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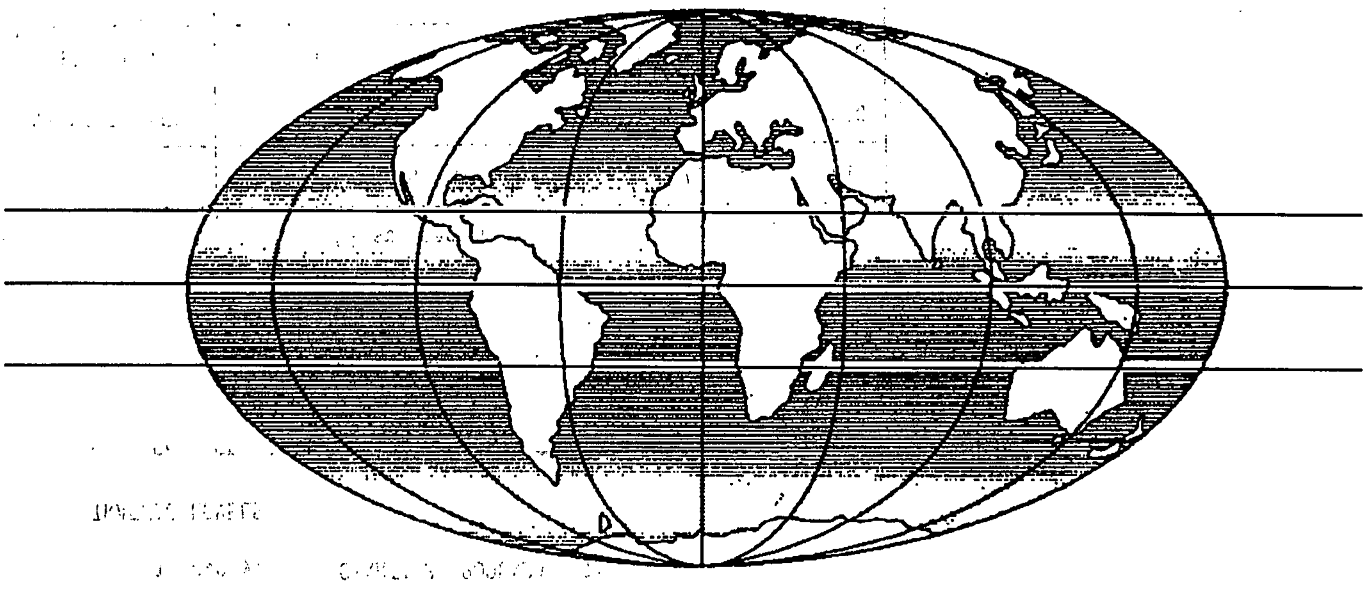
TITLE A design manual for small bridges

by J D Parry and T E Jones



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A DESIGN MANUAL FOR SMALL BRIDGES

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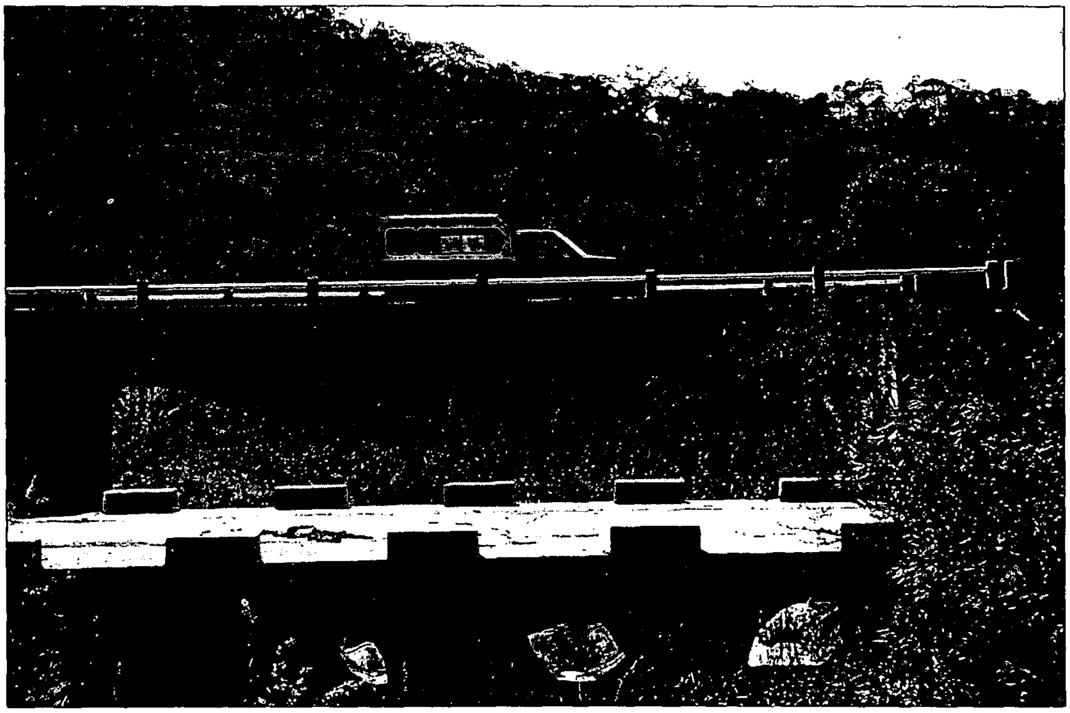


