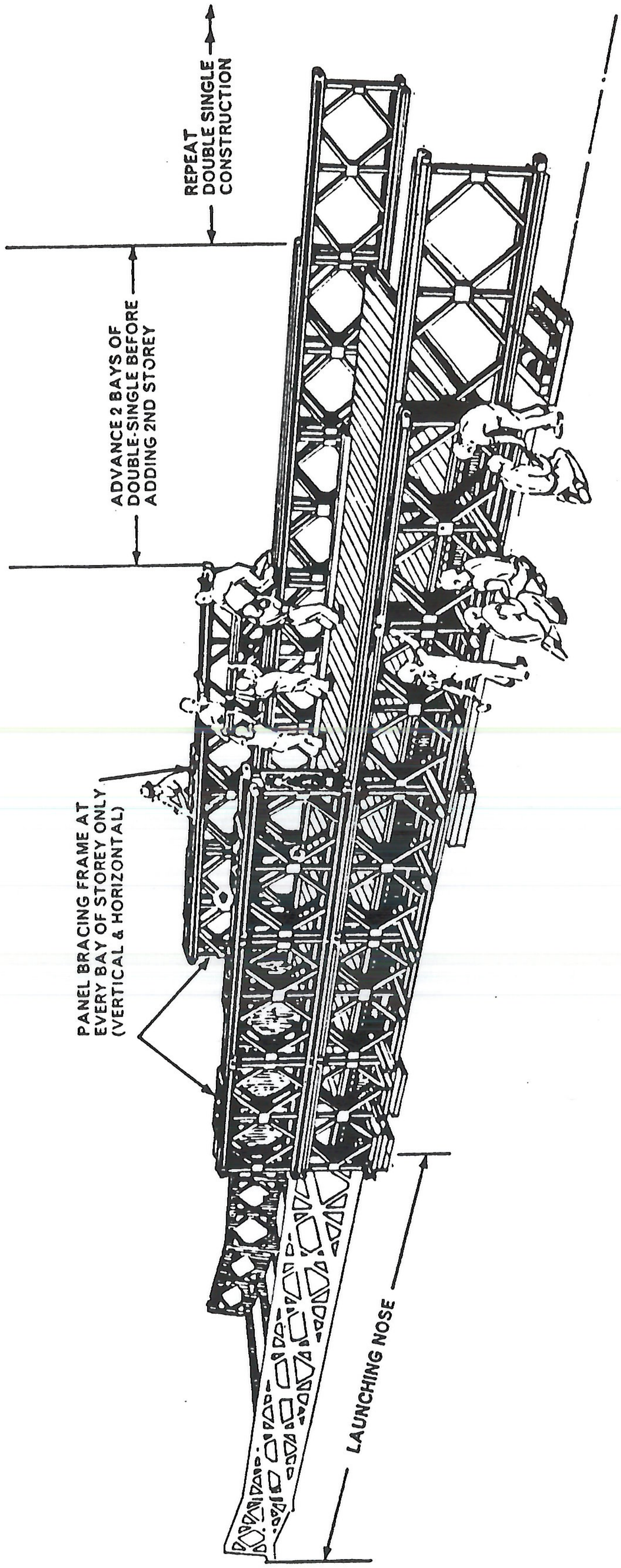
Double storey construction is used in preference to single-storey construction for longer and more permanent bridges.

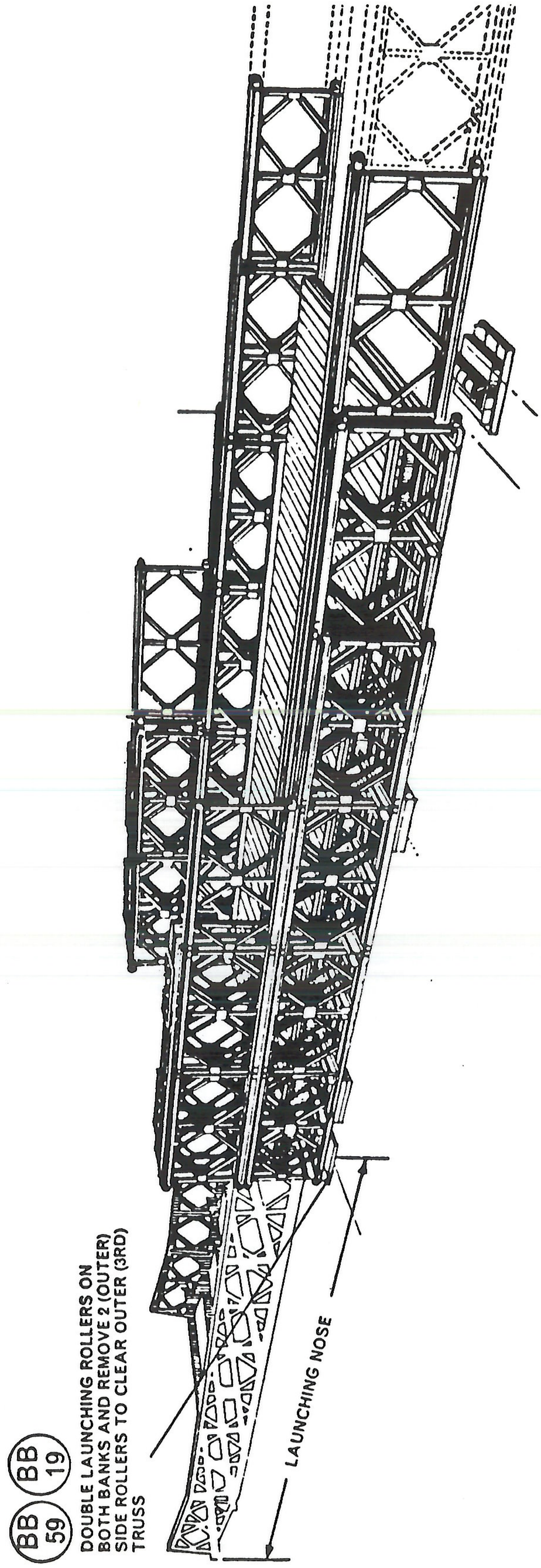
The method of launching with skeleton launching nose and rollers remains the same. However, the principle here to be observed is to keep the bridge back on the construction rollers as far as possible and to launch after construction is complete rather than to feed the bridge forward a few bays at a time as with single-storey construction. There may be sites where this approach may not be possible and it may be necessary to resort back to the technique used in single-storey construction which, in this case, will present certain attendant difficulties. It may be necessary to add a second storey to an existing single-storey bridge *in situ*.

The bottom storey of these bridges is exactly the same as in single-storey construction except that no bracing is put on the top chord. Extra rollers must be placed at the tail of the bridge to reduce the effects of sag which produces hogging near the launching roller position.

It is normal to place panels in the second storey by manpower alone. However, the use of a small mobile crane is advantageous.


BB2
PANEL BRACING FRAME AT
EVERY BAY OF TOP STOREY ONLY
(VERTICAL & HORIZONTAL)
BB9
CHORD BOLTS
(2 PER PANEL)
LAUNCHING NOSE


REPEAT
DOUBLE SINGLE
CONSTRUCTION
ADVANCE 2 BAYS OF
DOUBLE-SINGLE BEFORE
ADDING 2ND STOREY
PANEL BRACING FRAME AT
EVERY BAY OF STOREY ONLY
(VERTICAL & HORIZONTAL)
LAUNCHING NOSE


BB 59
BB 19
DOUBLE LAUNCHING ROLLERS ON BOTH BANKS AND REMOVE 2 (OUTER) SIDE ROLLERS TO CLEAR OUTER (3RD) TRUSS
LAUNCHING NOSE

TRIPLE-STOREY BRIDGES

Triple-storey bridges are normally launched as double-storey bridges and the third storey added after the bridge has been jacked down onto its bearings. Bracing frames must be fitted temporarily to the top chords of the double-storey bridge during launching and removed bay by bay as the third storey panels are added.

Panels must be added to the third storey commencing at the centre of the bridge and working outwards towards both ends of the bridge simultaneously. Care must be taken to ensure that work on the girders on both sides of the bridge is kept in step. Since the double-storey bridge may not usually be strong enough to carry a mobile crane, panels can be manhandled up into position. Considerable assistance can be obtained by erecting a temporary staging by fitting two or three transoms in the second storey with chesses across them. Panels can then be lifted from the bridge deck to the top storey in two stages. When construction of the third storey is completed, the *overhead bracing* may be added starting at the centre and working outwards to arrive at both ends of the bridge simultaneously. Where a mobile crane is available this may be used to place the overhead bracing in position, the bridge girders having now attained their full strength.

BAILEY PONTOON BRIDGES

The Bailey pontoon bridge is a straightforward development of the fixed span bridge. It consists of a series of short Bailey spans supported on floating pontoon piers with approach spans from the banks at each end. The three main parts of the bridge consist of:

- floating bays
- end floating bays
- landing bays

Normally bridges will be formed of two landing bays, two end floating bays, and any number of floating bays as required to fill the remainder of the wet gap. The superstructure and roadway of the floating bays are formed of exactly the same components as fixed span bridges and may be of single-single or double-single construction according to the load class of the bridge. The landing bays, or approach spans, are normal fixed spans resting on baseplates and bearings at the shore end and on the landing bay transom at the floating end. They may be of any form of construction up to triple-double, according to the span and the load class required. Connection between the different portions of the bridge is made by means of special posts which are attached to the superstructure of the bridge. These are connected together by a pin joint at the bottom only, so that a limited amount of articulation is possible. Tidal and flood conditions introduce certain complications as the length of the bridge varies with the rise and fall of the tide.

To construct a Bailey pontoon bridge, make a thorough reconnaissance of the site including such factors as width of water gap, height of each bank above water level, profile of each bank, tidal information, etc., and select suitable building sites for the different portions of the bridge. Ideally there will be four sites in all: two for the landing bays on the centreline of the bridge, one on each bank; and two for the floating portions, preferably upstream of the centreline on the home bank.

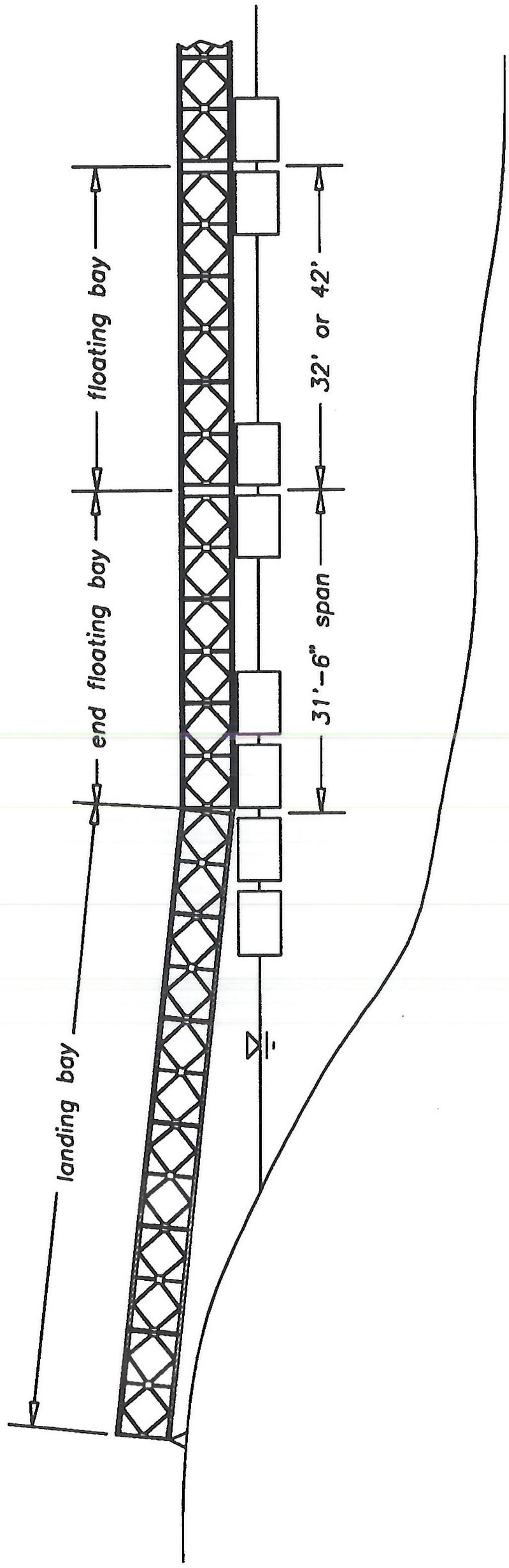
Approaches both to the bridge itself and also to the building sites must be carefully considered from the point of view of time and material. It must be remembered that up to 20 or more vehicles may have to be brought to each construction site.

Work is started on baseplate and roller grillages on each bank at the earliest opportunity, the stores for the far bank being ferried over on a pontoon pier. Construction of floating and end floating bays begins as soon as possible and of the landing bays as soon as the roller positions are prepared. Stores for the construction of the far landing bay should be ferried over by the first available floating bay.

To form the bridge, the two end floating bays are floated down to the centreline of the bridge so that both landing bays can be launched and connected with the landing bay transoms. The home landing bay is then boomed out and jacked down on to its bearings so that the end of the bridge is fixed. Enough floating bays are then connected with each end floating bay to fill the remainder of the gap. Finally, the far side landing bay is boomed out, so that connection is made between the centre floating bays. Bearings and baseplates on the far bank are then adjusted to take up any small inaccuracy in the original setting out and the shore end of the landing bay is jacked down. Ramps are positioned at each end of the bridge.

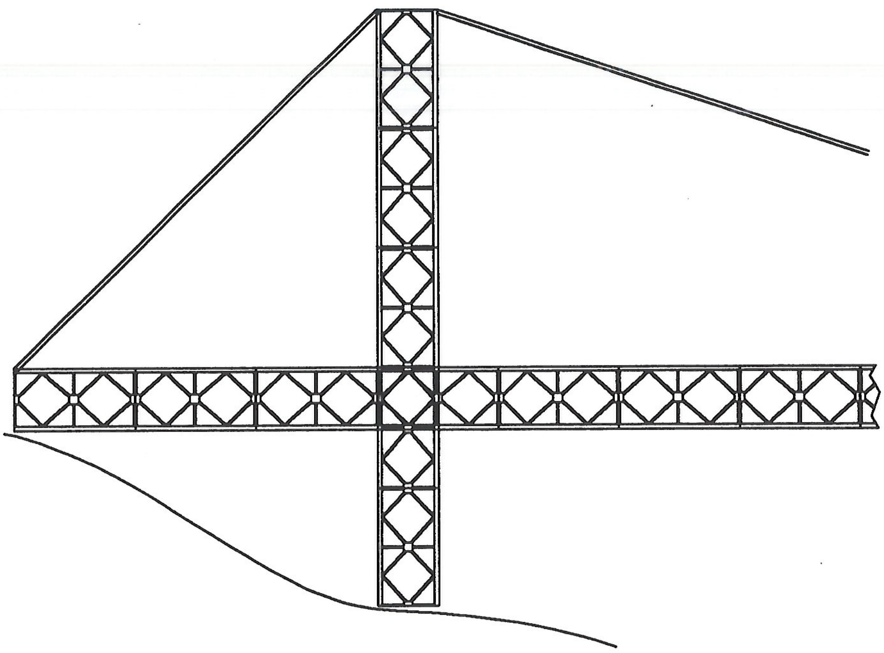
The floating portion of the bridge is anchored with pontoon anchors and cables. Upstream and downstream anchors should be provided as is usual for floating bridges.

