

**MODULAR STEEL BRIDGES**

**Colin McKenna  
Technical Director  
URS/Scott Wilson**

URS/Scott Wilson  
Scott House  
Alencon Link  
Basingstoke  
Hampshire  
RG21 7PP  
United Kingdom

**Abstract**

This paper considers the advantages of using modular steel bridges, currently available proprietary systems, requirements for procurement, issues of construction and the scope for local manufacture.

# 1<sup>st</sup> AFCAP PRACTITIONERS CONFERENCE 23<sup>rd</sup> to 25<sup>th</sup> November 2010

## 1. INTRODUCTION

Modular steel bridges can be best described as structures constructed from standardised components that can be assembled at their final location. There are a number of proprietary systems available throughout the world but there is also an opportunity to develop locally manufactured systems in Ethiopia and other countries.

A clearly defined specification is essential for procurement and the essential requirements for this will be discussed.

There are a number of potential methods of construction and erection available and the merits of each will be considered in relation to site context.

## 2. GENERAL DESCRIPTION

In considering modular steel bridges it is general to include within this description:

Warren truss type structures comprising simple bolted steel sections forming the horizontal chords, diagonal web members and the transverse cross girders. Depending on the size of the structures there might also be high level cross bracing between the trusses. These may be either of the “through” type, where the running deck sits at the level of the bottom chord or “deck” type, where the running deck is above the top chord of the truss. The decks of such bridges will generally be constructed of steel plate, concrete or timber.



**Photo 1 – Typical Truss Bridge**

and

Panel bridges formed of complex welded panels which are then pinned or bolted longitudinally, again with transverse cross girders to support the running deck. This type of structure is commonly referred to as a “Bailey Bridge” though that term is truly only associated with one particular manufacturer. The decks of such bridges will generally be constructed of either steel plate or timber.



**Photo 2 – Typical Panel Bridge**

## **1<sup>st</sup> AFCAP PRACTITIONERS CONFERENCE 23<sup>rd</sup> to 25<sup>th</sup> November 2010**

In addition there are other specialised proprietary systems utilising complex panels available.

This paper will concentrate on the first mentioned, Warren truss type structure and in particular the “through” type configuration.

### **2.1 Basic Principles**

The basic requirements of a modular bridge system are:

There should be as few standard parts as possible.

Varying spans and widths should be accommodated using combinations of standard parts.

The parts must be easy and cheap to manufacture from standard available sections with a high degree of accuracy and uniformity.

The individual parts must be of such size and weight as to permit easy transportation.

The system should allow for erection without requiring highly skilled labour or elaborate plant.

The bridges must be suitable for dismantling without damage to parts.

## **3. ADVANTAGES OF MODULAR STEEL BRIDGES**

### **Spans**

This type of bridge becomes advantageous once the required length of structure exceeds that which can be readily achieved with either culverts or simply supported reinforced concrete decks. This length can be considered to be 20m in most situations. However if the local characteristics of a particular crossing means that temporary support – falsework – proves difficult then spans less than that can be considered.

The upper limit on span is dependent on the size and weight of individual elements but 120m can be readily achieved.

### **Transportation**

The size and weight of elements is minimised by employing bolted connections at each node of the truss. By virtue of this large vehicles are not necessarily required for transport and this is advantageous in relation to the geometry and condition of any access road to a particular crossing site.

### **Labour and Plant**

The simple form of construction and limited size and weight of component parts mean that little mechanical plant is required for construction, though its use will improve speed of construction. The skill level required for construction is low and local participation can be encouraged. Depending on the particular method of erection – and this will be discussed later in this paper – a method of launching a bridge across its obstacle might be required..

## 1<sup>st</sup> AFCAP PRACTITIONERS CONFERENCE 23<sup>rd</sup> to 25<sup>th</sup> November 2010

### 4. PROPRIETARY SYSTEMS

There are numerous proprietary systems around the world for both panel types and truss type structures. By their very nature the truss type systems have, in general, been available for longer than the panel systems.

#### Truss systems:

- Callender Hamilton Bridges – produced by Balfour Beatty (UK)
- Eastbridge – produced by Eastbridge of New Zealand
- Waagner-Biro Modular Bridges – by Waagner-Biro of Austria
- Janson Portable Steel Bridge – by Janson International B.V. of The Netherlands

By their very nature all of these systems result in an end product that is generally similar to its competitors. Differences exist in the particular configuration of panel dimensions and component sizes.