ABSTRACT

OVERSEAS ROAD NOTE 9 – "A design manual for small bridges" is the latest in the series Overseas Road Notes published by the Transport Research Laboratory as part of the Aid programme of the British Overseas Development Administration.

The vast majority of structures found on road networks in developing countries are relatively small. The manual focuses on these structures and brings together all the essential requisites for their design from the initial surveys, calculations of waterways, hydraulic measurements, soil bearing pressures to the final structural design.

It is intended for use by bridge engineers but is also aimed at the general civil engineer who has responsibilities other than for bridges. For these engineers particularly, standard designs and tables of dimensions are provided wherever they simplify the design process or save time in detailing and calculation.

This paper illustrates the methodology and summarises the main chapters of the manual.

1. INTRODUCTION

This manual offers highway engineers a comprehensive set of guidelines to assist and simplify the process of designing small bridges and culverts. These structures are an essential part of every road network. They are far more common than large bridges and are simpler to design and construct. For the purposes of the manual, "small bridges" are defined as single or multi span structures with individual spans no more than 12m long, i.e. taking one span to bridge a two-lane highway with shoulders or two spans to bridge a dual carriageway.

The guidelines cover the entire design process, from the planning stage through site investigations and materials analysis, hydraulic design and structural design, to the final preparation of drawings and detailed specifications. There are many textbooks and other technical publications that provide excellent treatments of all these aspects of bridge design: some are listed in the manual as useful reference material for readers wishing to pursue subjects in more detail. These sources, however, are all intended for bridge engineers or students of bridge engineering. The present manual is meant to be of use in a bridge design office, but it is aimed also at the general civil engineer who is not a bridge specialist but who may nonetheless be required to construct a road that crosses a river or other obstruction. He may be a provincial roads engineer, extending a regional network of feeder roads with permanent bridges, an army engineer or an engineer involved in famine relief distribution, needing rapid but temporary solutions to bridging problems.

Because these non-specialist bridge builders have other professional responsibilities, they rarely have the time or expertise to work out all the necessary bridge design calculations from first principles. For this reason, the manual gives as much guidance as possible in the form of drawings and tables, covering two standards of traffic loading, single or multiple spans, a range of bridge materials – concrete, steel and timber – and a range of in situ soils.

Though the structural design of small bridges can be simplified by the use of stock solutions, the process of hydraulic design cannot be shortened in the same way. The chapters that deal with river hydraulics, hydraulic design and river works contain all the background information and procedures that the bridge designer will need in order to apply the detailed structural tables set out in subsequent chapters, but they assume the knowledge and experience of a qualified engineer as well as the availability of basic facilities for field investigation and soils analysis.

Where there are several possible methods of calculating a variable – for example, allowable bearing pressure or scour depth – the manual presents only the simplest of these methods but includes references to others. When it is thought likely to be helpful, typical calculations are worked out in the appendices to chapters.

2. PLANNING

The first part of the manual is concerned with planning, site investigations, river hydraulics and the hydraulic design of the structure. Planning involves site selection, traffic prediction and design life. It is also necessary at this stage to make an accurate assessment of the available resources, as this has a bearing on the materials to be used and hence the type of structure.

The size and form of the bridge will be decided by the characteristics of the obstacle, whether it is another road, a railway or a river. The essential features are the height of the superstructure and its length and the possibility of employing piers. Also, for a river crossing, account must be taken of the maximum discharge to be accommodated by the main structure, together with relief culverts or occasional overtopping.

Most countries have design loading standards for bridges, but some have not yet determined an appropriate standard for rural roads carrying low volumes of traffic. This manual offers standard design that conform with British Standard loading for 40 tonne gross weight vehicles, and with AASHTO loading for 20 tonne gross weight vehicles. (BSI, 1978 and AASHTO, 1983).