BAILEY FLOATING BRIDGE



BAILEY SUSPENSION BRIDGE

The Bailey suspension bridge was designed in 1943 to carry 12-ton loads at 80-ft. spacing over spans of up to 400 ft. The stiffening girders and supporting towers are constructed from standard Bailey bridge components, with the addition of a few special parts. In spite of the greater degree of preparatory work associated with the building of suspension bridges, especially the construction of anchorages for the main cables, a 400-ft. span bridge could be built in under three days with an untrained labour force of about 120. The stiffening girders carrying the roadway consist of the lightest form of Bailey bridge (single-storey construction) and the weight of the bridge, excluding towers, cables and anchorages, is only 37.3 lb. per sq. ft. of decking.



BAILEY UNDER-STRESSED BRIDGE

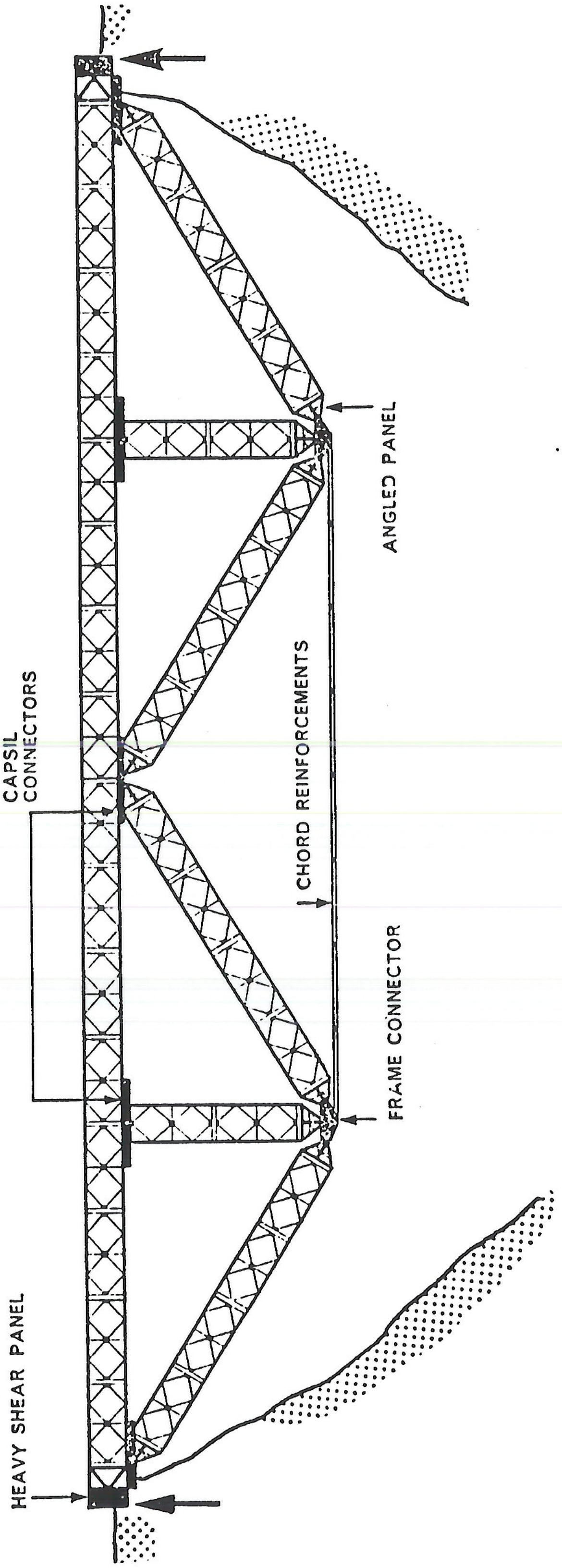
These bridges are constructed from standard Bailey panels formed into deep composite framed girders with heavy shear panels incorporated at the supports. A general arrangement for this type of bridge is illustrated on the next page. Designs for single spans of 330 ft. have been made to carry loads of up to 1,500 tons.

This type of beam construction can be of interest to the civil engineer when considering the problem of heavy support work in the construction of reinforced concrete bridges and other structures.

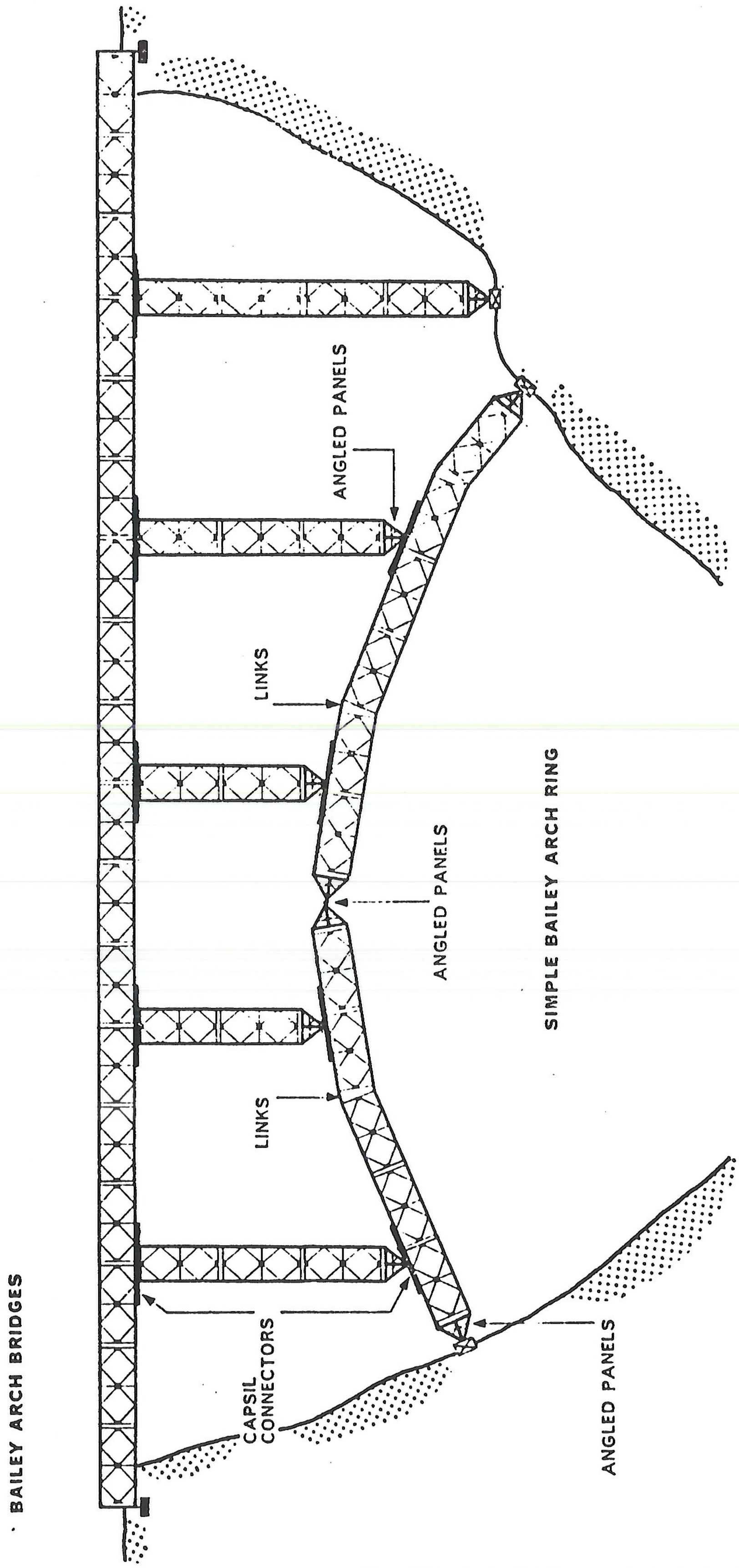
BAILEY ARCH BRIDGE

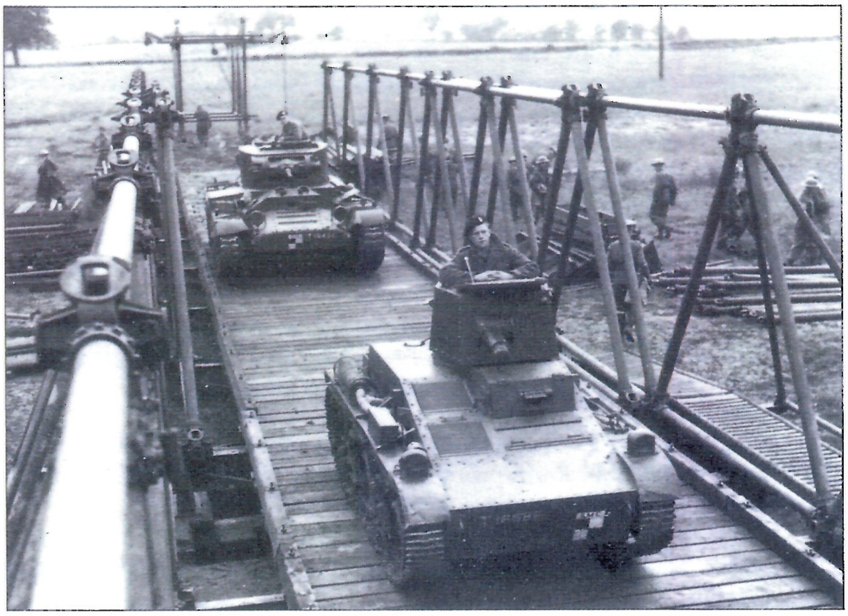
Designs have been prepared for Bailey arch bridges, the arch itself being constructed from standard Bailey components and loaded through Bailey columns, which in turn support a continuous girder bridge in normal Bailey bridge construction.

This type of Bailey arch structure is particularly economical as falsework to reinforce concrete arches and similar constructions. The general arrangement is illustrated on page 98.

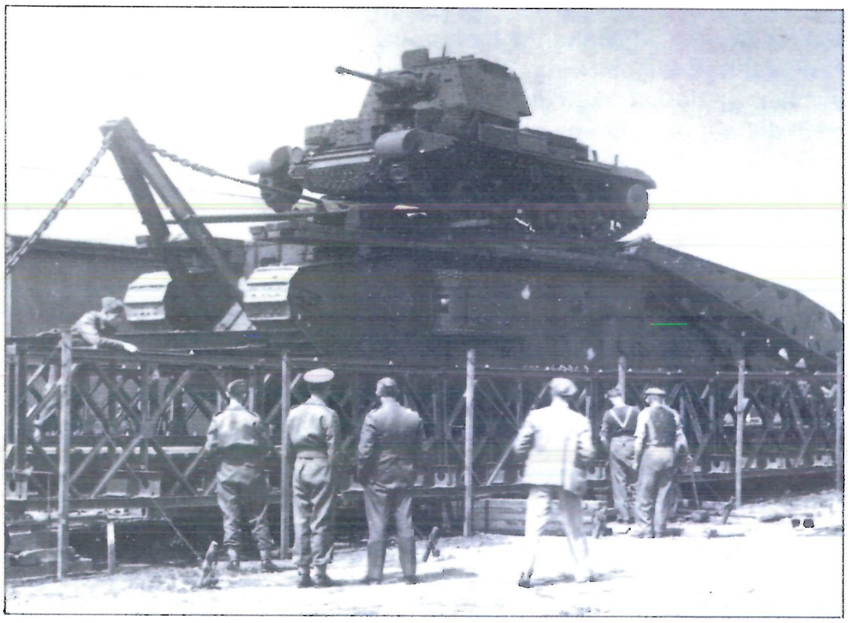


BAILEY FRAME-UNDERSTRESSED BRIDGE

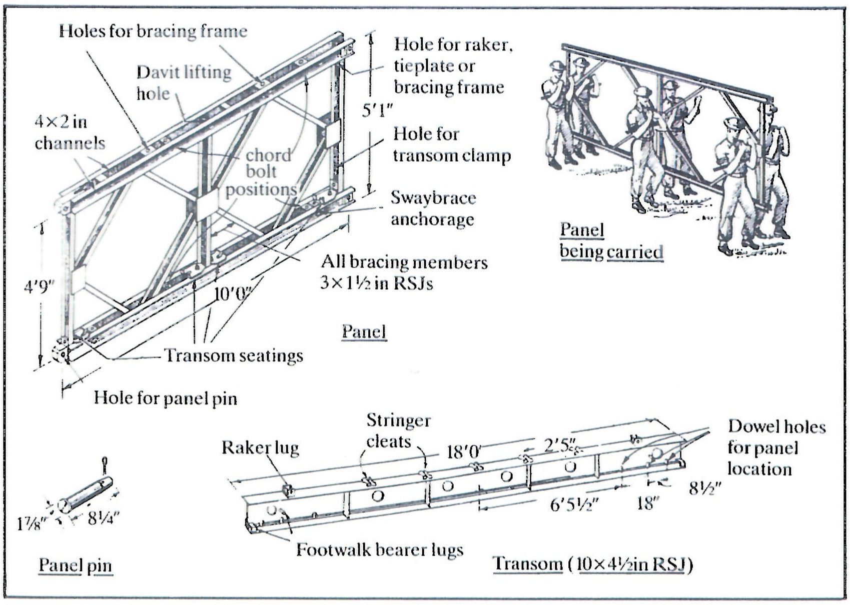

BAILEY ARCH BRIDGES
CAPSIL CONNECTORS
LINKS
ANGLED PANELS
LINKS
ANGLED PANELS
ANGLED PANELS
SIMPLE BAILEY ARCH RING



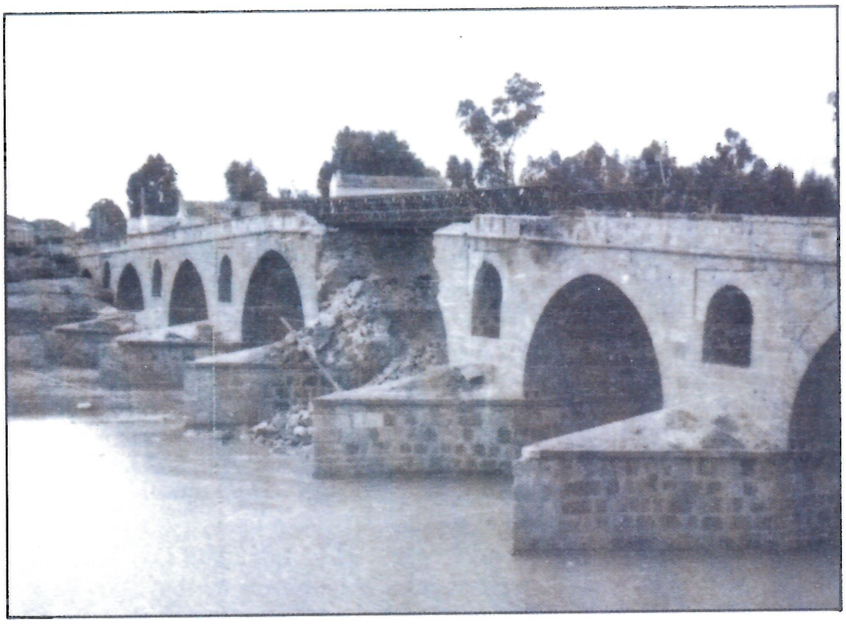
Light tanks crossing a Mark III Inglis bridge; note the knee bracing and the use of additional truss members at mid-span.