#### Panel Systems:

- Mabey Compact Bridges
- Mabey Delta Bridges
- Mabey Universal Bridges – all by Mabey and Johnson of UK
- Waagner-Biro Panel Bridges – by Waagner-Biro of Austria
- Janson Panel Bridges – by Janson International B.V. of The Netherlands
- Acrow Panel Bridges – by Acrow Corporation of America
- Quadricon Bridges – by Quadricon Pvt of India

Apart from the Mabey Delta bridging all of these systems are derivatives of the original Bailey bridging developed by Mabey and Johnson as military bridging designed to be assembled and erected by manpower alone.

The Mabey Delta bridging is formed of triangular sections connected together and then bolted to separate top and bottom chord members – something of a hybrid between panel and truss systems.

This represents only a selection of the available systems and in no way is intended to indicate preferred systems.

### 5. PROCUREMENT

Successful and cost effective procurement of modular bridges depends upon the clear definition of requirements.

Ideally the specification should:

- Encourage innovative responses to the Specification
- Ensure value for money as a result
- Involve as wide a range of potential suppliers as possible
- Provide end users with a wider choice of solutions to match their needs more precisely

There is no single specification that will be 100% appropriate for all situations and so a guidance document has been produced outlining the appropriate options to particular clauses.

Salient guidance clauses from a previously developed document are reproduced below.

## 5.1 GENERAL

### 5.1.1 Brief Description of the Contract

This clause should be extended to provide as much relevant information as possible that might influence the tender. Items to be noted include the number of bridges involved and their purpose, the geographical area, the timescale for supply, the port of landing, accessibility of final site destination, etc.

### 5.1.2 General Requirements

#### 1. Type of Structure

A choice of clauses is provided here:

For specific bridge sites that have been previously identified use clause 1(a)

#### 1(a) Permanent

The bridge(s) is/are to be designed as (a) permanent structure(s), assembled from easily erected modular components. There is no requirement for it/them to be dismantled and re-erected. The repair and replacement of damaged components shall be possible whilst the bridge(s) remain(s) in service.

Or where the supply is for a stock of parts that can be utilised on an emergency basis use clause 1(b)

#### 1(b) Temporary/Emergency

The bridge(s) is/are to be built as temporary structure(s), assembled from easily erected modular components. They/it shall be designed and installed such that they/it can be dismantled without damage to any of the components other than bolts or similar items used in connections and re-erected elsewhere. The variation in size and weight of similar components shall be minimised. The system should be capable of re-erection in a different configuration i.e. increase or decrease in length/width.

#### 2. Erection/Installation

2.1(a) Installation may be by either launching or by cantilever construction from one side of the crossing only. The use of temporary supports within the span is not considered feasible due to the low bearing capacity of the ground. The available working areas for erection are indicated on the attached plans.

2.1(b) Installation may be by either launching or by cantilever construction from one or both sides of the crossing. The use of temporary supports within the span is not considered feasible due to the low bearing capacity of the ground. The available working areas for erection are indicated on the attached plans.

2.1(c) Installation may be by either launching or by cantilever construction from one side of the crossing only. The use of temporary supports within the span is considered possible since exposed rock has been noted in the site investigation. No guarantee can be made of its competence and additional information should be sought by the supplier if he should wish to utilise temporary supports. The available working areas for erection are indicated on the attached plans.

2.1(d) Installation may be by either launching or by cantilever construction from one or both sides of the crossing. The use of temporary supports within the span is considered possible since exposed rock has been noted in the site investigation. No guarantee can be made

## **1<sup>st</sup> AFCAP PRACTITIONERS CONFERENCE 23<sup>rd</sup> to 25<sup>th</sup> November 2010**

of its competence and additional information should be sought by the supplier if he should wish to utilise temporary supports. The available working areas for erection are indicated on the attached plans.

- 2.2(a) Assembly and installation will be undertaken using manual methods. It should not be assumed that any mechanical plant will be available unless provided under this Contract. Any additional parts and equipment required for assembly and installation shall be provided under this Contract. However, actual assembly and installation on site are not required under this Contract.
- 2.2(b) Assembly and installation will be undertaken generally using manual methods. However the following mechanical plant will be available:

List items of plant that will definitely be available

Any additional parts and equipment required for assembly and installation shall be provided under this Contract. However, actual assembly and installation on site are not required under this Contract.

### **3. Weight of Components**

The maximum weight of any component that must be moved and positioned in the structure manually, without any mechanical aids, shall not exceed 300kg. The method statement for assembly must clearly state how items weighing in excess of this amount are to be erected.

It is suggested that this clause should always be included. The main elements that are likely to be in excess of this weight are transoms and steel deck panels.