Most two-axle medium commercial vehicles are loaded within the 15 tonne AASHTO limits, but when overloaded they may exceed these limits. HS 20-44 has therefore been used as a conservative standard. The British Standard HA 40 tables are recommended where overloaded three-axle lorries, forestry or quarry vehicles and construction plant are in use.

3. SITE SURVEY

Site selection is often a compromise between the simplest road alignment and the preferred bridge site. For a river crossing, the cheapest bridge site and the one that has the longest potential service life is that which:

- is on straight reach of the river
- is beyond the disturbing influence of large tributaries
- has well defined banks
- has reasonable straight approach roads
- permits as square a crossing as possible
- has good foundation conditions.

The purpose of the site investigation is:

- to measure the bearing capacity and characteristics of the soils at various depths all over the site and
- to establish river flow volumes, velocities and levels for normal and flood conditions.

Most river bridge failures result from the aggressive activity of the rivers and not the traffic carried. Attention is given in the manual to understanding the effects of water flow on bridge structures and the effect that bridge works may have on river flow that could result in new scour activity that in turn endangers bridge stability. Emphasis is laid on designing an adequate waterway through the bridge or culvert and protecting the foundations and river banks with rip rap, groynes, piled walls, aprons and curtain walls.

Fig. 1 illustrates the processes of both the planning stage and the design stage in the form of a flow diagram.

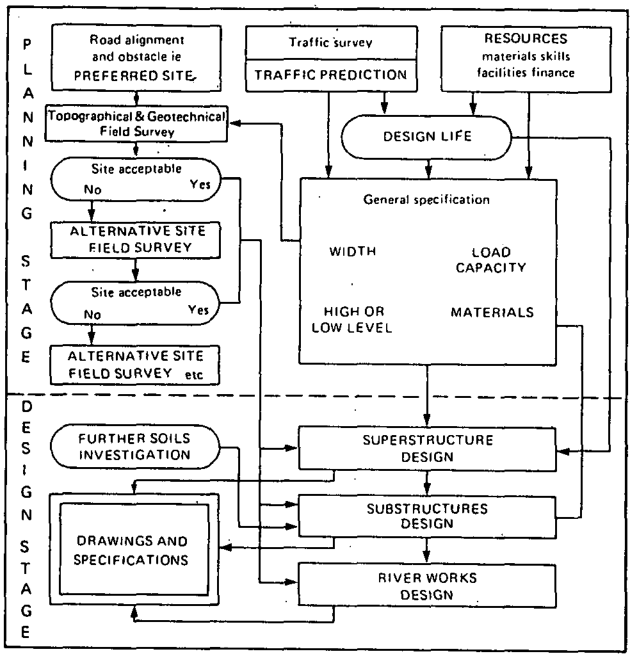


Fig. 1: Flow Diagram of the Design Process

4. SUBSTRUCTURES AND FOUNDATIONS

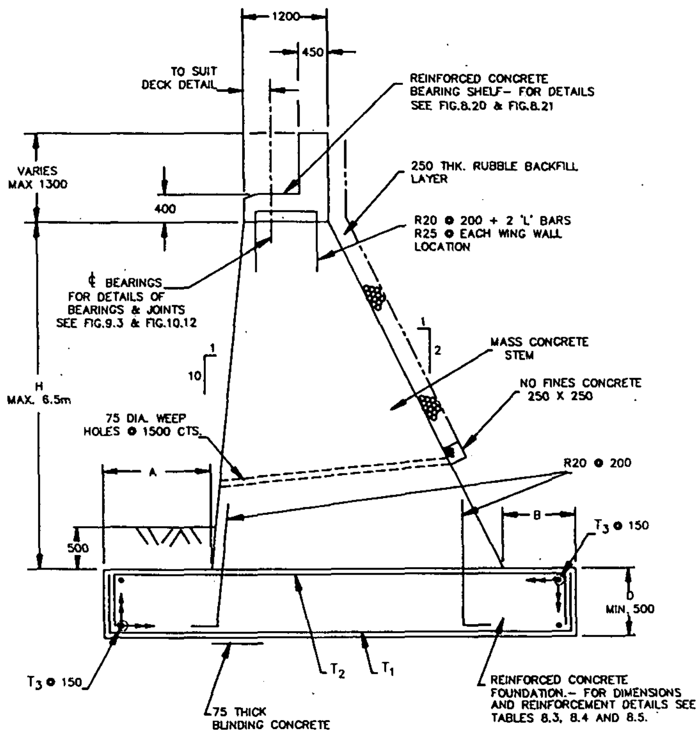
This section deals with the elements of a bridge that supports the dead load of the superstructure, resist the vertical and horizontal live loads on it from vehicles and the elements, retain the approach embankments and provide a smooth transition from road surfaces to the deck running surface. The essential features are:

- foundation slabs, that transmit the weight of the abutments and the superstructure directly to the supporting soil
- front walls with bearing shelves that support the superstructure and usually retain the soil of the embankment
- wing walls or retaining walls.