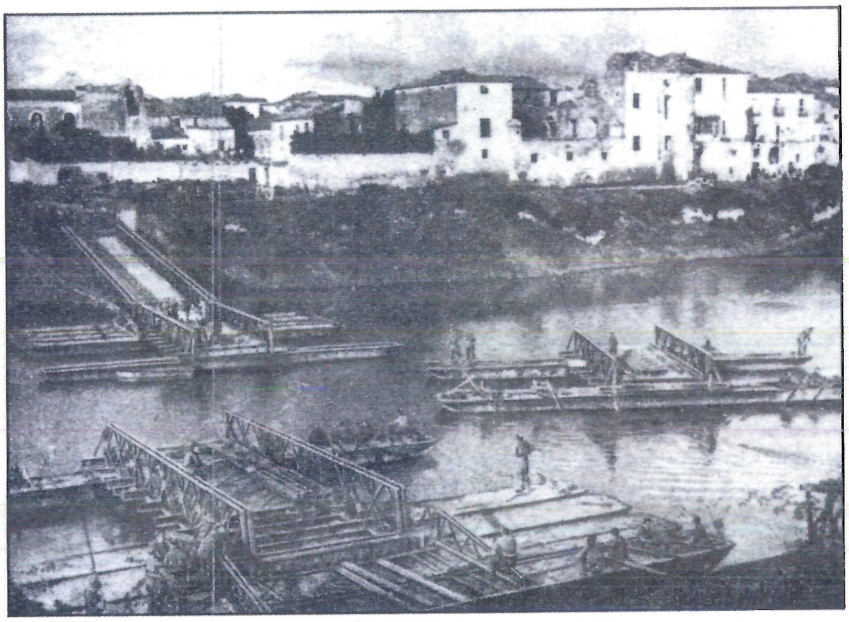
A double/single Bailey Bridge under test load at Christchurch, in early 1941. Donald Bailey is in the foreground in his familiar sports jacket and cap.



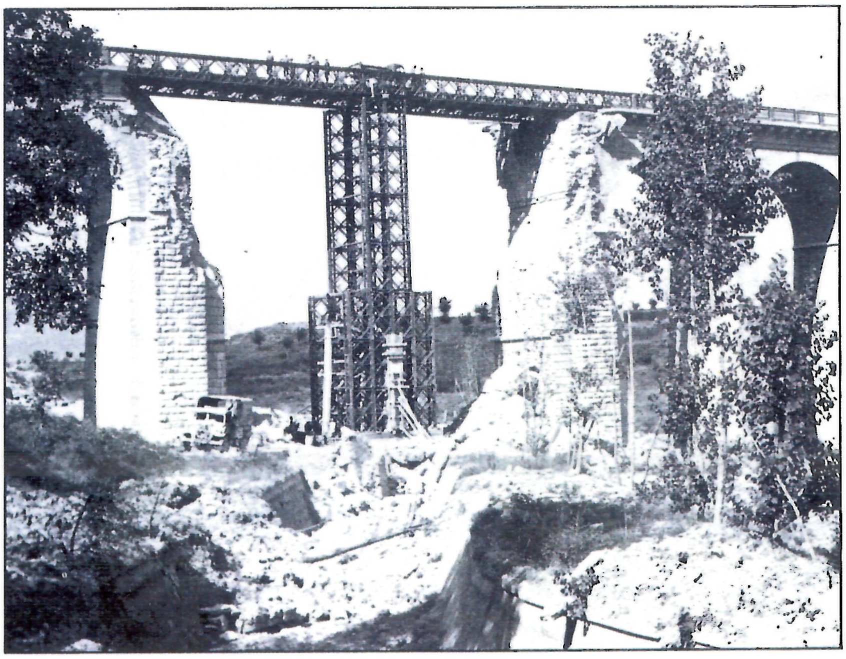
Details of the Bailey panel and transom.



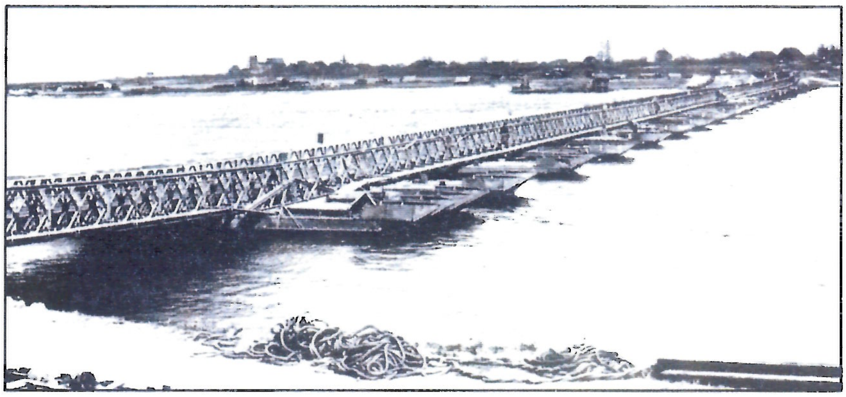
The first ever operational Bailey Bridge, a 100ft triple/single, built across the River Medjerda at Medjez el Bab, Tunisia, during the night of 26 November 1942.



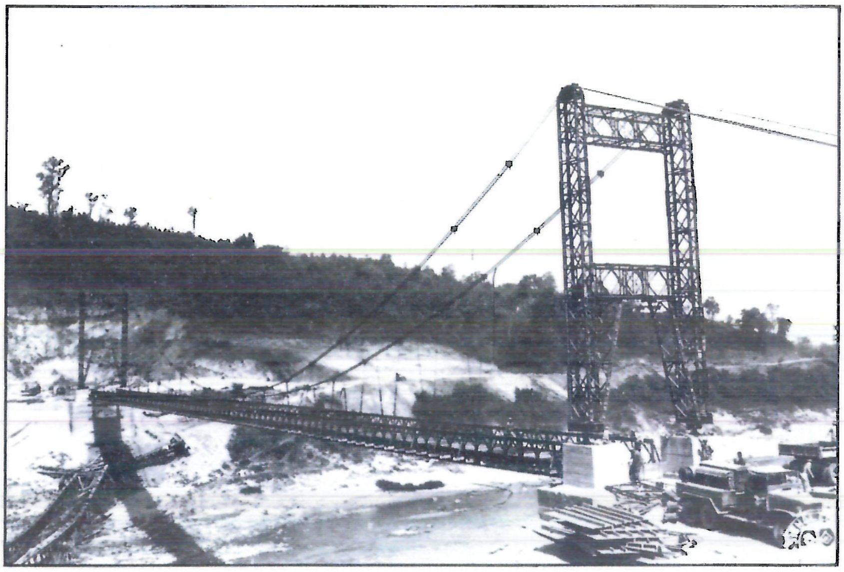
The first Bailey Pontoon Bridge built in action, crossing the River Volturno at Capua, Italy, in October 1943.



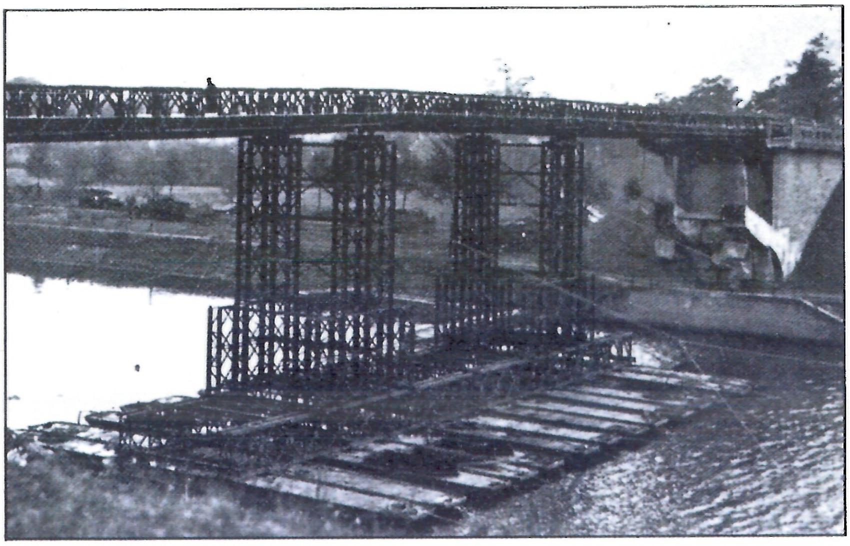
A high level Bailey built in Northern Italy by South African Engineers; the bridge was 390ft long, with an actual span of 200ft and a 70ft high pier.



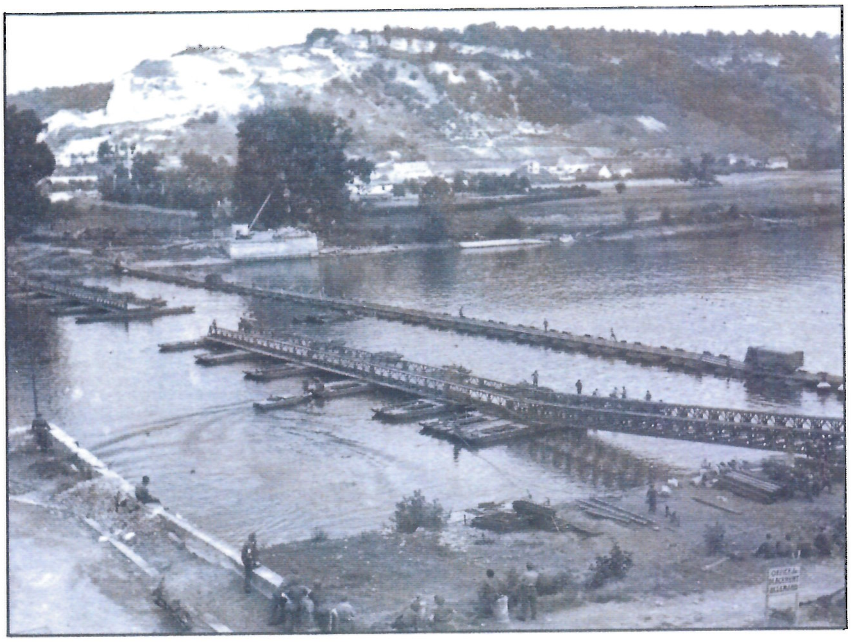
Digger Bridge, built across the Rhine at Xanten, Germany, was nearly 1200ft long and was built by 7 Army Troops Engineers on 24–25 March 1945.



A 440ft Bailey Suspension Bridge, built across the Shweli River, Burma, by American troops in early 1945.

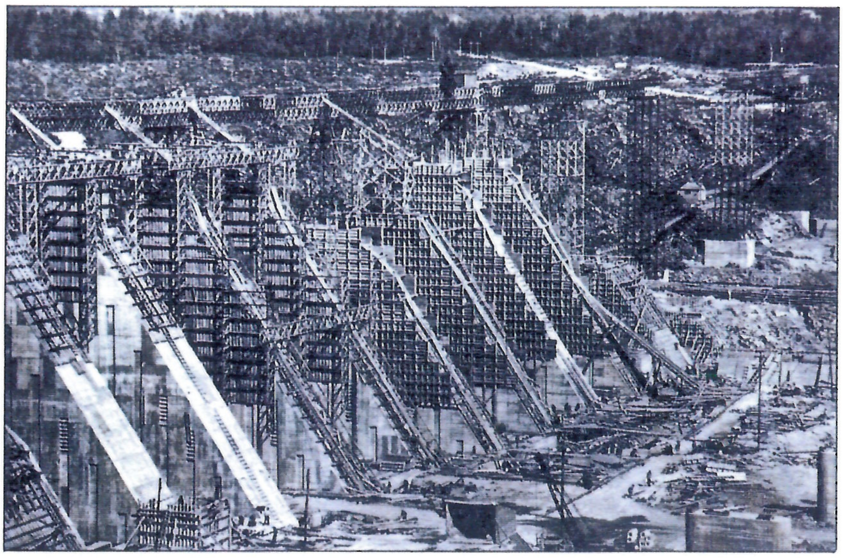


Tower Bridge, a high level floating Bailey built across the Maas-Vaal Canal at Hatert, Holland in July 1944. Note the extensive use of Bailey for the piers and superstructure.



The David and Goliath Bridges built across the River Seine, at Vernon, France. The 694ft Goliath Class 40 Bailey was built on 26–27 August 1944 by 7 Army Troops Engineers; David Bridge is a Class 9 Folding Boat Bridge.

Freeman Bridge was one of the semi-permanent Rhine bridges built after the War. The Class 24 bridge was built at Dusseldorf in two months; its length was 2391ft overall and it was opened to traffic in October 1945.



Extensive use of Bailey in the late 40's, for temporary works in Ontario for the Hydro Electric Company of Canada.

A Bailey Bridge from Thos. Storey (Engineers) used for construction equipment access on a site in the UK.

Thos. Storey (Engineers) supplied this Acrow Panel Bridge to open up a relief road following the eruption of Mt. St. Helens in America.

Here, an Acrow Panel Bridge is supported on Storey Uniflote pontoons to provide a floating bridge for the logging industry at Revelstoke, British Columbia, Canada.

This double lane floating Acrow Panel Bridge crosses the Demerara River in Guyana. At just under 2km in length, it is one of the longest floating bridges in the world and features a retracting span to allow passage of ships. Thos. Storey (Engineers) completed its construction in one year.

