STRUCTURES MANUAL

1ST EDITION

OCTOBER 2014

This document has been prepared for the Roads Authority of Namibia for the exclusive use of the Roads Authority and Consultants employed by the Roads Authority.

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The Chief Executive Officer
Private Bag 12030
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www.ra.org.na

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PREAMBLE

Summary of Contents

Preface

The Roads Authority of Namibia is a statutory body established in terms of the Roads Authority Act, Act 17 of 1999.

Section 3 of the Act sets out the object of the Authority as follows:

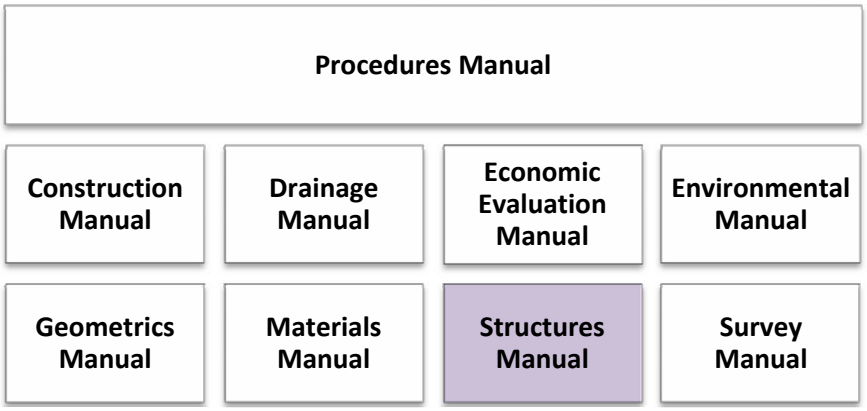
"Subject to this Act and the Road Fund Administration Act, the object of the Authority is to manage the national roads network in accordance with section 16 with a view to obtaining a safe and efficient road sector."

It is important to understand that "efficient" includes economic and financial efficiency as well as the common understanding of the word.

Key clauses of the Roads Authority Act that are of particular relevance to operational issues are Section 15 wherein the Roads Authority's functions are set out; and Section 16, which elaborates on one of these functions that being the management of the national road network including inter alia:

- The planning, design, construction and maintenance of roads;
- The quality control of materials required for the construction and maintenance of roads;
- The supervision of work contracted out; and
- The prescribing of minimum standards to achieve a safe road system and cause the least possible disruption to the environment.

These four aspects of the Roads Authority's mandate are complex and wide ranging. In order to assist it to comply with these obligations, the Roads Authority commissioned a suite of manuals applicable to road work and related matters. It consists of the following interlinked units:



The Geometrics Manual is supported by the **Standard Drawings** and the **Traffic Signs Policy**.

Additional manuals, such as a Maintenance Manual, may in future be required.

The Procedures Manual

The Procedures Manual is the controlling document of the suite of manuals depicted above. It describes the duties and responsibilities of consultants contracted to the Roads Authority for the preparation of designs, tenders for, and supervision of construction of roads by contract. It is also relevant to other projects such as feasibility studies and other investigations and studies carried out on behalf of the Roads Authority. In short, it is relevant to all projects carried out by external service providers for the Roads Authority.

Roads Authority personnel carrying out similar functions are also subject to the requirements of the Procedures Manual.

The manuals in general

The purpose of the suite of manuals is three-fold:

- To provide a basis for the attainment of uniformity of action of all persons carrying out design and related work for the Roads Authority, whether these be in-house personnel or external consultants;
- To promote the attainment of uniformity between in-house personnel and external consultants in the handling of construction projects.
- To set out the minimum standards and requirements of the Roads Authority, either directly in a specific manual or through its linkages with the other manuals in the suite.

These manuals are to be seen as books of reference and instructions to be used in the planning, design and administration of projects.

Both relevant in-house personnel and all consultants are therefore expected to make themselves thoroughly familiar with the contents of the Procedures Manual and such other manuals as may be relevant to a project, so that each project can pass through the different stages of planning, design, tendering and construction satisfactorily and that the submission of reports, records, drawings, documents, etc. is according to requirements.

Consultants must supply copies of relevant manuals to each designer and Engineer's Representative employed on construction contracts for the Roads Authority, which latter copies shall be kept at each Site Office.

Should any portion of this manual appear to be contradictory, either internally or in relation to any other manual; or insufficiently detailed, the Project Control Engineer must be contacted for a ruling.

Constructive criticism and suggestions for improvement of any of the manuals would be appreciated and should be addressed to:

The Chief Executive Officer, Roads Authority, Private Bag 12030, Windhoek, Namibia

with a copy to the Project Control Engineer.

Access to the manuals

The manuals can be downloaded from the RA website at: www.ra.org.na The RA will only upload the current amendment of the manuals on the site. It however remains the responsibility of the Consulting Engineer, upon his appointment, to confirm with the Project Control Engineer that the manuals on the website are the versions required for his specific appointment.

Definitions

The following definitions are relevant to all manuals:

Agreement	is the completed Agreement between the Roads Authority and the Consulting Engineer. Such Agreements may have different titles, depending on the source of funding.
Chief Executive Officer	is the person appointed under Section 14 of the Roads Authority Act to serve as Chief Executive Officer of the Roads Authority.
Date of Agreement	is the date on which it was signed by the last person signing.
Engineer	is the Consulting Engineer appointed by the Roads Authority to prepare a project or contract documents, or to supervise the execution of a contract.
Ministry	The Ministry of Works and Transport of the Government of Namibia
Permanent Secretary	is the official appointed to the post of Permanent Secretary of the Ministry of Works and Transport
Project Control Engineer	is the official appointed by the Chief Executive Officer to coordinate the execution of a specific project and to act as a link between the RA and the Consulting Engineer.
Roads Authority	is the Roads Authority constituted in terms of the Roads Authority Act, Act 17 of 1999

Guidelines for users of the manuals

The following icons are used throughout this edition of the Manuals:

CAUTION – This icon, usually accompanied by highlighted text, indicates that the user must be aware and use caution when following certain procedures or deviating from standard design methods.

YIELD – This icon indicates that the Roads Authority must be informed of an issue. This might be a deviation from the Terms of Reference; a deviation from design standards; or the achievement of milestones. Work may however continue.

STOP – Unlike for the yield icon, the stop icon indicates that the Roads Authority's written approval must be obtained before commencing with any further design or other tasks related to the issue for which approval is to be obtained.

NO ENTRY – This icon indicates no-go areas for practitioners. These could be set values for certain variables, or certain processes that may not be followed.

WORK IN PROGRESS – The "men at work" icon is used where sections can and should be extended or where work is pending. Due to funding or time constraints these parts or sections are not yet included in the manual.

Copyright of work done by the Consulting Engineer

All field books, data, calculations, plans, reports and tender documents produced in consequence of an appointment by the Roads Authority to carry out work in terms of these Manuals, become and remain the property of the RA upon submission of these items to the Roads Authority.