An important element of this chapter, and those concerning deck design, is the presentation of standard designs and tables of dimensions, whenever these can replace complex individual calculations. This includes a set of standard PC concrete abutment and pier drawings, with tables specifying dimensions, reinforcement etc., for spans up to 12m, heights to 6.5m and a range of soil conditions. The designs are conservative and take into account all the external forces from live and dead loads that substructures are normally expected to sustain.

Structural masonry may be used as a substitute for mass concrete. However, the engineer must be satisfied concerning the strength of the materials used, particularly when submerged in flowing water. A reinforced concrete bearing shelf for use with masonry abutments is also illustrated.

Fig. 2 is an example of the standard drawings that are presented for substructures.



ALL DIMENSIONS IN MILLIMETRES (mm).

Fig. 2: Abutment, Mass Concrete Vertical Section

Concrete abutments and piers may be built to support a timber superstructure that may be replaced at a later date with a more permanent material. In this case the final dead weight, width etc. are used in the abutment design.

5. SUPERSTRUCTURES

Superstructures are divided into three categories:

- reinforced concrete
- composite i.e. reinforced concrete and steel beams
- timber.

Reinforced Concrete Superstructures

This section presents standard designs for concrete slab decks from 4m to 12m spans for one, one and a half, and two lanes of traffic, for both BS-HA and HS20-44 loadings, using mild steel and high yield steel reinforcement.

Bearings

The simplest from of bearing is made by casting the concrete slab onto the abutment bearing shelf, with only a layer of bitumen felt separating the two concrete surfaces. This may be satisfactory for very short spans, up to 6m, but for longer spans there is a risk that thermal movements will damage both the supporting structure and the slab. For this reason simple rubber strip bearing are specified to support the slabs in the standard drawings.

Composite Superstructures

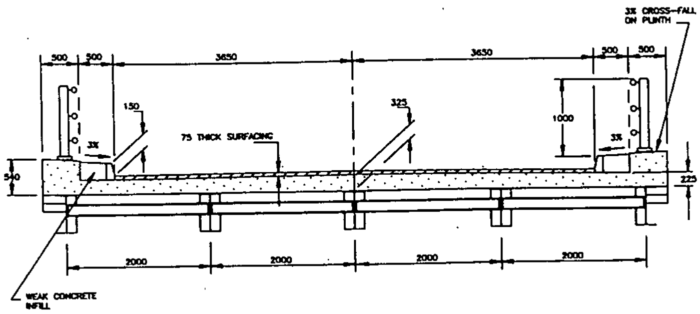
As an alternative to the solid concrete slab, this section presents a series of standard bridge decks constructed from steel beams with a composite concrete deck slab. The main beams and members are of standard rolled carbon steel sections, with the concrete slab reinforcement in either mild steel or high yield steel.

The advantages of steel/concrete composite deck structures are:

- ☐ The deck weight can be less than that of an equivalent all-concrete structure.
- ☐ The off-site prefabrication of the main load carrying elements of the bridge substantially reduced the work necessary on site, resulting in more rapid construction.
- ☐ No temporary supports are required during concreting of the deck slab, as the soffit shutters can be supported directly from the steel beams. This can be a particular advantage at locations with poor ground conditions, steeply sloping terrain, or with a fast flowing stream.
- ☐ Steel is a reliable material which is supplied with guaranteed strength properties, enabling structures of consistent reliability to be produced.

For permanent structures, adequate durability of the steel beams to ensure a service life of 50 years or more can be readily achieved by the use of a cast in situ concrete deck slab. Composite action of the slab and beams is achieved by the use of shear connectors welded to the top flanges of the beams and cast into the concrete.

An example of the standard drawings and tables for composite decks is shown in Fig. 3.