CHAPTER IV

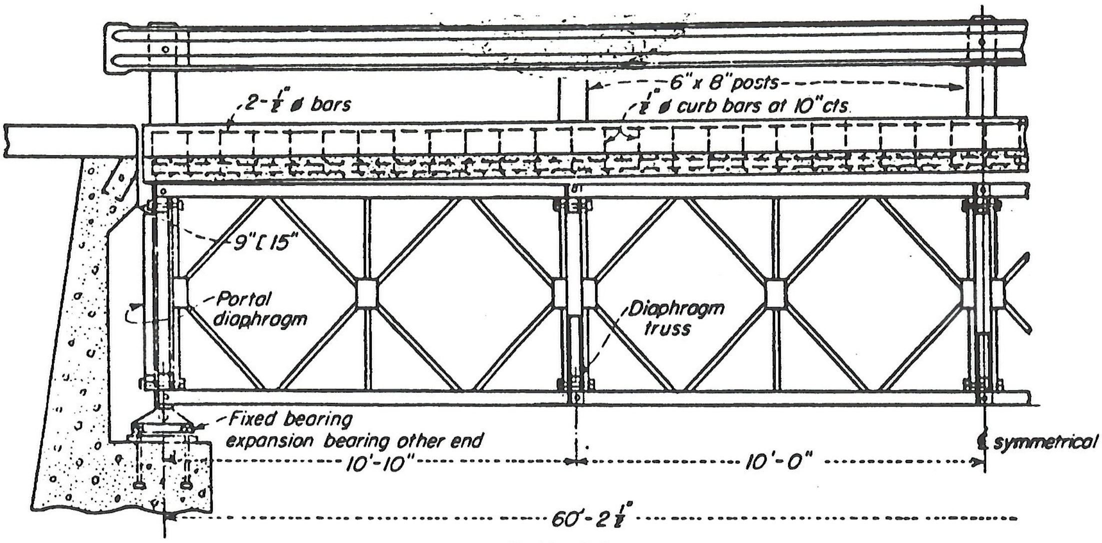
Other Uses for Bailey Bridge Components

IV. Other Uses For Bailey Bridge Components

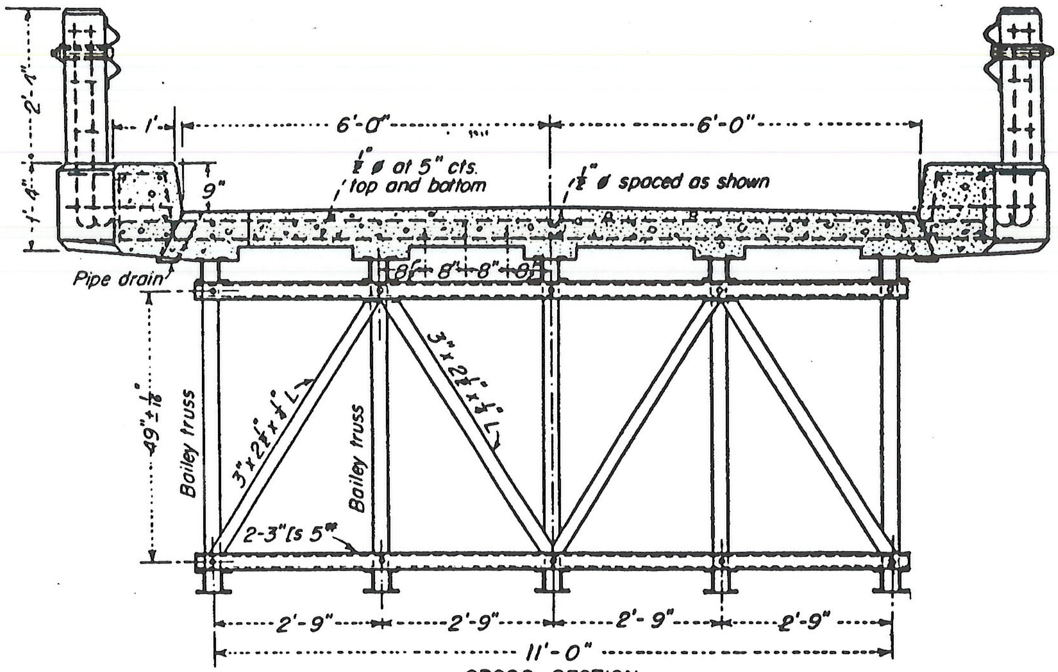
BAILEY TRUSSES USED FOR BRIDGE STRINGERS

During the late 1940s, the U.S. Forest Service turned to army surplus Bailey trusses for urgently needed bridges on access roads to California's forests. The chief departure from general wartime practice was to change the Bailey bridges from narrow through trusses decked with timber to wider deck-type structures with reinforced concrete roadways that minimize maintenance costs. These bridges incorporate the Bailey trusses as stringers, equally spaced beneath the deck slab, with span length and deck width, determining the number of trusses necessary to sustain the loading. A typical 60-ft. bridge with a 12-ft. roadway requires six 10-ft. Bailey panels in each of five stringers.

The total cost to construct a 60-ft. bridge of this design was 50 percent less than for a span with rolled section steel stringers. While this did not reflect a true comparison–due to the purchase of the surplus Baileys at a reduced price–the total weight of structural steel was 31 percent less and manhours spent on steel erection 62 percent less. If the Bailey panels were fabricated new for the job, a great portion of the material costs savings would be offset by higher manufacturing costs due to the intricate nature of the truss.



ELEVATION



CROSS SECTION

BAILEY BRIDGE GIRDERS IN OPEN EXCAVATION

An unusual adaptation of the Bailey bridge equipment was employed in the excavation operation carried out at Buckingham Palace.

The sheet piling to be used in this excavation was the largest section available but was considered insufficiently strong to retain the soil by cantilever action, and some means of holding the pile caps horizontally was deemed imperative. Orthodox methods of strutting from within the rectangular-shaped excavation were not favoured on account of the considerable quantities of timber involved and the difficult supply position. Additionally the employment of this method would have provided obstruction to the free removal of the soil.

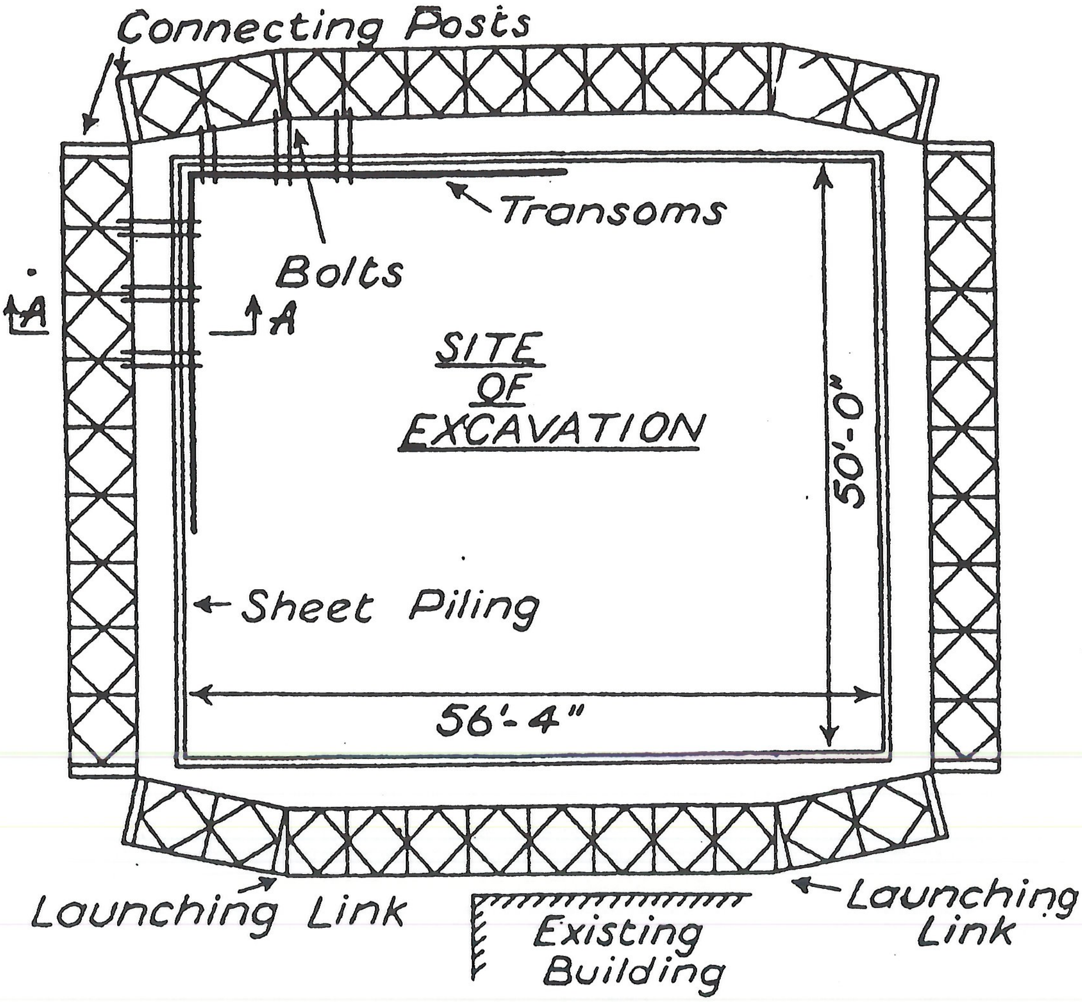
A ring-shaped girder consisting of four mutually supported girders laid horizontally, one to each side, round the outer lip of the excavation was thought to provide the best answer and Bailey bridge trusses appeared to be eminently suitable for this purpose.

Prediction of the amount of relief to be afforded the pile caps could not be determined with any certainty, but an arrangement of four girders of double-single construction, each taking their end support from the ends of the adjacent girders through connecting posts, was thought to be adequate. The use of the connecting posts at the corner junctions allowed free rotation at these points to accommodate changes of slope due to the deflection of the girders when under load.

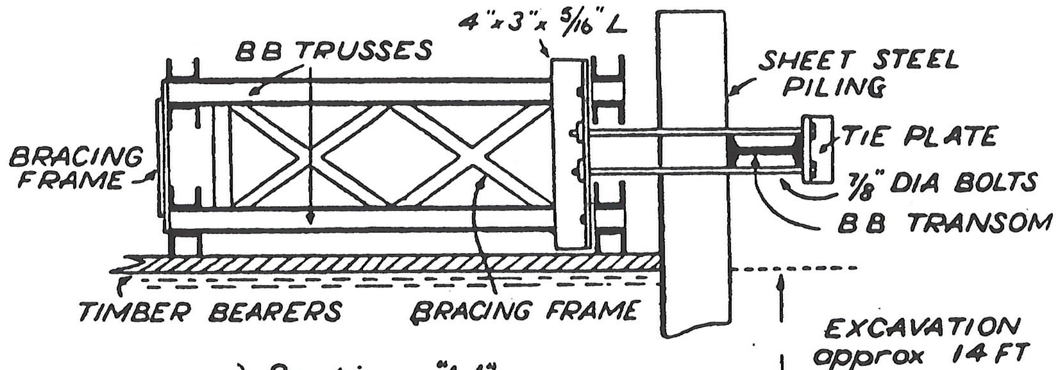
The use of straight girders on the longer side of the excavation would have left little clearance from the pile caps and no allowance for irregularity in their alignment. Launching links were therefore introduced into the top boom, and these served to strengthen the girders by inducing a large reverse bending moment from the supported reactions of the short girders, in addition to providing the extra clearance required.

In the operation the piles were first driven, and then a temporary timber stage was laid level and horizontal on the earth round the outside of the piles. The girders were then erected on the stage and the load applied to them by tightening the bolts of opposing girders until a predetermined deflection was registered. The excavation of the soil was then commenced.

The method proved itself successful both in economy of material and in the time spent in erection. In addition, the unobstructed site was invaluable in allowing speedy and uninterrupted removal of soil in the actual excavation operation.



PLAN



Section "AA"

BAILEY BRIDGING IN HYDROELECTRIC PROJECT

The construction of major hydroelectric power developments entails the use of construction equipment which is substantially larger than that used on most other types of construction. Mobile hoisting equipment is extensively used for handling concrete in buckets, placing heavy permanent equipment such as penstocks, turbine and generator parts, and transformers into place. Conventional structural steel or timber bridges to carry this equipment are expensive both in time and money. Design, fabrication and erection of such structures cannot be undertaken at relatively short notice, and in the case of steel spans, delivery to inaccessible sites may present a major problem in itself. Also, since such structures are temporary and have to be tailored to fit a given set of topographical conditions, which may never be repeated on another project, the salvage value of conventional construction may be only a little more than scrap. These shortcomings are overcome by the use of Bailey bridge material.

The Hydro-Electric Power Commission of Ontario, Canada, in 1949, had put forward the $75 million Des Joachims dam project on the Ottawa River. Around 4,000 tons of Bailey bridging was used in this project to assist in supporting conveyors for handling aggregate, supporting formwork for heavy concrete sections, and for building working platforms for large and heavy crawler cranes.

In the Des Joachims dam project, aggregate was sorted out into giant consecutive heaps of varying aggregate size to be eventually blended together in the right proportions to produce concrete of varying quality. Three general grades of concrete were produced consisting of lower quality concrete for the inner mass of the dam, medium quality concrete for the outer mass, and highest quality concrete for the powerhouse casings. After material was quarried out of the ground it was fed though a crusher and transported up a conveyor belt to a height reaching up to 90 ft over the ground. Upon reaching this level, the conveyor belt travelled horizontally where aggregate of various sizes dropped into separate piles underneath by screen sorting processes. The conveyor belts were supported by Bailey bridges and the towers supporting these consisted of Bailey bridge panels. The towers were A-frame shaped and straddled the pile of aggregate to avoid damage to the legs by unequal loading of the aggregate. At the base of these individual piles, a tunnel was used to extract a certain quantity from each pile by manually opening a hatch from within. This tunnel had a conveyor belt which led to the mixing plant where the concrete would be produced. The concrete was then conveyed over a 2,050 ft wide valley by a Bailey bridge trestle and finally delivered to the dam itself.