Acknowledgement

In preparation of this and the other manuals comprising this suite of manuals applicable to road works, considerable use, including direct application, has been made of similar work done previously by the predecessor in title of the Roads Authority and by other authorities, notably the manuals, directives and memoranda of the Western Cape Provincial Administration (South Africa), the Department of Transport (South Africa) and the South African National Roads Agency Ltd (SANRAL). These sources were used with due permission. The Roads Authority acknowledges with thanks the valuable content from these non-Namibian sources used in the Manuals, as well as that from Namibian sources such as the Meteorological Services, the Ministry of Environment and Tourism and others. It goes without saying that the Roads Authority also acknowledges with thanks all individual authors who contributed to the source documents from which content has been taken for use in these manuals.

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Tables

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1 INTRODUCTION

1.1 Objective

The aim of this manual is to set out the procedures and criteria which must be applied in the planning and design of bridges and other structures for the Roads Authority. The manual also gives an indication of an orderly set of drawings together with the information that must appear thereon.

The manual indicates what must be done but generally speaking, not how things should be done. It is therefore not intended as a replacement for engineering knowledge, experience and judgement. It is consequently also a requirement that the practitioner use ingenuity and originality in the design of the structure.

However, if ingenuity or originality implies a deviation from the procedures and criteria laid down herein, prior approval must be obtained from the Project Control Engineer.

Special procedures may have to be followed when third parties are involved such as Local or Rail authorities or foreign countries in the case of interstate bridges. Details must be obtained from or agreed with the Project Control Engineer.

1.2 Codes of Practice and Specifications

The codes of practice referred to in this manual are listed hereunder:

- Code of Practice for Design and Construction of Road-over-Rail and Rail-over-Road Bridges;
- TMH7 - Code of Practice for the Design of Highway Bridges and Culverts in South Africa;
- BS 5400 - Steel, Concrete and Composite Bridges; and
- BS 8004 - Code of Practice for Foundations.

The latest edition shall always be used.

BS 5400 and BS 8004 have been replaced by Eurocode. Until Eurocode is rolled out in southern Africa, the above codes will continue to be used.

The COLTO Standard Specifications for Road and Bridge Works for State Road Authorities shall be used for standard specifications. This document has requirements with regard to information to be shown on drawings. Drawings must comply with the requirements of this document.

Note that the COLTO specifications refer to SABS standards. SABS standards are being updated and are now referred to as SANS standards. Wherever an SABS standard is referred to, the latest SANS version, if published, shall be used.

When designing using non-standard techniques or elements such as incremental launching, balanced cantilever construction, precast segmental construction, cable-stayed structures, long railway structures, etc. reference must be made to international best practice, as TMH7 does not cover these approaches.

1.3 Reference to Other Manuals

This manual must be read in conjunction with the other manuals of the Roads Authority. This is specifically applicable with regard to the following:

1.3.1 Survey requirements

Site surveys shall be carried out for all bridges forming part of a project. The requirements for bridge site surveys are set out in the Survey Manual.

Site surveys are not normally required for culverts, but may be called for in the Terms of Reference or during the course of the project. In such cases the requirements of the Survey Manual in respect of bridge site surveys shall be complied with. Sufficient detail must however be picked up at all culverts so that the position, angle of skew, possible stream realignments and invert levels of all culverts may be determined satisfactorily.

1.3.2 Geotechnical requirements

The geotechnical investigations required for bridges as set out in the Procedures Manual shall be complied with.

2 DEFINITIONS AND IDENTIFICATION OF BRIDGES AND SUBSTRUCTURE ELEMENTS

A clear distinction is made in the prescribed procedures between major and minor structures. Major structures are generally bridges, while culverts and other road-related structures are classed as minor structures.

Structures not dealt with directly in this manual shall be considered to be Special Structures and dealt with accordingly.

The following definitions are specific to this Manual:

2.1 Major Structures

Bridges - A structure is defined as a bridge or major structure if it complies with any one of the following conditions:

- The length of any single clear span, measured perpendicular to the abutment or pier faces, is equal to or more than 6 m;
- The sum of the lengths of the clear spans is equal to or greater than 20m where multiple spans smaller than 6,0m are used;
- The difference in height between the top level of any foundation and the soffit of the deck is more than 6 m;
- If it is a grade separation structure, regardless of span or length; or
- If it is a road-over-rail or a rail-over-road structure, regardless of span or length.

Major Road - For the purposes of the following definitions of Underpass and Overpass, the major road at the crossing is that which carries the higher classification, eg if a Trunk Road and a Main Road cross, the Trunk Road will be regarded as the major road, irrespective of the traffic counts. Where both roads carry the same classification, the road with the higher traffic count will be regarded as the major road.

Overpass - An overpass is defined as a bridge over a major road.

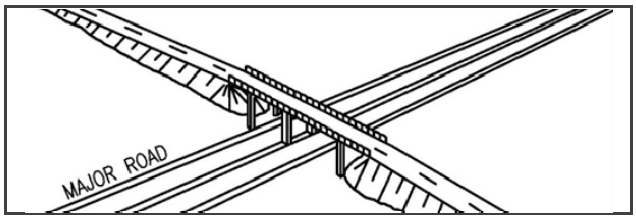

Figure 2-2 : Overpass

Underpass - An underpass is defined as a bridge under a major road.

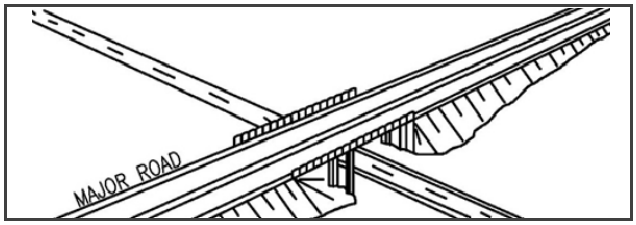

Figure 2-3 : Underpass

2.2 Minor structures

Minor structures are major culverts and other structures which do not comply with the definition of bridges (major structures). Auxiliary structures such as retaining walls, sign gantries, concrete traffic barriers, drifts, etc, are also classed as minor structures.

Major Culvert - A major culvert is a structure under a road which are not culverts designed from standard drawings or catalogues, which does not comply with the definition of a bridge, and which has a clear span equal to or more than 2.1m or with an opening equal to or exceeding 5.0m^2.

The Project Control Engineer may direct that a drift be constructed in lieu of a culvert.

Where an open water carrying structure or canal has to be included this shall be considered a minor structure.

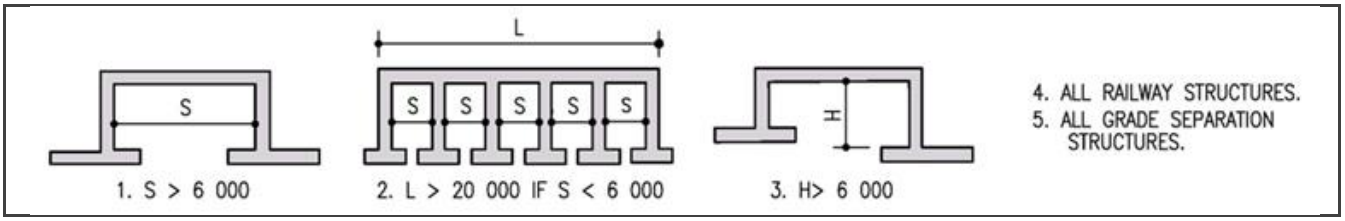

Figure 2-1 : Bridge

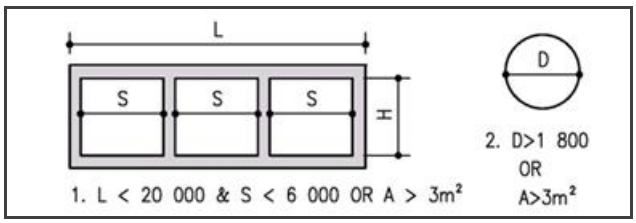

Figure 2-4 : Major Culvert

Retaining Wall - A retaining wall is defined as any structure retaining an excavation or a fill.