### **4. Design**

#### **4.1 For bridges specifically designed for a project:-**

The structural design of the bridge/each bridge shall be/have been carried out and independently checked by appropriately qualified and experienced engineers. The checking may be carried out by persons within the Designer's organisation, provided that they are independent of the original design team, or by an independent organisation. The Designer shall submit a certificate stating that the design is in compliance with this Specification and that it has been checked on completion of the final design and checking.

The design and checking procedure must be completed to a Quality Assurance System compliant with ISO 9001, and certification produced by the design and checking (if appropriate) organisations as verification of this.

#### **4.2 For Standard Bridge Designs:-**

The structural design of the bridge/each bridge shall be/have been originally carried out and independently checked by appropriately qualified and experienced engineers. The checking may be carried out by persons within the Designer's organisation, provided that they are independent of the original designers, or by an independent organisation. The Supplier shall submit a certificate stating that the design is in compliance with this Specification and that it has been checked. The design and checking procedure must be completed to a Quality Assurance System compliant with ISO 9001, and certification produced by the design and checking organisations as verification of this.

#### **4.3 For Bridges with Welded Panels:-**

The bridge(s) shall comply with the Specification and certification provided by the Supplier

## 1<sup>st</sup> AFCAP PRACTITIONERS CONFERENCE 23<sup>rd</sup> to 25<sup>th</sup> November 2010

that they/it have/has been tested as such. Independent review of the test data and test methods shall be carried out by persons within the Supplier's organisation, provided that they are independent of the original team, or by an independent organisation. Both the Supplier and Checking organisations must have Quality Assurance Procedures in place compliant with ISO 9001, and produce certification in order to verify this.

### 5. Fabrication

The manufacture of the steel components shall be undertaken only at the works of approved fabricators who shall have a Quality Control system in accordance with ISO 9002 in operation.

Assurance of the quality of the fabrication facilities used is required

### 5.3 Technical Requirements

#### 5.3.1 Geometric Requirements

##### 1. Spans

The Contract may be for one or more bridges of single or multi-span construction and therefore some combination of the clauses given below may be necessary. For Contracts with a large number of bridges the spans might be best included in tabular form.

Clauses 1(a) or 1(b) should be used for specific single span bridges. Clause 1(c) is for use in emergency stock supply Contracts.

##### Single Span Bridges

- 1(a) The minimum clear span between the faces of abutments shall be xx metres. The centreline of the bearings shall be a minimum of 400mm from the front face of the abutments.

*Or*

- 1(b) The actual clear span between the faces of existing abutments is xx.yyy metres. The size of bearing shelf at each abutment is ( ) mm long x ( ) mm wide

*Or*

- 1(c) The minimum span between bearings shall be xx metres.

##### Multi Span Bridges

- 1(d) The bridge(s) is/are of multi-span construction and the envisaged design provides the following arrangement:

Provide information on spans between abutments and piers

The Supplier may propose an alternative configuration for consideration but must provide a design for the specified configuration.

*Or*

- 1(e) The bridge(s) is/are of multi-span construction designed to be supported on existing supports in the following arrangement:

# 1<sup>st</sup> AFCAP PRACTITIONERS CONFERENCE 23<sup>rd</sup> to 25<sup>th</sup> November 2010

Provide information on spans between abutments and piers.

The size of bearing shelf at each abutment is ( ) mm long x ( ) mm wide and the size on top of the piers is ( ) mm long x ( ) mm wide.

## 2. Carriageway Width

Many countries have a specified minimum carriageway width and wherever possible this should be provided. It is often the case that this is less than the design width of the carriageway on a normal road cross section. In the absence of a specified width then the following are suggested as minimum values:

Single lane      3.00 metres  
Double lane     6.00 metres

## 3. Footways and pedestrian refuges

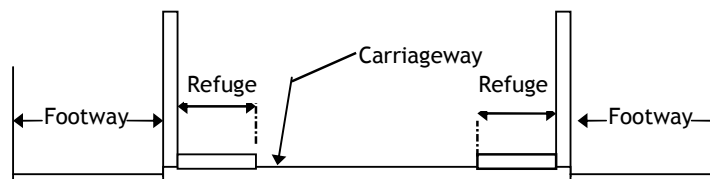


Fig 1.0 Footways and Pedestrian refuges

It is recommended that all bridges with a length in excess of 15 metres are provided with some form of pedestrian footway or refuge. The particular requirements at each bridge are a function of the pedestrian and vehicular traffic at the site.

As a minimum (for bridges in excess of 15 metres long) two refuges 750 mm wide, one either side of the carriageway, should be provided.

Where particular provision is to be made for pedestrians then this should be in accordance with any national standards where applicable. In the absence of a national standard then at least one footway should be provided outside of the main longitudinal truss members. A clear width of 1200 mm is appropriate for a single "external footway". If two "external footways" are provided then they should each be of 1000 mm clear width.