CHAPTER V

Tank-Launched Bridges

V. Tank-Launched Bridges

SCISSORS BRIDGE

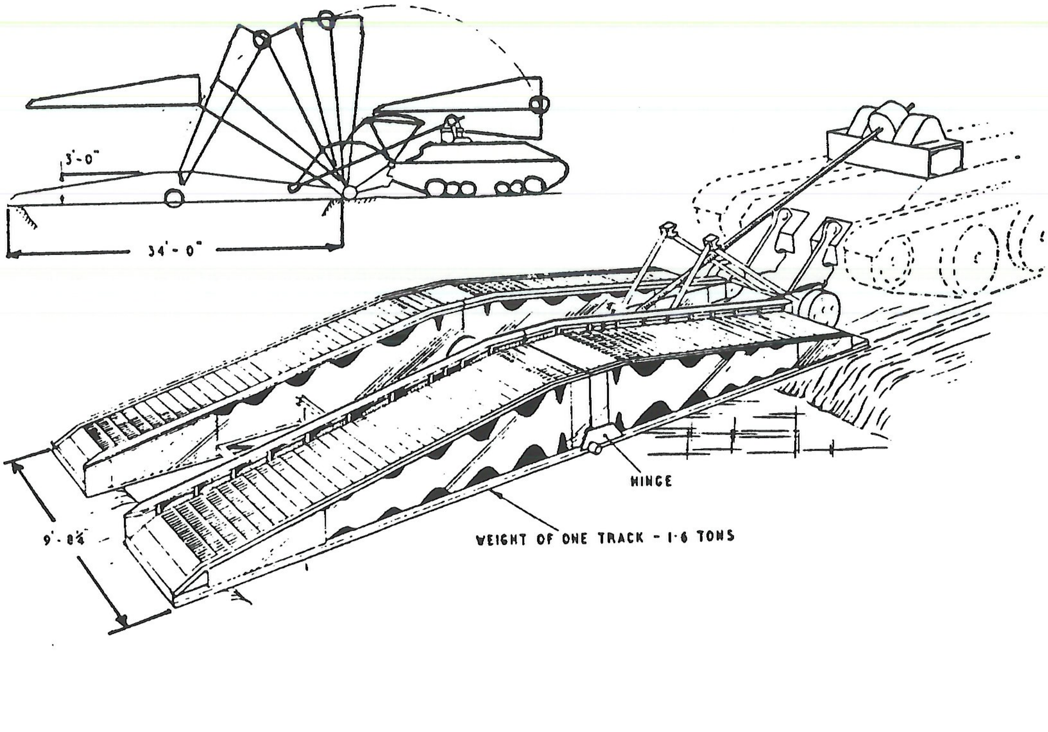
This tank-launched bridge was designed in the early years of World War II for forward operations by the Royal Armoured Corps. The roadway provided was 9 ft. 6 in. in width and had a load capacity of 30 tons on spans of up to 30 ft.

As shown in the figure, the bridge consisted of two plate-girder tracks spaced apart by diaphragms and cross-bracing. The two tracks were hinged at the centre of the bottom chords, and folded back bodily onto the top of the tank for transport. The outer main girders each consisted of a mild-steel web plate 3/16 in. in thickness, to which were welded chords made up of two 2½ in. × 2½ in. × 5/16 in. high-tensile structural-steel angles. Vertical stiffeners of lipped channel section were spaced at suitable intervals along the inner side of the web, and were spot-welded to the web and fillet-welded to the chord angles. Double webs were provided for a short distance at the ends of the girders. The inner girders of the tracks projected above the outer girders, to form wheel guides, and the top chords in this instance each consisted of a single angle with the toes of both legs welded to the web at an angle of 45°. Decking consisted of corrugatedsteel sheet welded to longitudinal steel troughing, which was, in turn, supported by rigidly-fixed cross-beams.

During launching, the near end of the bridge was locked to a small launching frame mounted on the front of the tank. This was rotated though 180° over two pivot points by the extension of a power-driven screwed shaft. After being rotated bodily into the vertical position, the two halves of the folded bridge were automatically opened out in the remainder of the launching cycle by the action of two steel cables. These were fixed to the forward half of the bridge and tensioned by a cam over a radiused segment at midspan, with the hinge in each bottom chord acting as a fulcrum.

It was essential to keep the weight of the bridge down to a minimum in order not to overload the tank's suspension, and also to keep the loads in the launching gear within practical limits. It will be observed that areas of the webs between stiffeners have been cut away to reduce weight. The total weight of the bridge as launched is 3¼ tons, or 36.4 lb. per sq. ft. of decking. The choice of plate-girder construction rather than trusses was dictated partly by the limitation in constructional depth and partly by the need to provide good bearing support over a substantial length of the bottom chords in order to cater for spans appreciably below 30 ft.

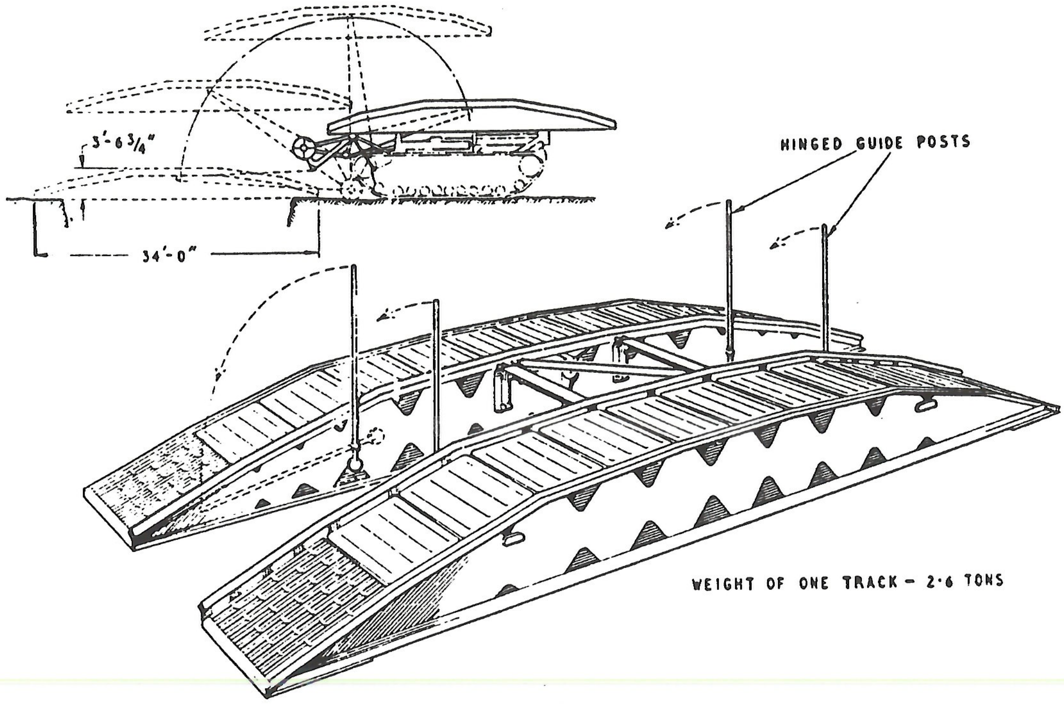
The bridge could be launched and the tank disengaged in a very short time without exposing any of the tank crew. Since no advance preparation of bankseats was possible with this type of bridge, its construction had to be sufficiently flexible in torsion to accommodate itself to some irregularity in the ground at the bridge bearings. Recovery of the bridge onto the bridgelayer could be made from either end, although it was accepted that in this operation hand-assistance is needed to connect the cables.



CHURCHILL BRIDGELAYER

This bridgelayer was developed during the later years of World War II to cater for the heavier tanks. The much larger Churchill tank was used as the launching vehicle, and this enabled the bridge to be carried and launched as one unit without the necessity of folding it for transport, as in the Scissors bridge.

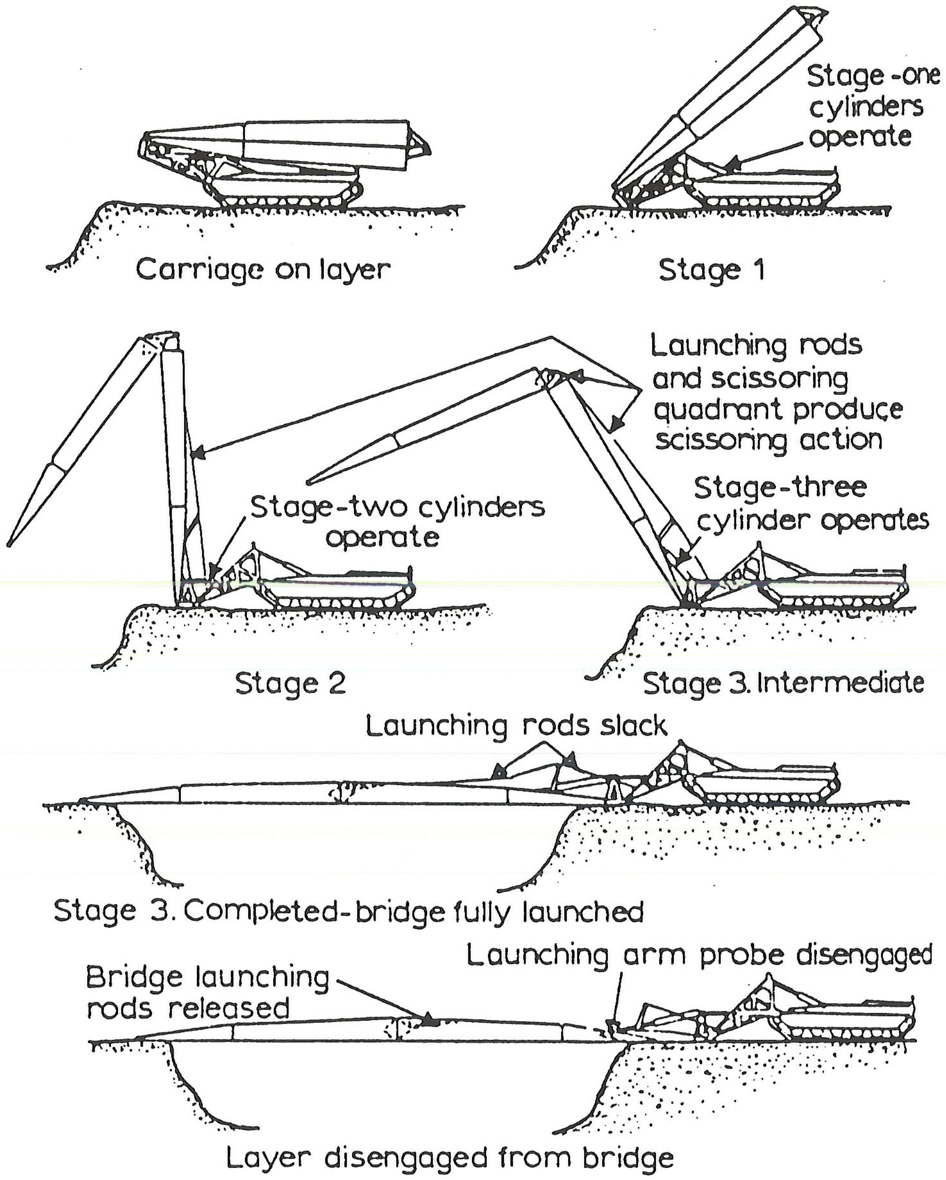
The bridge consisted of two tracks interconnected by diaphragms and bracing, and provided a roadway 12 ft. 1 in. in width with a clear span of 30 ft. The construction was very similar to the Scissors bridge, except that cast-aluminium alloy deck units were adopted in later versions of the bridge. As shown in the figure, launching was effected by rotation of a lever arm engaged in bearings at midspan above the centre of gravity of the bridge, so that the bridge remained horizontal throughout the whole of the launching cycle. Although this bridge had nearly three times the load capacity of the Scissors bridge, it weighed only 5.3 tons, or 48 lb. per sq. ft. of decking–an increase of 30 percent.


3'-6 3/4"
34'-0"
HINGED GUIDE POSTS
WEIGHT OF ONE TRACK - 2·6 TONS

CHIEFTAIN BRIDGELAYER

This bridge can take vehicles of up to 60 tons over a clear span of 75 ft. and is carried and laid by a Chieftain tank without its gun turret but fitted with a hydraulic launching mechanism. The bridge, the overall length of which is 80 ft. is hinged at the centre and folded during transport to reduce its stowed length to a little over half. When the tank arrives at the site, the bridge can be lowered into position as shown in the diagram on the next page by a series of hydraulic cylinders controlled from within the tank. For smaller gaps a bridge of 44 ft. length has been designed that can be carried in one unhinged length and launched in a similar manner.

The bridge is launched in three stages, each of which can be controlled by either the driver or commander. Hydraulic power to the five cylinders in the launching mechanism is provided by a pump run off the main engine. The bridge is normally carried horizontally above the tank where it is firmly clamped to prevent movement. Once the clamps have been mechanically removed, the launching sequence begins with operation of the Stage 1 cylinders that pivot the folded bridge about the forward part of the hull casting. This continues until the launching pad meets the ground or the cylinders reach the end of their stroke, when the folded bridge will be at about 30° to the horizontal.



Stage -one cylinders operate
Carriage on layer
Stage 1
Launching rods and scissoring quadrant produce scissoring action
Stage-two cylinders operate
Stage-three cylinder operates
Stage 2
Stage 3. Intermediate
Launching rods slack
Stage 3. Completed-bridge fully launched
Launching arm probe disengaged
Bridge launching rods released
Layer disengaged from bridge

The Stage 2 cylinders are then operated, tilting the launching pad on the ground until it is approximately level. The bridge is unfolded by means of tension rods connected at one end to the launching frame and at the other to quadrants which are pinned to the far half of the bridge. As the bridge is lowered, the rods rotate the far half to the horizontal.

When the Stage 2 cylinders have reached the end of their stroke, the single Stage 3 cylinder is actuated, lowering the bridge until the end reaches the far bank. At this point the rods will slacken and, on further lowering, the bridge becomes a rigid structure as the top chords butt together at its centre joint. The rods will then be quite free and can be detached from the launching structure, using the remotely operated release mechanism. By reversing the tank, the launching structure is removed from the bridge and the tank may retract all its cylinders and proceed to a rear area to pick up another bridge.

The bridge can be recovered from either end but this requires the emergence of the crew from the tank to recouple the launching rods, dig out embedded ends of the bridge when necessary and guide the launching arm probe into the lifting beam. This beam is pivoted at each end on spherical bearings, to allow the probe to enter with the launching arm at varying elevations. A conical hole is provided in this beam to simplify the probe's entry. After the launching rods are reconnected manually, the launching sequence is reversed, folding the bridge back to its horizontal position on the tank.

The 80 ft. bridge had to be designed within a weight limit of 12 tons and a folded height of 6 ft. in order to achieve acceptable mobility for the launching vehicle. This demanded a material with a high strength-to-weight ratio, high modulus (for acceptable central deflection, particularly under eccentric loading) but with adequate ductility throughout the climatic temperature range, good weldability and low distortion. The launching structure itself also needs a high strength-to-weight ratio.

The construction is all-welded with a basic girder section consisting of a 3/16 in. thick web with top and bottom chords welded up from folded sections. The top chord is of hollow rectangular sections to resist lateral buckling and the lower tension chord is of hollow triangular shape to shed dirt and mud. All the stiffeners are on the inside face of the web to keep a clean outer profile, U-sections being used under the crossgirders and plain stiffeners in between.