CROSS SECTION

B.S HA LOADING	
SPAN(m)	BEAM SIZE(mm)
6	457 X 191 X 67 UB
8	533 X 210 X 82 UB
10	610 X 229 X 113 UB
12	610 X 229 X 140 UB

AASHTO HS20-44 LOADING	
SPAN(m)	BEAM SIZE(mm)
6	457 X 191 X 67 UB
8	533 X 210 X 82 UB
10	616 X 229 X 101 UB
12	610 X 229 X 140 UB

Fig. 3: Composite Deck – 2-Lane Width

Parapets

Details of a suitable steel parapet system are also provided. Circular sections have been selected for the rails as they are most readily available throughout the world. Provision is made for badly damaged post or rails to unbolted and replaced.

Timber

This section contains designs for single-lane, timber beam decks suitable for AASHTO HS 20-44 loading and spans up to 12m. They are simple to construct and are particularly useful for rapid replacement of superstructures that have been damaged. Timber bridges like the one shown in Fig. 4 are common on rural roads in many countries.

Seasoned logs should be used whenever possible. They should be closely matched and positioned the same way, i.e. with the larger diameter ends all at the same end of the deck such that the decking planks can be fixed in contact with all the logs.

Rectangular timber beams, as shown in section in Figure 5, are also used as the main spanning members for bridges. Construction is easier with such a regular

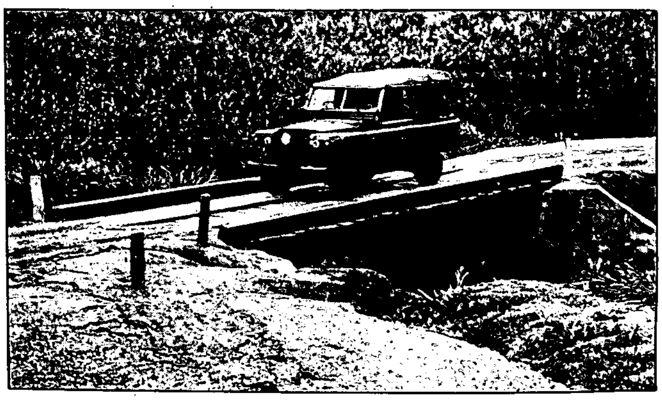
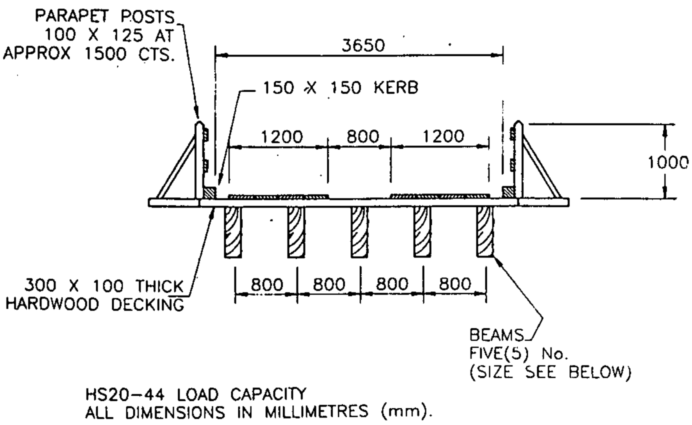


Fig. 4:



SPAN (m)	BEAM SIZE FOR TIMBER GROUP		
	GROUP A	GROUP B	GROUP C
4	150 X 375	150 X 500	200 X 550
6	150 X 475	200 X 550	200 X 700
8	200 X 500	200 X 650	250 X 750
10	200 X 600	250 X 725	300 X 850
12	200 X. 700	250 X 850	300 X 1000

Fig. 5: Timber Beam Bridge – Cross-Section

shape since each member rests on a flat surface and fixing of the decking to the beams is more positive.

Five further chapters in the manual discuss

- low level water crossings
- culverts
- emergency and temporary structures
- bridge building materials
- drawings and specifications

It is the purpose of this manual to provide all the necessary procedural guidance, tables, dimensions and material specifications to enable a civil or mechanical engineer with some field experience to prepare appropriate designs. A limited number of copies is available free of charge to government or educational organisations and individuals engaged in or studying highway engineering. Commercial organisations are asked to pay 10 pound sterling to cover packing and airmail cost.

6. ACKNOWLEDGEMENTS

This manual is based on a draft commissioned from Rendel Palmer and Tritton of London and includes additions and amendments from reviewers in Kenya, Zimbabwe, the Philippines and the United Kingdom. It is published by permission of the Chief Executive of the Transport Research Laboratory and forms part of the programme of work of the Overseas Centre sponsored by the Overseas Development Administration.

7. REFERENCE

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PARRY J D, 1991, A design manual for small bridges. Overseas Road Note 9. Crowthorne: Transport and Road Research Laboratory.