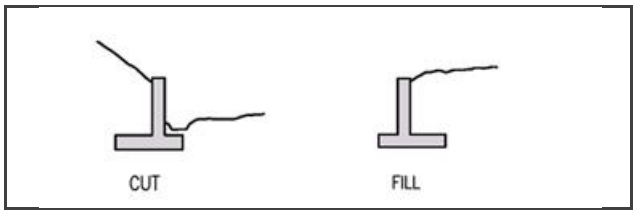

Figure 2-5 : Retaining wall

Sign Structure - A sign structure is defined as any gantry or cantilever structure which supports a road sign over or adjacent to a road. (All sign structures are regarded as minor structures despite the fact that some could be bridges according to 2.1).

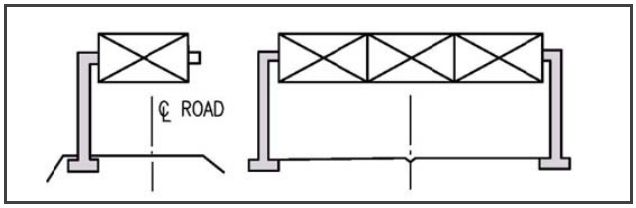

Figure 2-6 : Road sign structure

Cattle Creep - A cattle creep is a structure allowing the passage of animals under the road.

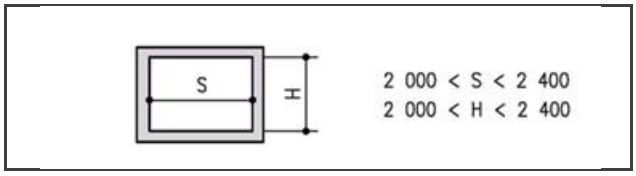

Figure 2-7 : Cattle creep

Pedestrian Underpass - A pedestrian underpass is a structure allowing the passage of pedestrians under the road.

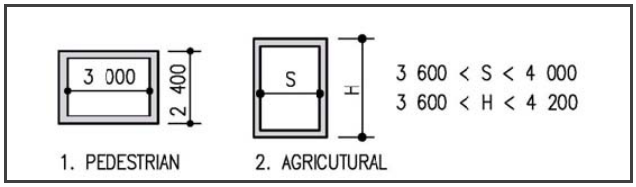

Figure 2-8 : Pedestrian/Agricultural underpass

Agricultural Underpass - An agricultural underpass is a structure allowing passage under the road for cross access for a farm.

Agricultural Overpass - An agricultural overpass is a structure allowing passage over the road for cross access for a farm.

Traffic Barrier - A traffic barrier is a specially designed concrete structure that serves as a safety element either in the median on dual carriageway roads or on the edges of any road in potentially dangerous positions.

2.3 Special structures

Structures not described under major or minor structures above shall be classed as Special Structures, such as tunnels.

In consultation with the Project Control Engineer, Special Structures may be classified as either major or minor structures and shall be treated in similar fashion to other structures in that category.

2.4 Identification of bridges and substructure elements

2.4.1 Bridge numbers

Bridges are the only structures that are assigned identification numbers.

These are known as bridge numbers and must be obtained from the Project Control Engineer after approval of the Preliminary Design Report.

Once these numbers have been issued, they must be referred to in all subsequent correspondence.

The assigned bridge number must be cast into each structure in the manner and at the positions shown on the Standard Drawings.

The process that must be followed to obtain bridge numbers is set out hereafter:

After the approval of the Bridge Schedule in the preliminary design report (example of completed bridge schedule in Figure 2.4.1 in Annexure), application for bridge and file numbers are requested from the Project

Control Engineer. The following documents must accompany all applications for bridge numbers (schedule to be completed shown in Annexure 2.4.2 in Annexure):

- Covering letter;
- Bridge Schedule :
  Bridges may provisionally be numbered A, B, C, etc. as shown in the first column of the bridge schedule. The spelling of place names, rivers, railway lines, farm names, etc. must be in accordance with the 1 : 50 000 topographic cadastral printed sheets of the Surveyor General;
- A completed 1:50 000 Strip Plan
  Where roads cross densely built-up areas and bridges are too close together and not clearly discernible on the 1 : 50 000 strip plan, it may be necessary to prepare a larger scale plan to clarify the position;
  The following information must be shown on the strip plan:
  - road alignment plotted accurately from co-ordinates;
  - interchanges; section distance in kilometre, with a note of the datum point;
  - position of the bridges with relevant information such as name, km-distance and number as shown on the Bridge Schedule;
  - numbers of intersecting roads crossing the road;
  - other relevant information affecting the road such as new roads, railway lines, airports, beginning and end of contract, etc; and
  - a Bridge Schedule as approved at Preliminary Design Stage, if any

NB: Although names of bridges and interchanges will be allocated by the Project Control Engineer, proposals in this regard may be shown on the bridge schedule.

2.4.2 Abutment and pier designations

The convention which must be followed in identifying abutments and piers is given in the Standard Drawings.

3 HYDRAULIC REQUIREMENTS

3.1 Design flood

The design flood shall be calculated in accordance with the requirements of the Drainage Manual.

3.2 Freeboard

The freeboard at a structure shall comply with the requirements of the Drainage Manual.

3.3 Additional Requirements

3.3.1 Afflux/Backwater and velocity of flow

Afflux for the design discharge, shall:

- Be limited by the consequences of inundation which may be attributed to such afflux; and
- Not exceed 0.6 m unless agreed to by the Project Control Engineer.

3.3.2 Flood damage restriction

The incidence of flooding shall not be regarded as an infrequent extreme event. All culvert and bridge sites must be inspected with a view to identifying soil erodibility, stream meanders and possible long term embankment settlements. The design shall recognise the necessity to restrict flood damage and attention shall be paid, in particular, to the following:

- The founding conditions at each site shall be physically explored and such exploration shall be adequate and meticulous;
- Natural stream meanders shall be studied and the anticipated direction of floodwaters considered in locating the structure. If necessary, channel changes shall be excavated and river training works or other construction which would reduce erosion problems and the risk of damage to the structure considered. Where appropriate, canalisation of a new stream bed should be considered.
- Where relief bridges or culverts are used to maintain natural flow distribution and reduce backwater, caution shall be exercised in proportioning the size and in locating such structures to avoid undue scour or changes in the course of the main stream channel.
- Structures shall, wherever economically feasible, be founded on rock or other non-erodible material. Where not so founded and where the stream discharges at erosive velocities, protection against damage shall be provided by curtain or cut-off walls, rip-rap, stream bed paving, sheet piles, gabions or other suitable means;
- Embankment slopes adjacent to all structures subject to erosion shall be adequately protected by rip-rap or other appropriate means ;
- The clear width of all high-level structure openings shall be sufficient for the passage without damage to the structure of the largest flotsam or debris which may be expected. For bridges designed to be overtopped, precautions shall be taken to minimise damage to the structure by debris and flooding;
- Caution shall be exercised in the utilisation of rigid "floating" structures, such as cellular concrete culverts, which may suffer damage due to relatively small bed disturbances;
- Piers shall be so located as to afford minimum restriction of the waterway, especially in the main stream channel. In general, piers shall be placed as nearly parallel to the direction of the stream current as is practicable, due consideration being given to the speed and direction of the current at both the ordinary and high water states to avoid such deflections of the current as may cause damage to the foundations of the structure or to the adjacent stream banks; and
- Solid piers shall be used in preference to open trestle-type piers where there is a potential for a large amount of debris to be trapped.