CHAPTER VI

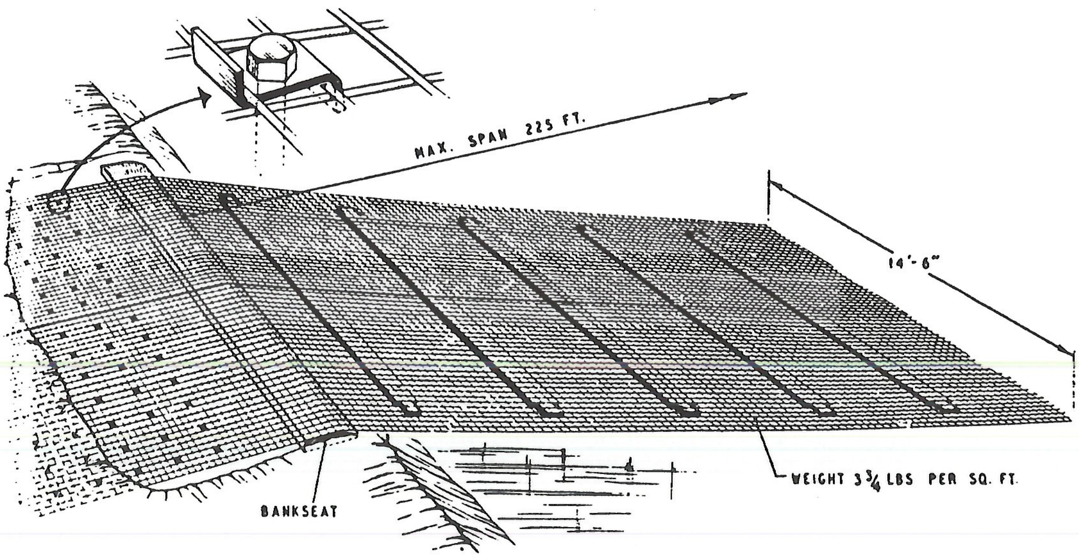
Alternative Rapid Bridging

VI. Alternative Rapid Bridging

UNSTIFFENED SUSPENSION BRIDGE

In 1944, increasing attention was being directed to the requirements of the army in Malaya. In the difficult terrain encountered, transport and supply difficulties were immense, and an urgent need had arisen for a rapid means of transporting the lighter loads, such as jeeps towing six-pounder anti-tank guns over deep ravines, which might be up to 200 ft across. The equipment had to be transportable by air and be available at very short notice. An unstiffened form of suspension bridge was developed to meet this requirement. It consisted simply of steel wire mesh reinforcement, tensioned across the gap between anchorages and stiffened laterally by timber planks secured under the reinforcement at 2-ft centres. The standard deadload sag:span ratio adopted was 1:17, the bridge being tensioned to this profile with suitable tackles.

The maximum permissible live-load of 2½ tons consisted of a single laden jeep towing a six-pounder anti-tank gun, and under this load the maximum pull on the anchorages was 18.8 tons for a clear span of 225 ft. With its four-wheel drive and low-gear ratio, the jeep was well able to climb up the steepening gradient as it approached the bankseats, and the lateral stability of the bridge was surprisingly good. The suspended weight of a 225-ft span bridge was only 4 tons, equivalent to 3¾ lb per sq ft of roadway. This form of unstiffened suspension bridge was later reinforced with additional layers of wire mesh to carry single loads of 10 tons over spans of up to 240 ft.



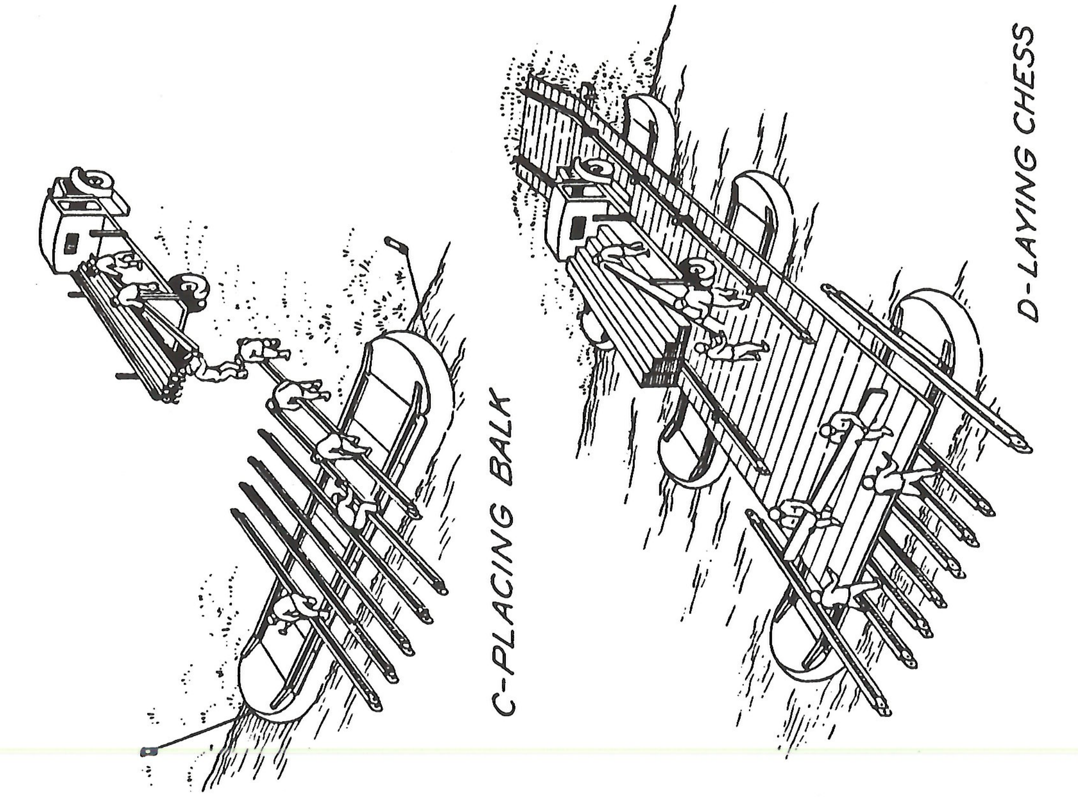
FLOATING MARINE CORPS BRIDGE

During World War II, it was assumed that the Marines fighting in the Pacific could expect to land on one of two type of islands. The first would be coral atolls or volcanic islets on which no bridging would be required. Here the primary engineer mission would be water supply and assault demolition, with the secondary task to assist the pioneer (shore party) battalion in landing supplies. The second type of operation would be on large, undeveloped, jungle-covered islands where the primary engineer mission would be to build pioneer roads and bridge the numerous streams which flow from the mountainous interior. These streams, in the mountains, were swift and shallow with a hard bottom; they could easily be forded by tanks but would require some kind of trestle for wheeled vehicles. These same streams, where they crossed the coastal plains, became deep and sluggish, with marshy banks. Here a floating bridge capable of carrying tanks and other vehicles had to be provided. At that time the Marines used light tanks, weighing about 18 tons.

The Marines later adopted the medium M4 tank which weighed 34 tons and as a result, the engineers found themselves in a position in which none of their floating bridges could carry it. The Army had two bridges which would carry this tank. The first was the 25-ton pontoon bridge, but this was not considered since the pontoons took up too much volume when shipping space was always at a premium. The second was the steel treadway bridge on pneumatic floats. This was compact but each individual treadway weighed one ton and required special crane-trucks for transporting and setting them. Here again shipping limitations prevented the inclusion of a one-purpose truck.

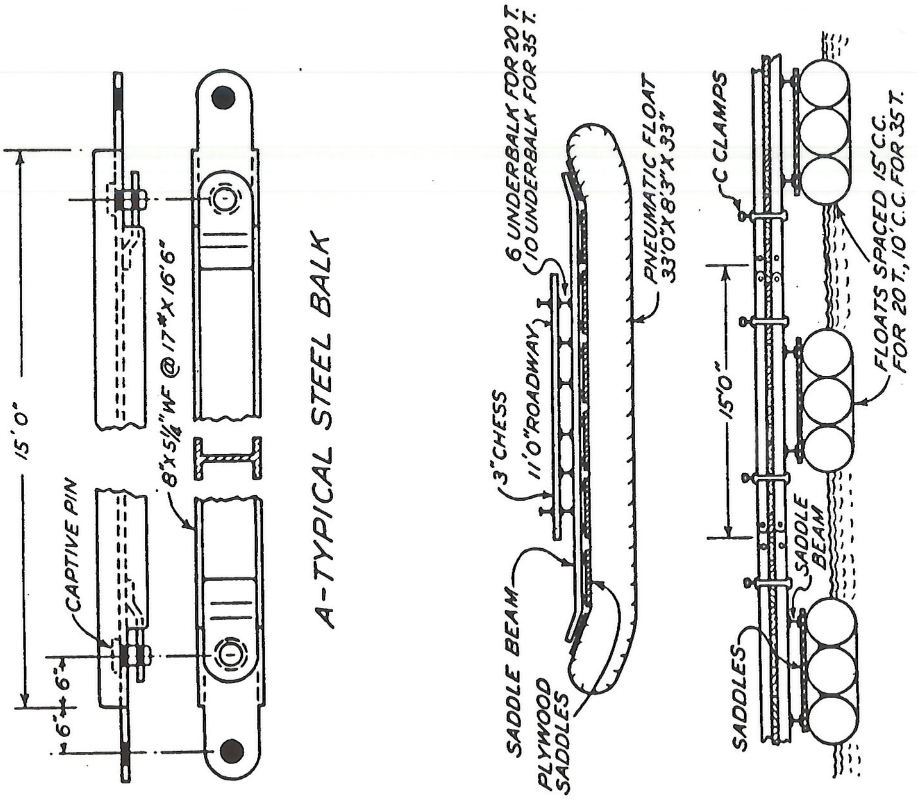
A floating bridge was developed which employed a 28-ft pneumatic float, wood chess, and a steel stringer (balk). These stringers were 8 × 6 inch beams weighing 17 pounds, pin-connected. This bridge would stow compactly and had the great advantage that all parts could be handcarried. It was felt that these steel stringers had many other uses: they could be used in fixed bridges and docks, and could be cut and welded with existing equipment. Therefore the Marines adopted and procured this bridge. Each battalion had sufficient material to build 315 ft of floating bridge of 20-tons capacity or 210 ft of 35-tons capacity.

At the same time, the Bailey bridge was adopted, with one bridge (120 ft of double-double bridging) being included in the Table of Equipment of each Combat Engineer Battalion.



C-PLACING BALK

D-LAYING CHESS



A-TYPICAL STEEL BALK

B-ASSEMBLED BRIDGE

CANADIAN MAGNESIUM ALLOY ASSAULT BRIDGE

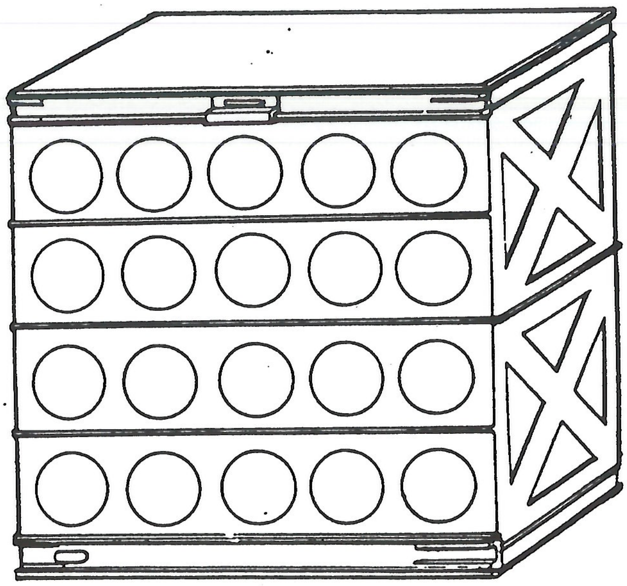
Early in 1944, the possibilities of jungle warfare loomed up for the Allies, and the transport of supplies through the jungle on narrow tracks and across precipitous ravines and mountain streams presented one of the major problems. Equipment could only be brought in by men on foot, or by pack animals, and trails thus formed would have to be improved after the initial advance to take jeeps and their loads.

After a series of discussions between Canadian Military Headquarters, the Ministry of Supply and the War Office in London, it was agreed that Canada, with her development facilities and knowledge of magnesium alloys, should undertake the design and construction, from magnesium, of a light infantry assault bridge to be used as a fixed span bridge over precipitous ravines or mountain streams, and also as a pontoon bridge on sluggish streams. All parts of the bridge must be suitable for transportation in one-man loads over long distances in the jungle, and it should be possible for twelve men to carry 100 ft of completed bridge 100 yards from the building site. The bridge should be initially capable of supporting infantry in file, and pack animals over a minimum clear fixed span of 100 ft, and when in use as a pontoon bridge, should withstand currents of 5 mph. Both types of bridges should be capable of being converted or strengthened to take jeep traffic.

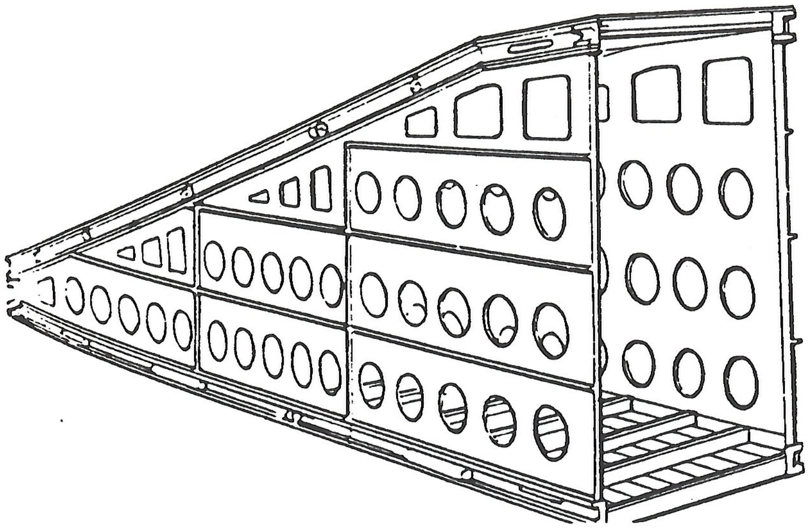
The design follows that of the common deck plate girder bridge. The structure is subdivided into bays 4 ft long and 27 in. wide, dimensions determined for the transportation by one man. A span of 100 ft is capable of supporting a live load of 100 lb per lineal foot, which is approximately one infantry man after another, each wearing full battle equipment. When two bridges are used abreast, a live load consisting of a jeep towing a six-pounder gun is capable of crossing the 100-ft span.