## 4. Vertical clearance

Vertical clearance to overhead bracing and the like is required to prevent damage by high vehicles or their loads. In the absence of any particular national standard a clearance of 5.5 metres should be adopted unless the known traffic along the route dictates a value greater than this.

5. **Depth of structure**

The structural depth may affect the vertical road alignment and hence the overall project cost. The lowest level may be determined by a calculated flood level and hence a minimum depth may be desirable. In other cases the bridge may be well above any flood level and the minimum depth may be relatively large. In this instance a “deck type” structure may be appropriate. An absolute minimum of 0.90 metres (from finished deck level to underside of edge beam) should be specified to prevent any potential supplier not complying with this requirement.

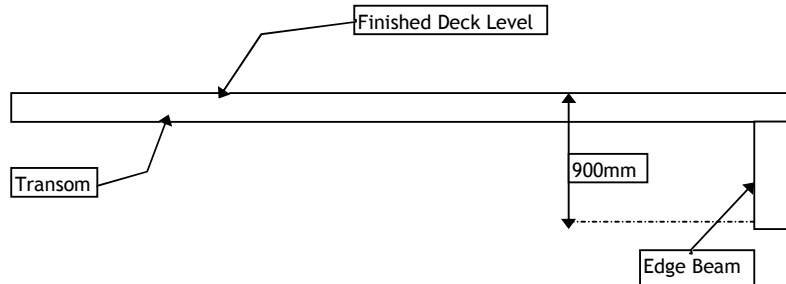


Fig 2.0 Minimum structural depth

5.3.2 **Design Loadings**

1. **Highway Live Loads**

The required clause will depend upon the requirements of the country to which the bridges are to be supplied. Some national standards refer to British Standards, others to AASHTO or Eurocodes and some countries may not refer to any. Problems can arise in the Specification of loading to one code and element design to another. This should be avoided

2. **Fatigue**

The design life of steel bridges is generally dependent upon the number of cycles of loading applied. The following table is a guide to the requirements for the Specification:

**Table 1 – Loading cycles for traffic volume and bridge location**

Location	Traffic volume	Number of Cycles
Rural	Low	200,000
Rural	High	500,000
Urban	Low	500,000
Urban	High	2,000,000

3. **Pedestrian Loading**

Pedestrian walkways should be designed for the appropriate loadings. If it is possible that these walkways might be used by traffic other than pedestrian traffic then appropriate loadings should be determined.

4. **Accidental Wheel Loading**

It is essential that all elements within the trusses that may be subject to wheel loads are adequate to support them.

5. **Wind load**

Wind loading is unlikely to be critical in the design of the simply supported superstructure steelwork but may be critical for the design of bearings and continuous superstructures.

## 6. Temperature

Temperature range is unlikely to be critical in the design of the superstructure steelwork but is likely to be critical for the design of bearings. The appropriate minimum and maximum values should be determined from local knowledge where these are not contained in national design standards.

## 7. Seismic effects

In some regions the effect of seismic events may be significant and due regard should be given to this in the design. It is outside of the scope of this document to provide values of horizontal acceleration coefficients for all locations. Reference should be made to national codes or specialist literature or available data. A vertical acceleration equal to 1g should be applied in either direction in all instances where horizontal effects are considered. Some categorisation of seismic resistance versus route importance may be appropriate. On routes of low economic importance it may be acceptable not to design for seismic loading and accept that a degree of re-construction would be necessary in the event of an earthquake.

### 5.3.3 Element Design

Individual elements should be designed to the appropriate standards compatible with the loadings.

### 5.3.4 Materials

#### 1. Structural Steel

The particular specification for steel should be stated

#### 2. Connections

The use of bolts in clearance holes in main longitudinal element connections shall not be permitted.

The use of site welding will not be permitted.

#### 3. Deck

There is good reason to specify a concrete deck on “permanent” bridges. They are quieter and more durable. However the construction period will be longer than with steel decking and the materials must be provided locally.

### 5.3.5 Corrosion Protection

At the present time it is not considered that paint systems should be considered for the corrosion protection of steelwork. There is an ongoing maintenance requirement to the recipient which it cannot be guaranteed will be fulfilled. Consequently only galvanising of main elements is included in the Specification.

### 5.3.6 Pedestrian Protection

In addition to providing an adequate barrier along the edge of an external footway, it is also important to prevent pedestrians from falling through the main trusses or panels when they are walking along an internal refuge. The loadings given in the Specification are those in BS 7818 for Class 2. This is “a normal duty guard rail and may be employed for all purposes except where crowd loading is anticipated or where the risk of vandalism is severe”.