3.3.3 Structural features

Open abutments are not favoured on river structures and should only be used where it can be shown that there is considerable economic advantage. The cost of embankment and protection works must be included in such an economic exercise.

Abutments on piles must be placed deep enough and with the provision of cut-off walls to prevent settlement of the road embankment behind the structure during floods.

Square-ended piers are not acceptable. They shall be either pointed or preferably, where reasonably practical, rounded.

3.3.4 Scour

Consideration must be given to the effects of scour.

Scour shall be calculated in accordance with the requirements of the Drainage Manual.

3.3.5 Bank protection works

Bank protection works, where required, shall be provided up to high flood level for the design return period only.

4 DESIGN STANDARDS

4.1 Introduction

All structures shall be designed to be functionally and aesthetically pleasing and effective. A degree of uniformity is desirable for the structures to be included in any one contract so that construction economies can be effected.

The serviceable design life of structures for cost-benefit analysis purposes in accordance with the Economic Evaluation Manual must exceed the specified 20 year analysis period and could be regarded as 50 years for minor structures and 100 years for major structures. In the case of most rural roads with a reasonably permanent horizontal alignment a residual life for major structures could hence be motivated in the economic evaluation.

4.2 Bridge Geometry

4.2.1 Vertical clearance

The minimum vertical clearance over the full width including shoulders, of any proclaimed roadway shall be 5.2 m for a vehicular structure and 5.5 m for a pedestrian structure (see Figure 4.1). The minimum vertical clearance to sign gantries shall be 5.7 m. The abovementioned clearances include an allowance of 0.1 m for possible future resurfacing of the road passing under the structure.

On existing bridges where the minimum vertical clearance falls below 4.9 m, clearance shall be restored to 5.2 m by raising the deck or by lowering the road.

This requirement shall however be discussed with the Project Control Engineer (PCE) who may instruct clearance restriction warning signs to be installed instead of rectifying the clearance.

4.2.2 Horizontal clearance

The horizontal clearances shall comply with the standards shown on Figure 4.1. These also apply to sign gantries. Where the use of these clearances results in substandard sight distances, they shall be increased to meet the geometric design requirements.

Where it is the intention to widen the road passing underneath the bridge at some future date, allowance must be made for this in determining the horizontal and vertical clearances.

On existing bridges where the horizontal clearance is sub-standard, this must be discussed with the Project Control Engineer. Guardrails or concrete barriers may be required in such cases, together with appropriate warning signs.

4.3 Temporary clearances during construction

Lane widths may be reduced during construction to 3.4 m. This may be further reduced to 3.0 m if appropriate traffic calming measures are installed.

Vertical clearance may be reduced to 4.9 m during construction. This may be further reduced to 4.7 m if appropriate warning signs as well as a rigid gauging gantry are erected.

Temporary sub-standard clearances shall be agreed to by the Project Control Engineer.

4.4 Bridge widths

Bridge and structure widths shall comply with the standards shown in the Standard Drawings of the Roads Authority.

4.5 Railway structures

The clearances and other design aspects of railway structures shall be in accordance with the latest edition of the Code of Practice for design and construction of road-over-rail and rail-over-road bridges of TransNamib.

Plans for railway structures must be on the same size sheets as for road bridges, with provision for approval by TransNamib, after approval by the Project Control Engineer.

4.6 Medians on bridges

Medians at bridges on divided highways shall be decked over where:

- The product of the distance between the edges of inside balustrades or parapets and the bridge length is less than 180 m²; or
- The distance between the edges of inside balustrades or parapets is less than 3 m for any length of bridge; or
- The necessity of constructing solid concrete protecting parapets across the median e.g. for structures over electrified railway lines, would otherwise arise; or
- Analysis shows that it is economically advantageous to deck the median in.

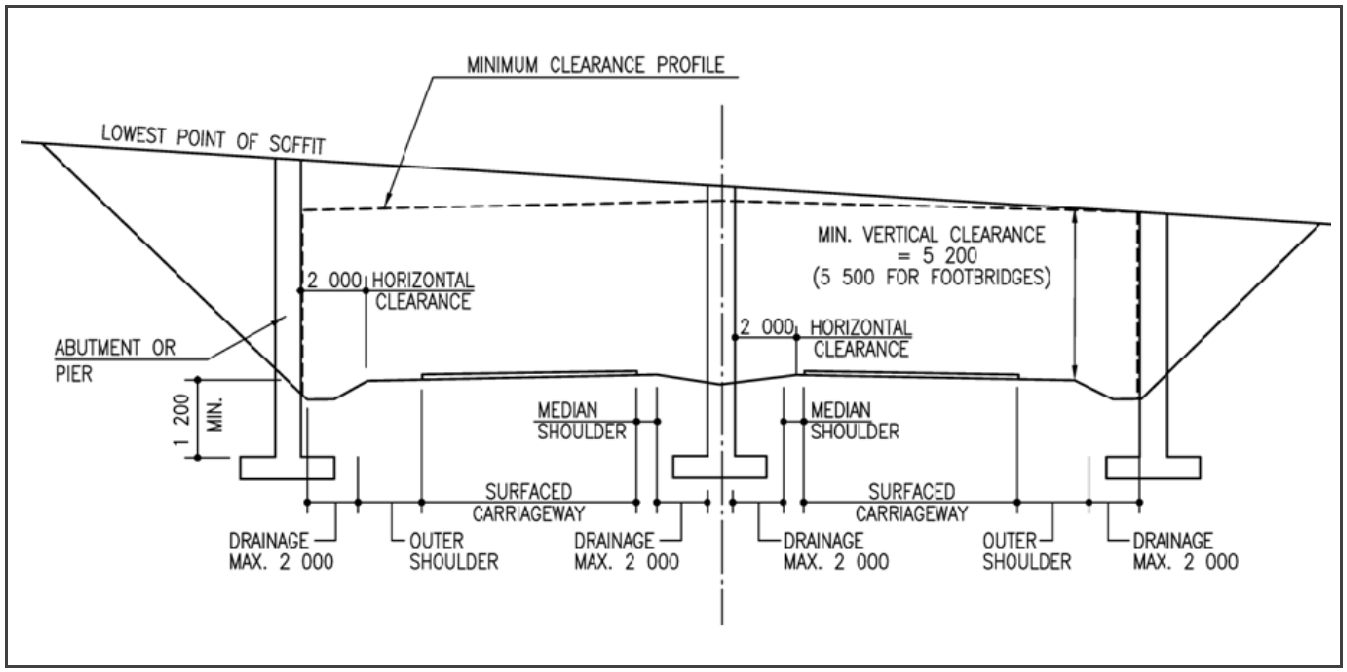

Figure 4-1 : Clearance diagram (double carriageway shown)

4.7 Pedestrian facilities

No elevated sidewalks are to be provided on freeway bridges.