The dead load for design purposes is 20-lb per lineal foot. It is observed that magnesium weighs 0.65 times that of aluminium and about three times less than that of steel. The deck panels are 27 in. wide by 4 ft long, and are combined with the transverse vertical brace frames, and fold into a load slightly in excess of 27 lb. This load is folded into four, the deck being doubled, likewise the brace frame, and the two meet in a common hinge. The deck is of a hard rolled plate, while the side panels and bracing frames are made of a soft alloy to permit forming. The sides or webs are 4 ft long and 4 ft deep, and fold, likewise four times into a pack about 1 ft wide and 4 ft long, each side weighing 27 lb. Each 4-ft section is fastened together by a chord connector which consists of a hook, eccentric and pin, thus eliminating the use of bolts and nuts.

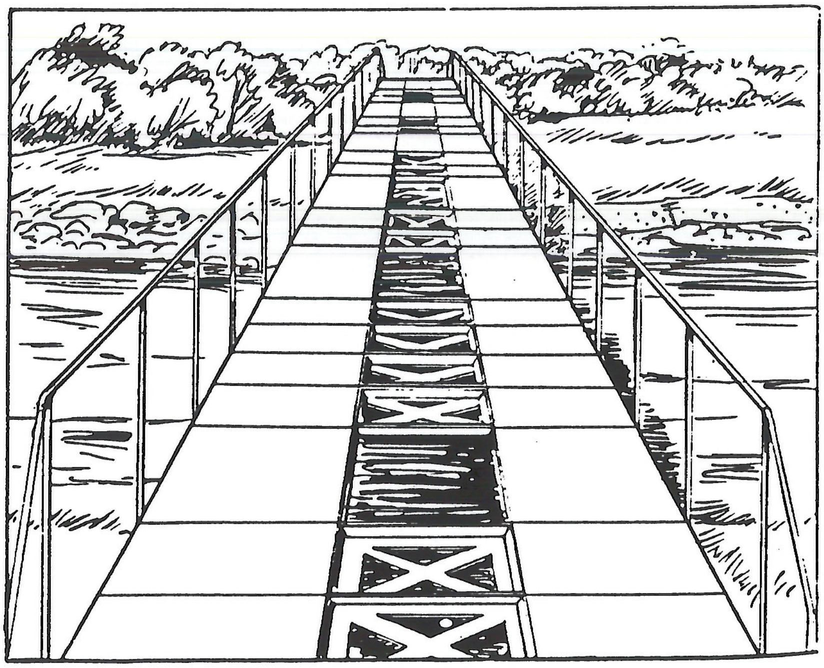
One hundred feet of bridge comprises 17 standard bays equal to 68 ft and two hornbeam sections each 16 ft made up in increments of 4 ft. The hornbeam section is decked top and bottom to permit its use as a ramp if necessary. Standard bays are decked only on top, the bottom of the bay being braced by a frame. A standard bay is made from four component parts all of which are standard and interchangeable. No component part weighs more than 27 lb, and it may be folded up so that it can be carried quite comfortably in a pack on a man's back.



Standard 4' x 4' x 27" bay in magnesium alloy



Hornbeam section assembled ready for attaching to standard bay



100-ft magnesium alloy span with double-bridge brace frame in position

BRIDGES USING REINFORCED PLASTIC

A bridge that expands to 30 ft in length, weighs only 110 lb and yet can carry loads of more than ¾ ton had been developed in Denver, Colorado in 1969. The bridge is able to collapse to a length 30 times less than its extended span making transport easy. A primary reason for its light weight is the use of reinforced plastics for the bridge surface.

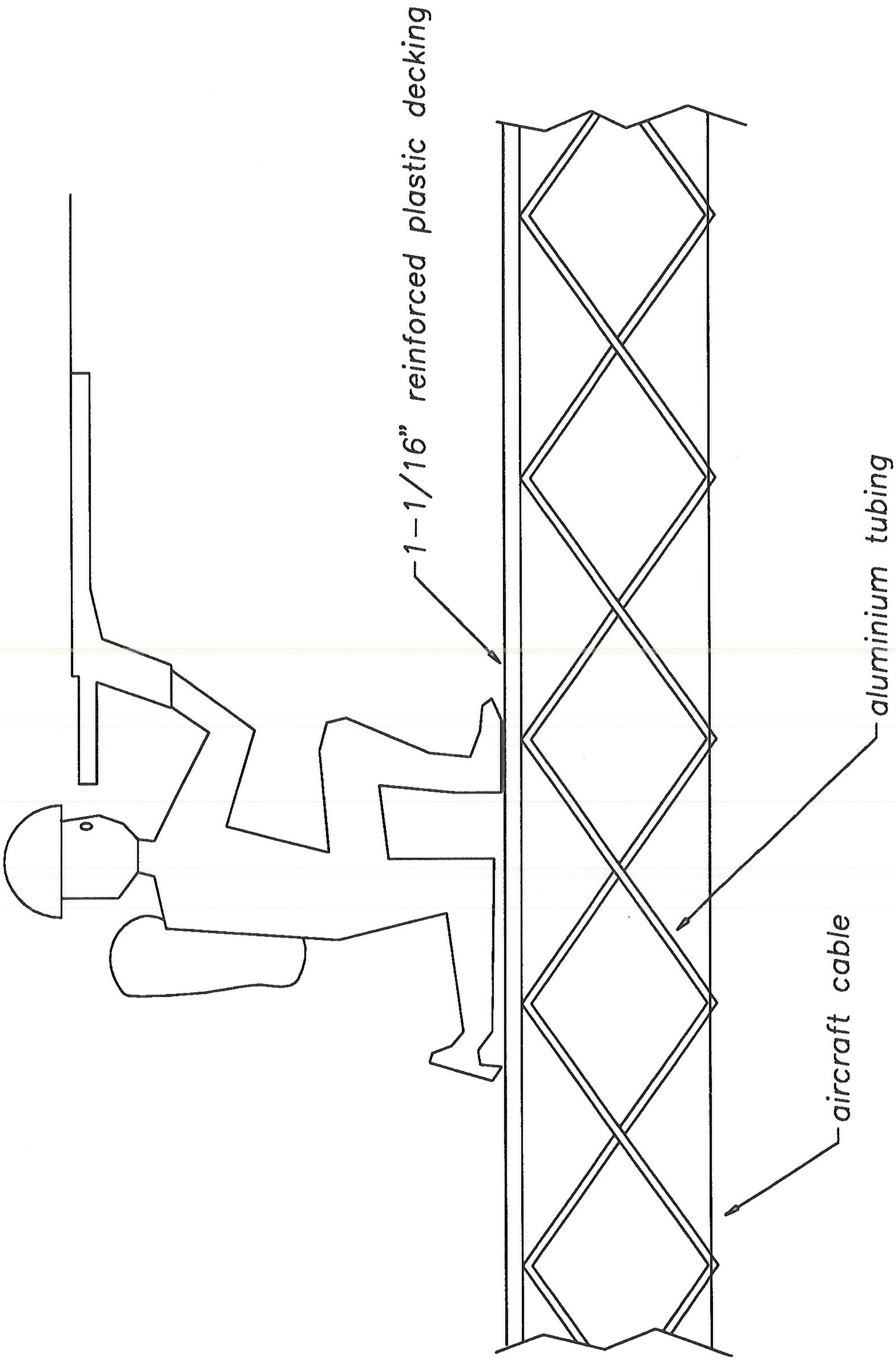
Replacing plywood, the reinforced plastic panels have cut the weight of the bridge decking by approximately 55 percent and the total weight of the bridge by 20-25 percent. A paper-reinforced honeycomb structure is combined with epoxy and fibreglass to form the 1-1/16-inch-thick deck surface.

The bridge consists of two main parts: the high-strength aluminium alloy framework and the reinforced plastic deck panels. The span is approximately 98 percent complete when it is delivered to the site. The 30-ft span bridge can be erected by two men in ten minutes without the necessity of hand tools. An added advantage is that in case of damage to the bridge surface, repair is quick and easy. With a small kit, the decking can be patched, cured and ready for traffic in approximately an hour.

The bridge makes use of rectangular or triangulated pantograph beams. Utility of ordinary single-plane pantograph beams is limited to shorter spans because of a tendency toward torsional and bending weaknesses. The triangulated pantograph mechanism, however, overcomes these problems. A relatively high degree of truss efficiency is achieved by providing aircraft cables along the bottom of the truss to take the main tension load and by using the bridge decking to take the top-side compression loads.

Assembly involves expanding the bridge across the gap, then laying the reinforced plastic panels on top of the structure ahead of the traffic. Pins attached through predrilled holes in the panels link into metal plates below to secure the deck. A second plate rotates to cover the bolt heads, insuring their retention.

More recently, carbon-fibre has been used in place of the aluminium tubing. Using carbon-fibre has the result of adding additional strength and a total weight reduction of an additional 20 percent. Major military applications would be for spans 60-200 ft long, capable of carrying heavy military loads such as tanks. Other practical applications include man-packed military or expedition footbridges, single-lane, single-span vehicle bridges, civilian emergency bridges for both pedestrian and motor traffic, and expandable boat docks and unloading ramps.


1–1/16" reinforced plastic decking
aluminium tubing
aircraft cable

LANDFILL

It is often overlooked that a crossing may be effected by the use of landfill using local materials such as stone, gravel, coral, or whatever is in supply. This alternative to a true bridge was a major issue during the campaigns of World War II in Algeria and Tunisia. The supply of bridge materials was never the quantity required to fulfil these campaigns and it was necessary to use landfill for replacing destroyed bridges.

Landfill bridges have difficulties and limitations of their own. The largest problem associated with landfill bridges is river erosion, when, under certain flow conditions, the landfill bridge may subside. Culverts may have to be placed in effective positions to alleviate this problem. However, this requires an experienced engineer familiar with the characteristics of river flow. Another problem involves the choice of material where plaster, dust, and other such materials may create problems in the landfill. Landfill bridges may be built by practically most military units where a bulldozer is available.

Landfill bridges proved successful in North Africa due to the relatively low river flow and a great abundance of landfill material. They have also proved successful in France where the rivers Marne and Moselle were forded.

FOAM BRIDGES

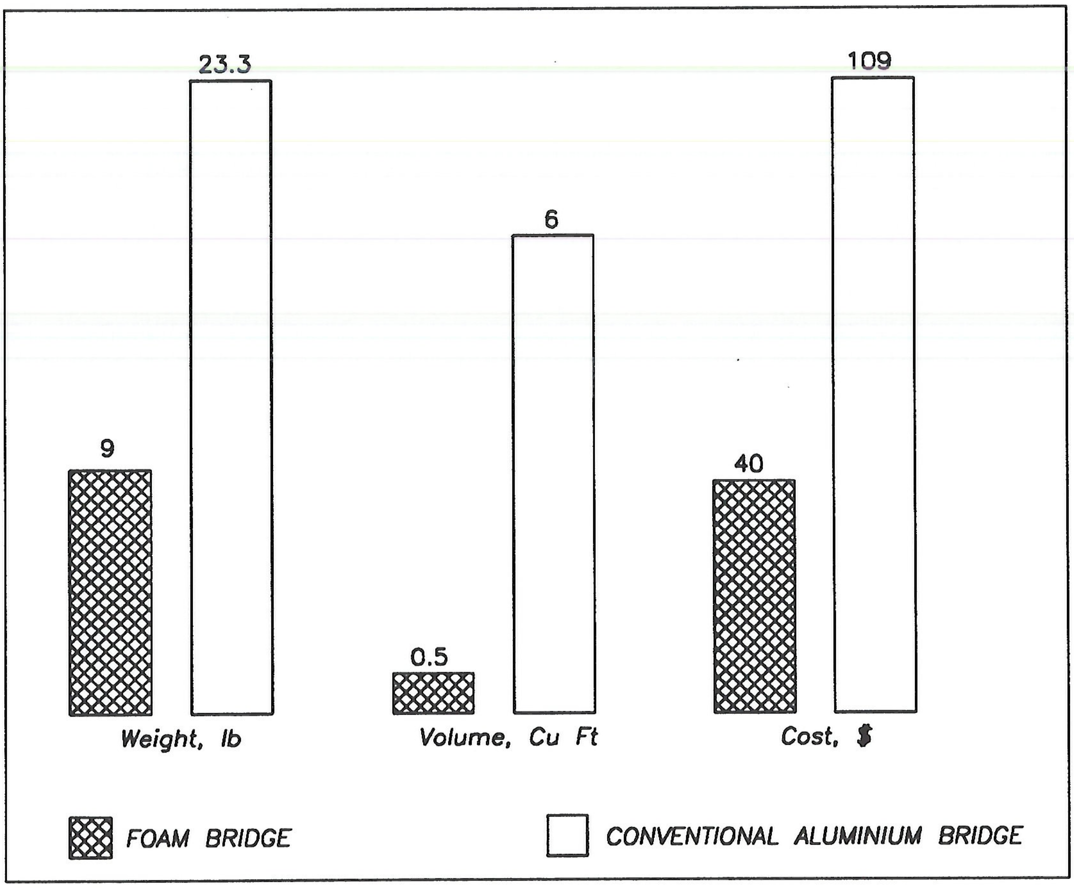
During 1985, extensive research by USA-CERL took place in the design of foam structures as an alternative to the expensive and bulky bridging and rafting equipment used by the U.S. Army.

Flotation bridging and rafting equipment that uses pneumatic floats is vulnerable to damage from river debris and small-arms fire. The thin metal skins of other float components are easily ruptured and often are not repairable in the field. The ruptured section must be removed and, if the proper aluminium welding equipment and skilled welders are at hand, repaired. In most cases, however, repair is a depot maintenance task. There is also a problem during the construction of bridges and rafts in that they must be assembled on the body of water to be crossed, thus exposing the erection crews to hostile fire for long periods of time.

USA-CERL conducted research to develop and evaluate polymer-foam-based materials for use in crossing nonfordable water obstacles by tactical vehicles, individuals, and groups of soldiers. A foamed plastic must meet several criteria for the field use of bridges and rafts. A low-density foam will provide the maximum displacement per unit volume, produce a lightweight final system, and support more weight in water. To reduce water absorption and the likelihood of water logging, the foam must have a high percentage of closed cells. Its components must mix easily and safely and not require special processing equipment for curing. The foam must also have the mechanical properties necessary to withstand vehicular and foot traffic loads and be priced low enough to justify its use. Rigid polyurethane foam, with a density of 2 lb per cubic ft, was the best commercially available material that met these criteria.

Rigid polyurethane foam is made from two liquid components: one contains polymeric diphenylmethane diisocyanate and the other is a mixture of polyether polyols, refrigerant-11, an amine or tin catalyst, and a small amount of silicone. When mixed together, the two components expand more than 25 times their original volume, becoming hard and relatively inflexible. This expansion can take from a few seconds to several minutes, depending on the amount of catalyst used. For use as a bridge or raft, the foam must be shaped into a usable configuration. This is done by pouring the mixed liquid components into forms before the foaming begins. These forms, using a standard canvas material, also increase the foam's cross-sectional stiffness and provide a tough outer skin to reduce damage to the foam by traffic and rough handling. Moisture migration into the foam is also limited because the form fabric is water repellant.