## 1<sup>st</sup> AFCAP PRACTITIONERS CONFERENCE 23<sup>rd</sup> to 25<sup>th</sup> November 2010

### 5.3.7 Movement Joints

It is not anticipated that sophisticated proprietary movement joints will be required except in unusual situations. The clause is included to cover the design of any ancillary plates and the like that might be required between the end of the main structure and the abutment ballast wall to reduce the gap to a permissible size.

### 5.3.8 Bearings

Bearings should be as simple to install as possible.

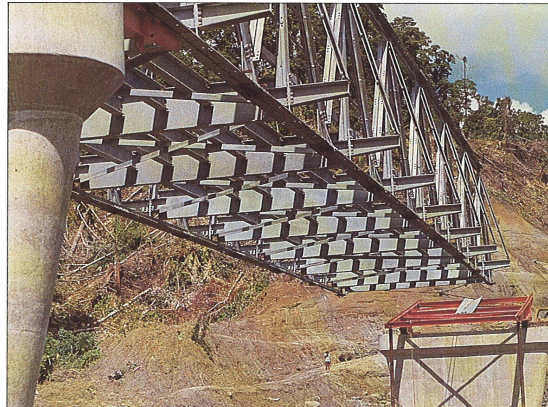
### 5.3.9 Identification, Packing and Shipping

Clear identification of, and prevention of damage to, components is essential in the types of structures covered by the Specification in order to allow easy erection.

## 6 Construction

The suppliers of the components of a modular steel bridge will base their design and the necessary temporary materials around a particular form of construction and provide a method statement for the safe and efficient erection of the bridge. The erection itself will not usually be undertaken by the supplier, though they may well provide advice. It is important that a team is established that has the ability to erect the structure in a methodical manner. This has historically often fallen to the duty of the engineering sections of the national army, given the association of this type of bridge with military activities.

Traditionally the majority of bridges have been erected by launching. This entails constructing the bridge on one bank and then pulling (or pushing) it across the gap to be spanned and lowering into its final position.



**Photo 3 – Launching**

More recently there has been a greater prevalence of erection by cantilevering across the gap from one abutment – progressively adding components to the tip of the structure until the full span is completed.



Photos 4 and 5 – Cantilever Construction

Both methods have their advantages and risks. Considerations to be borne in mind in selection of the method are:

- Available equipment
- Topography of the site
- Access – particularly to the remote side
- Experience of the workforce

### 6.1 Temporary Components

Some temporary components will be required to ensure stability during the erection phase.

For launching it is usual to include a “nose” of somewhat lighter construction than the final structure. This allows the counterweight (“kentledge”) that is required at the rear of the structure for stability to be smaller than would otherwise be the case. Should a nose not be used then stability can be maintained with a somewhat heavier counterweight.

To minimise the force required to push (or pull) the structure into position it is usual to provide temporary rollers over which the bottom chords of the trusses can move freely during their passing.

In the case of cantilever erection the requirement for a temporary nose is eliminated, but a greater counterweight will be required behind the abutment.

In some circumstances it may prove economic to construct a temporary, intermediate support in order to reduce the length of cantilever during both a launch or cantilever construction operation.

### 6.2 Plant and Equipment

As previously noted this type of bridge is designed to be erected with a minimum of mechanical assistance. It can, of course, be advantageous if such assistance is available.

Typically it would be of benefit to have the following available:

- Small crane for lifting components, particularly in the case of launched construction where construction is land based.
- Small crane or tripod hoist for lifting components at tip of cantilever when cantilever construction is used.
- Wheeled trolley on temporary rails to assist with transport of components from abutment to end of cantilever.

## 7 Local Fabrication Potential

The question of local fabrication is a commercial one that must be considered by local businesses.

## 1<sup>st</sup> AFCAP PRACTITIONERS CONFERENCE 23<sup>rd</sup> to 25<sup>th</sup> November 2010

The decisions that must be made are outside the scope of this paper and so only an indication of the benefits can be highlighted herein.

Raw materials will need to be imported as for any other form of construction, but all fabrication should be within local capacity.

If we return to the basic principles for these structures as defined in paragraph 2.1:

- There should be as few standard parts as possible.
- Varying spans and widths should be accommodated using combinations of standard parts.
- The parts must be easy and cheap to manufacture from standard available sections with a high degree of accuracy and uniformity.
- The individual parts must be of such size and weight as to permit easy transportation.

If these aspects are within the capability of an organised fabrication facility, even with modest technology, then with the right investment and encouragement there should be no reason why a local system should not be developed.

### **KEY WORDS**

Bridges, steel