Where the expected pedestrian volume exceeds 500 per day; or the bridge forms the access route between a residential area and a school, industrial or commercial area, a sidewalk of at least 1.2 m wide shall be provided, with the New Jersey type bridge parapets raised to suit a 180 mm high kerb to the sidewalk.

4.8 Parapets

Parapets shall be the New Jersey type designed and detailed in accordance with the details shown in the Standard Drawings.

For railway bridges, the requirements of TransNamib shall be met in respect of parapets.

4.9 Length of wing and return walls and jack spans

Where the approach road to the structure is in fill, the lengths of wing and return walls of abutments of bridges and culverts and lengths of jack spans shall be based on the flattest of the following slopes:

- The natural angle of repose of the fill material;
- 1:1½; or
- 1:2 where the fill height is less than 2 m; or

Where the fill is at risk of being eroded, is shall be clad in block paving, grouted stone pitching, concrete slabs or similar protection.

The end of the wingwall shall be a minimum of 300 mm beyond the theoretical point of intersection of the road surface with the above slope.

5 LOADINGS

5.1 Scope

This section covers the loads to be used in the design of road structures and is applicable to dead loads, superimposed dead loads and live loads which are normally encountered.

Guidance is provided here as to the intensity of the loads that must be provided for the various classes of route or structure.

Note that all actions must be increased by the factor γfL x γf3 where γf3 is equal to:

- for Serviceability Limit State;
- 1.15 for Ultimate Limit State where plastic or yield line theory is used; and
- 1.10 for Ultimate Limit State where elastic theory is used.

5.2 Load Specification

5.2.1 General

The quantitative and qualitative description of the loads to be used in design unless otherwise amended by this document shall be according to TMH 7, the Code of Practice for the Design of Highway Bridges and Culverts in South Africa, Parts 1 and 2.

The specification of the loads and the partial load factors to be used must be taken from Part 2 of the TMH 7 document which has been formulated for use with the Limit State Design Method.

5.2.2 Nominal superimposed dead load (Clause 2.3.1, TMH 7 Part 2)

A minimum design thickness of 100 mm of asphalt over the full surfaced width of the structure shall be used. This is to allow for future overlays or future correction for creep.

5.2.3 Traffic loading for bridges

The traffic load to be applied to a bridge shall be confirmed with the Project Control Engineer, who will take cognisance of the current and future planned use of the route or road for which the bridge is designed.

The general classification is included in Table 5-1:

TYPE OF ROAD	LOADING
District	NA + NB24
Main	NA + NB24
Trunk	NA + NB30 + NC24
Freeway & Super load routes	NA + NB36 + NC30

Table 5-1 : Bridge loading

5.2.4 Traffic loading on culverts

Traffic loading on culverts, which include minor and major culverts, must comply with Clauses 2.6.6 and 3.6 of Part 2 of TMH 7.

5.2.5 Traffic loading on sidewalks and cycle tracks

Where bridges carry traffic loads as well as sidewalk and cycle track loads, the full width of the deck must be designed to carry traffic loading to allow for future widening of the roadways.

5.2.6 Parapets

Parapets shall be classified as follows:

Class I - those that are required to resist impact by vehicles on highway bridges;

Class II - those that are required to contain only pedestrians on highway or pedestrian bridges; and

Railway parapet - those that must comply with the requirements of TransNamib.

Class II balustrades shall only be used on highway bridges where a barrier capable of resisting the loads prescribed for a Class I parapet and of height above road level not less than 700mm is introduced at the inside edge of the sidewalk.

5.2.7 Traffic impact forces on bridge supports

The minimum design speed "v" in Clause 3.7.2 of Part 2 of TMH 7 shall be 120 km/h.

5.2.8 Wind action

In the case where the forces caused by wind action are insignificant, such as concrete slab or beam and slab bridges where the length is less than 20m, width more than 10m, and the average height of the structure above ground is less than 10m, no assessment of wind action need be made.

5.2.9 Flood action

The additional horizontal force caused by debris (Clause 3.9.2.2 of Part 2 of TMH 7) shall be taken as 180 kN, except if it can be shown that the force can be reduced. The minimum value of the force is 90 kN.

5.2.10 Earthquake action

Earthquake action forces can be ignored when the bridge length is less than 20 m or the average height is less than 10 m.

5.2.11 Temperature effects

The extremes of shade air temperature in Clause 4.5.2 of Part 2 of TMH 7 shall be as follows:

DESCRIPTION	TEMPERATURE °C	
	MIN	MAX
Coastal (less than 5km from coast)	10	40
Inland	-5	45

Table 5-2 : Air temperature limits

No adjustment for altitude need be made to these figures.

5.2.12 Nominal force for frictional bearing restraint

The following additional values for frictional bearing restraint are to be added to Clause 4.5.7.3 of TMH 7 Part 2.

DESCRIPTION	COEFFICIENT OF FRICTION
Sliding bearing, steel on hard copper alloy	0.15
Sliding bearing, steel on steel or cast iron	0.25

Table 5-3 : Coefficient of friction

These values can be used where no tests have been done to determine the coefficient of friction.

For elastomeric bearings where displacements are accommodated by distortion of the rubber, the force F shall be derived from the equation:

$$F = A \times G \times \Delta / T$$

where:

- A = loaded modulus of the rubber
- G = shear modulus of the rubber
- Δ = maximum displacement to be accommodated by the bearing

T = total thickness of rubber in the bearing

6 DESIGN

6.1 Concrete bridges

Concrete bridges shall be designed in accordance with TMH 7 Part 3.

The use of other design codes such as Eurocode, BS5400 and CEB/FIP will only be allowed if TMH 7 is unclear, or if these codes are specifically referred to in this manual.

6.2 Steel bridges, composite steel bridges and steel overhead sign structures

These structures shall be designed in accordance with BS 5400 Part 3 and Part 5.

6.3 Supplementary Codes

Where designs are not covered by the above Codes, a suitable Supplementary Code may be used, which must be approved by the Project Control Engineer in advance of its use.

Eurocode may be used in the following cases:

- Rail-structure interaction on long railway bridges;
- Rolling-stock dynamic analysis on railway bridges classed as sensitive in terms of Eurocode;
- Vibration on pedestrian bridges on structures classed as sensitive in terms of Eurocode;
- Creep and shrinkage on structures sensitive to these, including balanced cantilever and long bridges. The proposed mix design must be tested for creep and shrinkage to calibrate the creep and shrinkage model.

6.4 Special design provisions

6.4.1 Exposure conditions

Structures within 60 km of the coast or subject to mild pollution effects shall be considered to be in a "Severe" environment for the application of Table 1 of Part 3 of TMH 7.