The foam footbridge is a foam deck attached across 8-ft long, 1-ft-diameter cylindrical foam pontoons spaced 5 ft apart. The deck sections are 4 ft wide and 20 ft long with a 3-ft-wide walkway; they are tied together with nylon straps to form a bridge. The prototype cost for 1 linear ft of bridge was $40; it weighed 9 lb and required 0.5 cubic ft of shipping space. In comparison, 1 linear ft of an aluminium footbridge had cost $108.82, weighed 23.3 lb, and required 6.1 cubic ft of space. The graph below compares the weight, volume, and cost of the foam bridge with the conventional aluminium type.



CHAPTER VII

Conclusion

VII. Conclusion

In 1946, Donald Bailey was knighted for his valuable contribution to the Allied victory of World War II from his bridge. The Experimental Bridging Establishment (EBE) was then reorganized and subsequently, known as the Military Engineering Experimental Establishment (MEXE) of which Sir Donald Bailey became the Assistant Director, becoming the first civilian Director in 1957. Also in 1946 he was awarded the Honourary Degree of Doctor of Engineering by the University of Sheffield of which he had attended.

In September 1962, after thirty-four years spent at EBE/MEXE, Sir Donald Bailey went on to become Dean of the Royal Military College of Science at Shrivenham, where his reputation and prestige did much to enhance the status of the college. In 1966, he retired from the Civil Service and returned to Christchurch where he had first settled in 1928. He then became Technical Consultant to Thos Storey (Engineers) Ltd and remained as such until his death on 4 May 1985 at the age of 83.

The post-war development of the Bailey bridge included the introduction of the Standard Widened Bailey Bridge and then the Extra Widened Bailey bridge progressively increasing the roadway width. This was later followed by the design and development of the Heavy Girder Bridge (HGB) in the late 40s and early 50s. This bridge was in many respects a scaled-up version of the Bailey bridge, and in consequence, Sir Donald Bailey took considerable interest in its development. The Heavy Girder Bridge was a much heavier bridge than the Bailey and was built using bridging cranes. The bridge is of note because it introduced the use of weldable quality aluminium alloy components as light alloy crossgirders for the launching nose and for the deck panels.

During this period, new floating equipments were introduced to replace the Bailey Pontoon Bridge; however, it was not until 1971 that the Medium Girder Bridge (MGB) came into service to replace the Bailey as a dry support bridge for use by the Sappers in the battle zone. Although the Medium Girder Bridge is an excellent bridge reducing construction man-hours by about 95 percent and all up weight by about 70 percent, when compared with a Bailey bridge of similar span and load class, it lacks the versatility of the Bailey and extensive use of high-quality light alloys makes it very much more expensive.

In this post-war period the potential for the use of the Bailey bridge for temporary and permanent civilian bridging was exploited worldwide by the civil engineer, as was its versatility for other purposes, such as gantries, towers, support structures, formwork and a wide range of temporary works on large projects. A firm at the forefront of the current supply and manufacture of the Bailey is Thos. Storey (Engineers) Ltd. The firm was founded by Thomas Storey in Stockport, in 1936, and after the war and as a direct result of its involvement in wartime production, the firm was granted a licence to manufacture Bailey bridging by the National Research Development Corporation. This licence was extended in 1950, giving Storey's exclusive worldwide rights for the manufacture and sale of the bridge. The firm joined the Acrow Group in 1960 and continued to expand successfully, winning the Queen's Award for Export Achievement in 1969 and again in 1977. Following the receivership of the Acrow Group in 1984, Thos. Storey (Engineers) Ltd arranged a management buy out from the receivership, with the backing of several well-known and respected City institutions.

After initial production of the bridge as used by the Army during the war, Storey first modified the panel to include a built-in transom clamp. Soon, however, the sizes of the rolled steam beams used for the vertical and diagonal members in the panels ceased to be available, and a new panel was introduced using rectangular hollow sections for these members. At the same time the opportunity was taken to make use of the more readily available Grade 55C steel and the built-in transom clamp was dropped, being no longer advantageous with the use of the hollow sections. A new steel decking system was introduced and the equipment was known as Storey Bailey Bridging.

In the late 1960s, Thos. Storey developed the Acrow Panel Bridge, taking full advantage of the latest materials and manufacturing techniques, with the intention of eliminating some of the limitations that had become apparent in the Bailey, bearing in mind that it had been introduced nearly 30 years earlier as a bridge for temporary use under wartime conditions. Many types of unit construction were studied, but none were found to offer advantages over the Bailey principles when the prime factors of *cost, simplicity, speed of erection, carrying capacity,* and *versatility* were considered. The basic configuration of the Bailey panel was therefore retained, improved performance resulting from the continued use of rectangular hollow sections and Grade 55C steel as with the Storey Bailey bridge. The main change to the panel has been to move the transom position from its original position adjacent to the panel verticals, to a new position in the bottom of the panel diamond, a configuration used with success in the Heavy Girder Bridge. The resulting stronger transom seat has meant that stronger transoms could be used, only two being used per 10 ft bay of bridge as opposed to the two or four used with the Bailey. This allows rakers to be fitted at 5 ft intervals, thus improving the stiffness of the top chord.

Other improvements included the introduction of a range of decking systems, offering four different roadway widths, from 11 ft 3 in. to 23 ft 8½ in. wide, and three different decking strengths, together with a choice of timber of steel decking. Additionally, panels and other components can be provided painted or hot-dipped galvanised. The overall result of the various improvements is that the shear capacity of the new panels is some 67 percent greater than for the Bailey, the bending capacity has been increased by about 25 percent, and the fatigue life is about four times that of the standard Bailey panel.

Indeed it says much for the excellence of the equipment that the situation remains much the same today, with continuing considerable sales of Bailey bridging and its modern derivatives throughout the world.

APPENDICES

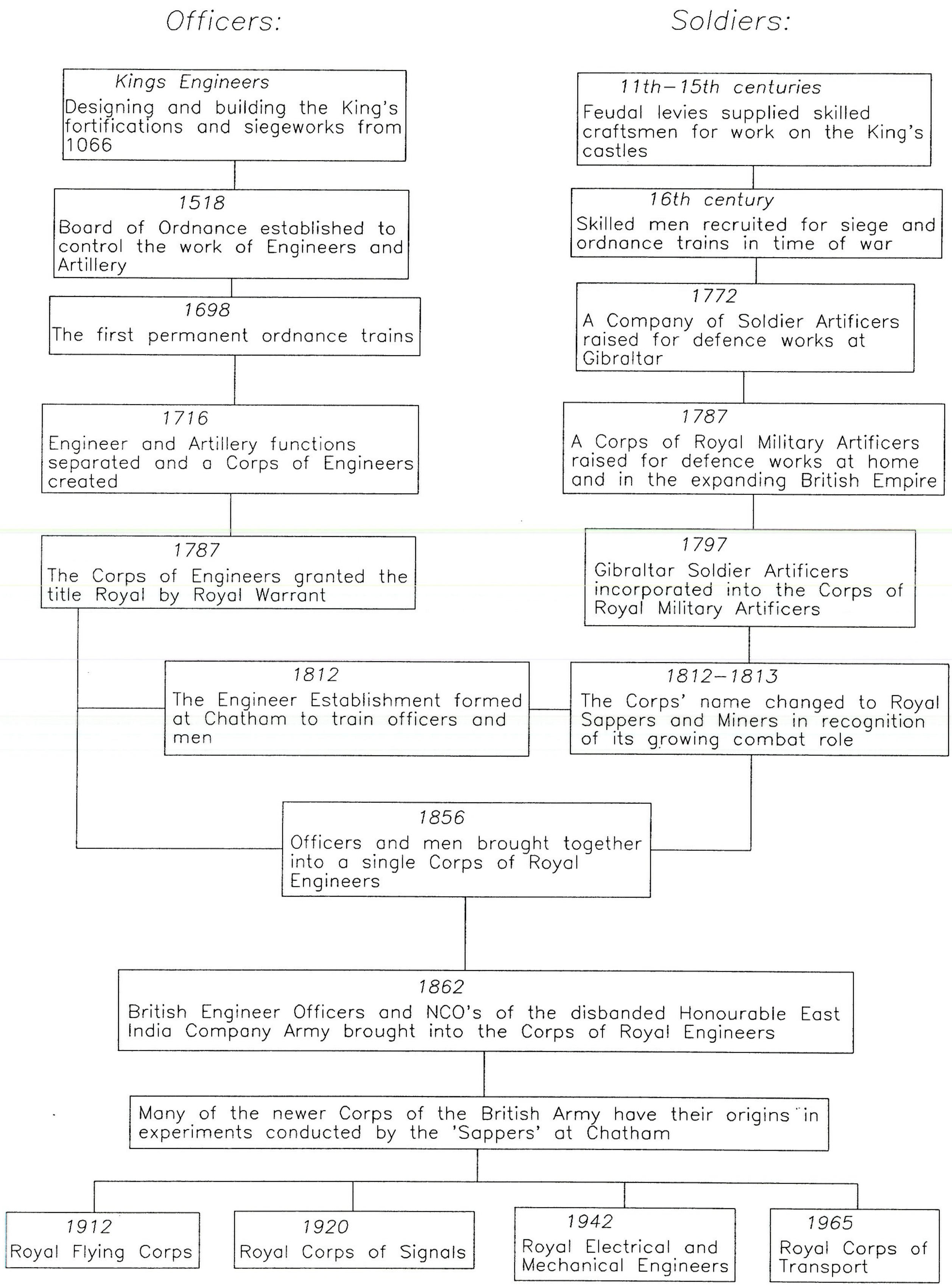
Appendix A: Origin of the Royal Engineers

The Royal Engineers trace their origins back to the earliest King's Engineers brought from Normandy by William the Conqueror in 1066 to build sophisticated siege machines and castles that would dominate the English countryside for centuries.

As military engineers they can claim descent from the soldiers of ancient Rome whose roads and bridges were as important as their forts in imposing colonial rule on a scattered empire. In Britain's own empire in the nineteenth century Royal Engineers built railways, cities and canals. At home they experimented with diving and flying and in the sciences. Their work gave a basis for the development of many of the newer specialist units found in the British Armed Forces of today.

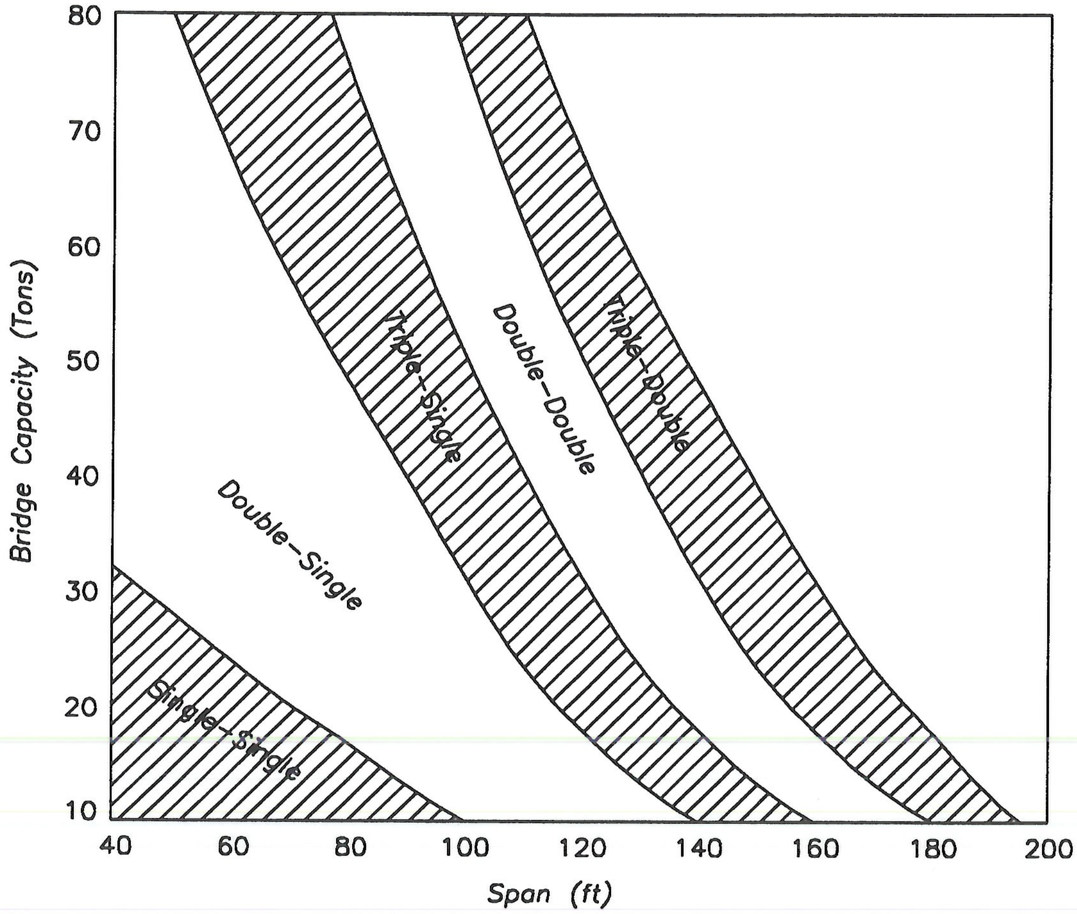
Sappers were responsible for the construction of harbours, airfields, and bridges under observed fire including such tasks as clearing minefields of unexploded bombs. Responsibility for the development of rapid bridging equipment for use by the Sappers was given to the Experimental Bridging Company (EBE) based at Christchurch in 1919. This was later known as the Military Engineering Experimental Establishment (MEXE).

The Corps of Royal Engineers



Appendix B: Load Capacity of Bailey Bridges

SAFE CAPACITY OF BAILEY BRIDGES IN TONS					
Span (ft)	single-single	double-single	triple-single	double-double	triple-double
40	32	-	-	-	-
50	28	80	-	-	-
60	24	67	-	-	-
70	20	57	-	-	-
80	17	48	75	-	-
90	13	40	62	-	-
100	10	31	50	75	-
110	-	23	40	61	80
120	-	18	31	50	67
130	-	13	23	40	57
140	-	10	18	31	48
150	-	-	13	23	39
160	-	-	10	18	31
170	-	-	-	13	23
180	-	-	-	10	18
190	-	-	-	-	12


80
70
60
50
40
30
20
10
40
60
80
100
120
140
160
180
200
Bridge Capacity (Tons)
Span (ft)
Triple-Single
Double-Double
Triple-Double
Double-Single
Single-Single

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