Structures within 5 km of the coast or subject to severe pollution effects shall be considered to be in a "Very Severe" environment for the application of Table 1 of Part 3 of TMH 7.

Under any exposure condition where the backfill material is aggressive, all shuttered concrete faces of abutments, piers and cast in-situ culverts that will be in contact with earth shall be painted with 2 coats of bituminous waterproofing compound complying with SABS 1183 to provide for a total dry film thickness of not less than 500 microns.

6.4.2 Deflections

Clause 2.2.4 of TMH 7 Part 3 shall apply.

The instantaneous deflection under live loading shall not exceed 1/800 of the span, nor shall the instantaneous deflection under transient forces or the delayed deflection (creep and shrinkage) under permanently applied forces adversely affect the appearance or efficiency of the structure or its parts.

The horizontal deflection of reinforced concrete walls shall not exceed 1/200 of the height of the wall.

6.4.3 Prestressed concrete

Prestressing classes are defined as follows:

Class 1 - The concrete develops no tension under service loads;

Class 2 - The concrete does develop tension but this does not exceed the lower-bound tensile strength of concrete (95% probability of NOT cracking.) In other words, it is unlikely that the concrete will crack.

Class 3 - The concrete is allowed to crack under service loads, but the crack widths are limited depending on the exposure conditions.

Prestressed members shall be designed for the Serviceability Limit State to the following requirements:

Class I for the maximum of:

- 50% NA loading (combination 1); or
- 18 units of NB loading (combination 1); and

Class 2 for the maximum of:

- 100% NA loading (combinations 1 & 2); or
- 100% NB loading (combinations 1 & 2); or
- 100% NC loading (combination 1), and

Class 2 or Class 3:

- for full service load (combinations 1, 2 & 3)

Crack widths shall be checked for Class 3 conditions. The following maximum crack width limits shall apply:

- 0,1 mm, but the incremental stress shall not exceed 75 MPa
- 0,2 mm or greater, but the incremental stress shall not exceed 150 MPa

In addition, the Ultimate Limit State shall be checked using partial load factors in accordance with TMH 7.

6.5 Additional structural design considerations

6.5.1 Design for low maintenance and to facilitate maintenance

Structures must be designed and detailed with low maintenance in mind. The following items especially need to be considered:

6.5.1.1 Expansion joints

The cost of replacing expansion joints, with the associated accommodation of traffic, is particularly high. In choosing an expansion joint this must be borne in mind. Where feasible, expansion joints must be avoided as in the case of integral bridges.

6.5.1.2 Bearings

Bearings do not have a design life of 100 years. Bearings must be designed to be replaced or refurbished in place. This requires sufficient space for access and temporary jacking around the bearings. Where feasible, piers must be cast integral with the bridge deck, removing the need for a bearing.

6.5.1.3 Resistance to damage

Structural elements must be robust and resistant to damage. Precast beams and thin piers are particularly susceptible to impact damage.

6.5.1.4 Differential shrinkage

Where there is a significant time period between adjacent casts at a construction joint, differential shrinkage needs to be considered. This applies especially to the joint between a base and the pier or abutment. It also applies to parapets which are cast several months after the deck – water can penetrate the base of the parapet and corrode the reinforcement. Galvanizing of the starter bars to parapets or other methods of control needs to be considered. If the risk of corrosion of the reinforcement at other construction joints is considered high, such as at coastal areas, galvanising of starter bars must also be considered at such joints.

6.5.1.5 Cover to reinforcement

Concrete cover to thin elements such as parapets, precast beams and thin piers must be maintained. Parapets are especially prone to corrosion due to insufficient cover.

6.5.2 Bearings

Bearings shall be designed in accordance with BS 5400 Part 9.

Provision shall be made in the design for the inspection of bearings in service and for their possible replacement.

With regard to replacement of pot bearings, spherical bearings and elastomeric bearings the following shall be adhered to:

- Sufficient space shall be allowed between the top of the bearing seat and the deck soffit to install temporary jacks for bearing replacement. A minimum of 200 mm vertical gap will be required for shorter spans while 300 to 400 mm will be required for longer spans. Where agreed to by the Project Control Engineer, other forms of temporary support may be used, such as propping off the foundations;
- The deck and the bearing seating, and where relevant other structural elements, shall be designed to carry these temporary jack loads, paying particular attention to bursting reinforcement; and
- The positions of the temporary jacks and/or other jacking system details shall be shown on the drawings.

Similar consideration must be given to other forms of bearings.

Rubber strip bearings and malthoid bearings as used on very short spans do not require to be designed for bearing replacement.

6.5.3 Stability

The stability of the structure and its parts shall be considered under the effects of design forces derived from multiplying characteristic forces by the appropriate values of the load partial safety factors for the ultimate limit state. Attention is drawn to Table 17 of TMH 7 - Part 2 relating to values to be applied to forces causing a relieving effect.

The least restoring nominal moment shall not be less than the greatest Ultimate Limit State overturning moment.

Uplift shall be similarly considered and counterweight or anchorage provided as necessary.

6.5.4 Foundation design

The design of foundations shall be based on the principles set out in British Standard Code of Practice BS 8004.

6.5.5 Spill-through abutments

In calculating earth pressure on spill-through abutments, no reduction shall be made on account of the distance between columns if it is less than three times the width across the back of the columns. For greater spacing, earth pressure on each column shall be taken on a width equal to three times their actual width. The effect of the earth in front of the columns causing a relieving horizontal force shall be ignored.

The depths of capping beams and suspended return or wing walls shall be such as to project at least one metre into the adjoining embankment fill and the length of each return or wing wall shall exceed the minimum necessary to retain the filling material by at least one metre.

6.5.6 Foundation slabs

For grade separation structures, the depth from the adjacent underpassing road shoulder level to the top of the foundation slabs shall be not less than 1,2 metres to allow for drainage and services.

6.5.7 Piled foundations

Careful consideration shall be given to the size and type of pile to be used in the design. Piles shall, in particular, be able to penetrate to the required depths during installation.

For river structures, consideration shall be given to the effects of scour and floodwater forces in achieving a robust design. In addition, cast-in-situ piles used for such structures shall be concreted within a permanent casing.

Whenever appropriate, Contactors shall be afforded the opportunity of offering alternative pile solutions.

6.5.8 Expansion joints

Expansion joints shall be designed for the temperature ranges specified in Clause 5.2.11 of this Manual.

An allowance shall be made for long term creep and shrinkage in structures utilising prestressed members.

Drainage water passing from the deck into an expansion joint shall be dealt with so as not to cause unsightly stains on the structure.

Rubber water stops shall not be used in expansion joints.

6.5.9 Approach slabs

Approach slabs shall be provided for all major structures on bitumen surfaced roads.

The slab shall be 200 mm thick and extend 3 metres back from the curtain wall in the direction of the road centre line, with a fall of 100 mm.

Approach slabs shall be provided for the full width of the roadway.

The slabs must be kept 100 mm clear of wingwall faces to prevent fouling of the wall, should settlement take place.

The top of the supporting nib should be 800 mm below the finished road level at the carriageway centre line.

The approach slab shall be designed for both earth load and NA loading over a span of 2m in the longitudinal direction of the structure. Only bottom layer reinforcement is required.

Waterproof underlay or 40 mm thick blinding shall be provided under the approach slab.

6.5.10 Pre-stressing anchors

The Consulting Engineer is responsible for the design of the bursting reinforcement at the prestressing anchors for the system assumed by him, based on TMH7 Part 3 Section 4.8.5.

6.5.11 Precast concrete portal culverts

The requirements for the design of precast culverts are covered in the Standard Drawings and are not repeated in this Manual.

6.5.12 Utility services

No utility services may be allowed for in the design of or fixed to a structure without the prior written approval of the Project Control Engineer. The Consulting Engineer shall advise the Project Control Engineer concerning the structural, maintenance and aesthetic implications of incorporating a utility service, its location and the method of fixing.

The Project Control Engineer shall issue written approval for the incorporation of the utility only after the requirements set out in the Procedures Manual have been met.

However, one 100 mm diameter duct per side shall always be provided per bridge structure. The Consulting Engineer shall determine the likely additional requirements and if approved by the PCE, provide for any additional ducts, particularly in urban areas.

7 DRAWINGS

7.1 List of final working drawings

The final set of bridge plans shall consist of at least the following, in the order given:

1. Site Plan;
2. General Arrangement Plan(s);
3. Foundation Details;
4. Concrete and Reinforcement Details of the Abutments;
5. Concrete and Reinforcement Details of the Piers;
6. Concrete and Reinforcement Details of the Deck;
7. Prestressing Details;
8. Concrete and Reinforcement Details of the Parapets;
9. Miscellaneous Details (such as bearings, expansion joints, drainage details, bridge number plates etc);
10. Bending Schedule(s).

At least the following information must be shown on the working drawings:

7.2 Site Plan

The site plan shall be drawn to a scale of 1:500 or 1:1 000 depending on the terrain and the size of the bridge. If these scales are not practical, any other convenient scale may be used. In all cases the scale must be such that a distance of at least 150 metres from the edges and ends of the bridge or bridges is covered.

The **site plan** must show the following information:

1. The bridge in position together with the crossing point distance on the major road and the cross road or railway line plus the angle of skew and the radii of curves (if any). At a river bridge the km-distance must be shown at the bridge centre point. The bridge must be so positioned that it lies horizontally across the sheet, with increasing km-distance from left to right.
2. Position, description and level of permanent bench marks.

3 Positions and identifying numbers of boreholes and test holes.
4 Road reserve.
5 Formation and lane widths.
6 Destinations and numbers of roads.
7 Direction of traffic flow (arrow for each lane).
8 Distance marked every 20 metres and numbered every 100 metres on the major road and cross road on the centre line.
9 Existing services.
10 Detail of river canalisation (if any). When canalisation is proposed at river bridges, it may be necessary to draw two Site Plans; one on a small scale, say 1:2 000, to show the extent of the canalisation and the other one on a bigger scale, say 1:200, to show the bridge in position.
11 Detail of dykes, chutes, protection works, embankments and retaining walls.
12 Fences and boundaries.
13 Proposed traffic deviations, only if these are not shown on the roadworks drawings.
14 North point.
15 Cuts and fills.

The locality plan forms part of the Site Plan and may be drawn to any practical scale so that the bridge location can easily be determined. A convenient scale is normally 1:50 000. The size of the Locality Plan is normally a circle of 150 millimetre diameter.

The following information must be shown on the **Locality Plan**:

1 Extract from the 1:50 000 topo-cadastral map;
2 co-ordinate grid;
3 position of the bridge clearly marked with a 20 millimetre circle;
4 north point;
5 the new road alignment, cross roads with their numbers and kilometre distances and railway lines with their designations;
6 names of rivers and their directions of flow;
7 names of cities and towns in the vicinity of the bridge;
8 the cadastral name, number and boundaries of the farm on which the bridge is located.

7.3 General Arrangement Plans

7.3.1 Longitudinal sections

The Longitudinal Section of the road should preferably be drawn to a 1:100 or 1:200 vertical scale and to a 1:1 000 or 1:2 000 horizontal scale. If these scales are not practical, any other convenient scale may be used but the 1:10 distortion must be maintained. In all cases the scale must be such that at least 300 metres on both sides of the bridge is shown. In the case of a grade separation bridge, a longitudinal section of both roads is required. For a river bridge, a longitudinal section of the river is also required. In the case of dual carriageway roads, a longitudinal section is required for each carriageway unless the horizontal and vertical alignments of the two carriageways are exactly the same.

The following information must be shown:

1 design speed;
2 gradient of road;
3 numbers and destinations of roads;
4 the bridge in position showing the deck, abutments, piers and footings;
5 km distance;
6 original ground and final levels;
7 depth of cuts and height of fills
8 information on horizontal and vertical curves;
9 length and rate of superelevation (if applicable);
10 maximum flood level calculated and return periods (if applicable);
11 highest known flood level (if applicable);
12 founding material conditions, rock and natural ground lines.

Where the bridge design forms part of a road design, the longitudinal section of the road could be combined with the longitudinal section of the bridge into one long-section, with only the ground and final road levels, and the stake values of the road over a distance of 50 metres to both sides of the bridge shown in addition to the requirements of Clause 7.3.4.

7.3.2 Cross section of road(s)

A convenient scale depends on the road width but is normally between 1:100 and 1:200. The following information must be shown:

1 the total formation width;
2 the width of the lanes and shoulders;
3 the crossfall and/or superelevation of the road;
4 the median width if applicable; and
5 the side slopes.

As in the case for the longitudinal sections, the cross section data could be omitted where the bridge forms part of a road design, in which case a reference to the relevant road drawing number would be adequate.

7.3.3 Plan of the bridge

A convenient scale is normally between 1:100 and 1:250. The following information must be shown:

1 road formation width, lane and shoulder widths;
2 drainage of the deck and the position of the drainage chutes down the fill;
3 deck levels above the abutments and piers;
4 positions of the foundations;
5 positions and numbers of the boreholes;
6 direction of flow of the river (if it is a river bridge);
7 the guardrails;
8 the angle of skew;
9 destinations and directions of traffic flow;
10 the point of minimum vertical clearance for grade separation structures;
11 the km-distance and co-ordinates of the intersection point of the centre lines of the roads, or in the case of a river bridge the intersection of the bridge centre point and the centreline of the road;
12 north point;
13 cuts and fills.

7.3.4 Longitudinal section of the bridge

The Longitudinal Section of the bridge is normally drawn along the bridge centre line. In the case where a dual carriageway road crosses over a river, a road or a railway line and the bridges differ so much from each other that they are in fact two separate structures, a longitudinal section is required for each bridge. When the bridges differ very little, only one longitudinal section with dimensions of the two bridges will be sufficient.

The scale should be the same as that of the plan. The following information must be shown:

1 span length(s);
2 levels on top of the deck on the centre line of the abutments and pier(s);
3 levels at the top of the footings;
4 thickness of the asphalt, deck, footings and blinding layer;
5 basic dimensions of the abutments, piers, footings and piles (if any);
6 the approach slab with its basic dimensions;
7 bearings, weep holes and no-fines concrete (if applicable);
8 in case of a grade separation bridge the major dimensions of the road under the bridge must be shown as well as any future widening;
9 the clearance diagram and the actual minimum vertical clearance;
10 destinations of the road;
11 rock line (if any) and intended founding level.

7.3.5 Elevation of the bridge

Although the parapet and/or the guardrail and the road destinations must be shown on the elevation, it is not necessary to show any dimensions. In the case of a river bridge, however, the design flood level and the highest known flood level must be shown.

7.3.6 Cross section of the deck

Only concrete dimensions, the parapet, service ducts, and the side walk must be shown on the cross section.

A convenient scale for the cross section is normally 1:50.

7.3.7 Design and hydraulic data

The following information is required:

General design notes:

1 design method, eg. elastic or limit state;
2 design codes used.

Design loadings:

3 iii. live load;
4 iv. dead load;
5 v. earth pressure

Design parameters:

6 vi. the modular ratio (if applicable);
7 vii. Young's Modulus for concrete, reinforcing and prestressing steel;

8 viii. creep and shrinkage factors for prestressed concrete;
9 ix. friction and wobble factors "μ" and "k" used in the design of the prestressing;
10 x. coefficient of thermal expansion for the concrete;
11 xi. coefficient of friction of the bearings;
12 xii. internal angle of friction of the backfill material;
13 material strength and stress:
14 xiii. concrete classes and characteristic cube strengths (f_{cu}) in footings, blinding layers, abutments, piers, deck and balustrades;
15 xiv. type, class and characteristic yield strength (f_y) of reinforcing steel;
16 xv. Ultimate Tensile Stress for prestressing steel;
17 xvi. characteristic strength for structural steel where applicable.
18 Substructure:
19 xvii. type of founding material;
20 xviii. permissible and design bearing pressure;
21 xix. superstructure type of expansion joint used;
22 xx. type of balustrade used and service ducts;
23 xxi. calculated deflections.
24 hydraulic information:
25 xxii. catchment area in square kilometres;
26 xxiii. flood in cumec and return period;
27 xxiv. calculated design flood level with and without the bridge;
28 xxv. calculated design water speeds with and without the bridge;
29 xxvi. highest flood level known with the date of occurrence;
30 xxvii. backwater caused by the bridge;
31 xxviii. freeboard;
32 xxix. influence of any dams up or downstream on the calculated design flood level.

7.4 Foundation details

7.4.1 Foundation plan

1 the position of the setting out line in relation to the bridge centre line, where relevant;
2 adequate dimensions and other information to set out the foundations.
3 the road centre line, or in the case of a grade separation structure, both road centre lines with the intersection point, and the angle of skew;
4 the design forces on the piles (if applicable).

7.4.2 Trial pit and/or borehole results

The trial pit and borehole profiles must be drawn to a vertical scale of 1:100. The symbols used for the various materials must be in accordance with the requirements of the Materials Manual or as agreed with the Project Control Engineer. The data given must include:

1 The identification number of each Borehole;
2 the ground level at each trial pit or borehole;
3 the level of each layer;
4 the founding level and the bearing capacity at founding level.
5 standard penetration and any other geotechnical test results as may be available.

7.4.3 Seismic survey

If a seismic survey was done, the velocity of seismic waves in each layer as well as the expected rock level, if any, must be recorded on the drawing.

7.5 Concrete and Reinforcement Details of the Abutments

The concrete and reinforcement details of the abutments must appear on separate sheets.

1 Elevations, plans and sections of the abutments showing all concrete dimensions as well as levels. Where piles or caissons are to be used, the estimated length thereof must also be shown.
2 The concrete class and type of finish.
3 Positions of bearings or bearing pads.
4 Details of drainage pipes, weep holes and no-fines concrete.
5 Jacking details for future replacement of bearings.
6 Cross reference to other relevant plans.
7 Special methods of curing, if applicable.
8 Reinforcement details including cover to the reinforcement.

7.6 Concrete and Reinforcement Details of the Piers

The concrete and reinforcement details of the piers must appear on separate sheets

1 Elevations, plans and sections of the piers showing all concrete dimensions as well as levels. Where piles or caissons are to be used, the estimated length thereof must also be shown;
2 The concrete class and type of finish;
3 Positions of bearings or bearing pads;
4 Jacking details for future replacement of bearings;
5 Cross reference to other relevant plans;
6 Special methods of curing if applicable;
7 Reinforcement details including cover to steel.

7.7 Concrete and Reinforcement Details of the Deck

The concrete and reinforcing details of the deck must appear on separate sheets.

1 A plan of the deck showing all dimensions and final concrete levels;
2 A cross section with balustrade showing all deck dimensions;
3 A longitudinal section with dimensions;
4 Deck drainage layout;
5 The concrete class and type of finish;
6 Stages for casting the deck if relevant;
7 A table showing the elastic deflections under various loading combinations;
8 Cross reference to other relevant plans;
9 Special methods of curing, if applicable;
10 Reinforcement details including cover to steel.

7.8 Prestressing Details

1 Cable profiles in the longitudinal and transverse directions of the deck;
2 An elevation, plan and section of the precast beams (if any) showing the cable layout;
3 A cross section of the deck showing the cable layout;
4 The type of prestressing system used in the design;
5 The diameter and type of cables used;
6 The Ultimate Tensile Stress;
7 The friction factor, "μ";
8 The wobble factor "k";
9 The jacking force before losses;
10 The minimum cube strength required before cables may be stressed;
11 The method of stressing the cables, e.g. stressed from both ends simultaneously or from one end only;
12 Stressing sequence of the cables;
13 The amount of slip-in of the anchorage wedges;
14 A note to the effect that the contractor is responsible for the saddles to support the cables;
15 A note to the effect that the contractor is responsible for any reinforcement around the anchors that is required to resist the compression immediately behind the anchors, as well as any change in reinforcement, concrete dimensions, etc. in the case where his prestressing system differs from the system assumed at the design stage.

7.9 Concrete and Reinforcement Details of the Parapets

1 an elevation, section and general layout of the parapets showing all concrete details;
2 special methods of curing, if applicable;
3 Reinforcement details, including cover to steel.

7.10 Miscellaneous Details

Fully dimensioned details of elements not covered elsewhere, including related reinforcement and fixing details, must be shown on the Miscellaneous Details sheet(s). These may for instance include:

1 Bearing manufacturing and installation details;
2 Key plan showing the bearing layout;
3 Maximum and minimum loads on bearings;
4 Maximum movement of bearings and any presetting that may be required;
5 Expansion joint manufacturing and installation details;
6 Deck drainage details;
7 Manufacturing and installation details for bridge number plates;
8 if lamp posts are required, a fixing detail thereof must be shown on this sheet; etc

7.11 Bending Schedules

Reinforcement must be detailed in accordance with SABS 0144. The reinforcement schedules must show the following information in tabular format:

1 the structural member where the bar is to be fixed;
2 the item number, type, diameter, quantity and length of each bar;
3 the shape code indicating the required bending details for each bar;
4 the total length and mass for each diameter of bar;
5 the total mass of each type of steel;
6 the total mass for each structural member.

Bending schedules must accompany the final bridge plans for approval, but need not be bound into the tender documents.