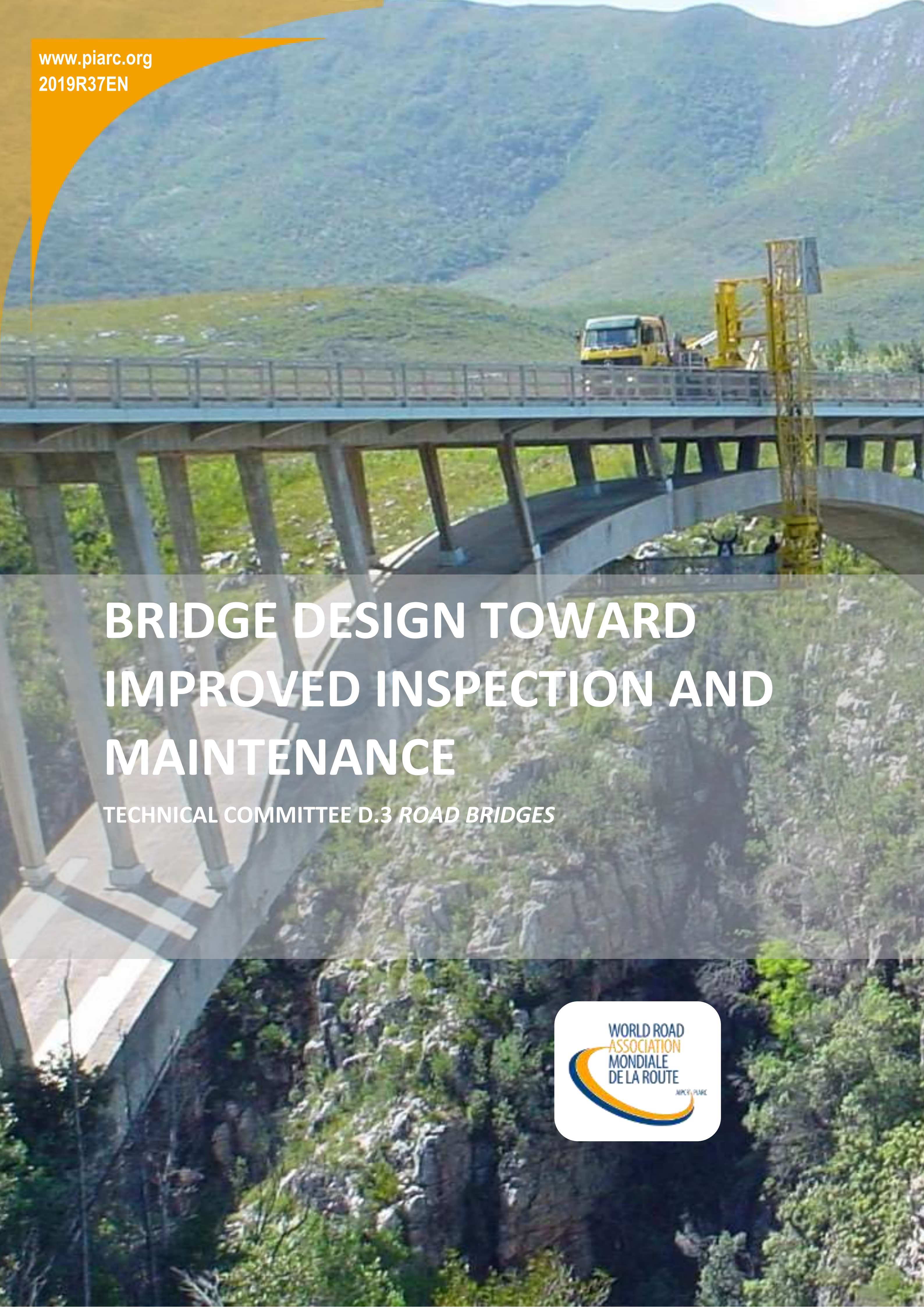

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BRIDGE DESIGN TOWARD IMPROVED INSPECTION AND MAINTENANCE

TECHNICAL COMMITTEE D.3 *ROAD BRIDGES*

WORLD ROAD ASSOCIATION
MONDIALE DE LA ROUTE
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STATEMENTS

The World Road Association (PIARC) is a nonprofit organization established in 1909 to improve international co-operation and to foster progress in the field of roads and road transport.

The study that is the subject of this report was defined in the PIARC Strategic Plan 2016– 2019 and approved by the Council of the World Road Association, whose members are representatives of the member national governments. The members of the Technical Committee responsible for this report were nominated by the member national governments for their special competences.

Any opinions, findings, conclusions and recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of their parent organizations or agencies.

This report is available from the internet site of the World Road Association (PIARC): http://www.piarc.org

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EXECUTIVE SUMMARY

2019R37EN

BRIDGE DESIGN TOWARD IMPROVED INSPECTION AND MAINTENANCE

The principle of designing bridges while having in mind the future inspections and maintenance has often been overlooked in the past, when in the design stage greater emphasis was placed on firstly fulfilling just the "initial requirements" of the bridge – mainly structural safety and serviceability – and secondly minimizing the initial capital cost. This approach has, in many instances, resulted in costly future maintenance which far exceeded the initial capital savings of not considering the aspects of inspection and maintenance.

Thus, bridges need to be designed so that they can be easily and properly inspected and maintained. This requires that the aspects of inspections and maintenance are seen as an integral consideration in the design instead of being treated as an afterthought. All elements of a bridge should be designed such that a bridge owner is able to inspect and maintain them, as well as to take into account elements that will need to be replaced during the design life of the bridge.

This report presents the outcome of an investigation into the design and detailing practices from various countries that are specifically directed toward facilitating the undertaking of future inspections, maintenance and replacement of bridge elements. This investigation was undertaken by Working Group 1 of Technical Committee (TC) D.3, Road Bridges, of the World Road Association (PIARC) during the 2016 – 2019 cycle.

The methodology used in this investigation was to seek out and gather information from member countries of TC D.3 on experiences and practices on the subject of designing toward improved future inspection and maintenance. This was accomplished through a survey based on a specifically developed questionnaire and case study template that invited the member countries to describe their experiences and practices in this regard and to share examples.

17 responses were received from 15 different countries to the questionnaire. The responses received were then compared and analysed and the output of this investigation is a review of each country's provisions and practices and the production of a consolidated set of best practice guidelines and recommendations on the subject. The investigation presented in this report is intended to draw awareness and provide some guidelines on the design and construction of bridges toward improved future inspections, maintenance and replacement of bridge elements.

CONTENTS

1. INTRODUCTION

PIARC, also referred to as the World Road Association, was established in 1909 as a non-profit organization with the broad aim of promoting international cooperation on issues related to roads and road transport. It has over 100 member countries of which around two thirds are from developing countries. Its vision is to be the world leader in the exchange of knowledge on roads, road transport policy and road transport practices within an integrated sustainable transport context.

The World Road Association achieves its vision through a series of technical committees established within five themes as part of its Strategic Plan. The themes for the 2016 – 2019 cycle are:

- A: Management and Finance
- B: Access and Mobility
- C: Safety
- D: Infrastructure
- E: Climate Change, Environment and Disasters

The goal of Theme D is to improve the quality of road infrastructure through the effective management of assets in accordance with user expectations and managers' requests. While new technologies, social and environmental developments are expanding the sphere of interest for road authorities, infrastructure and asset management remains their core business. The need for more efficient use of funds requires constant improvement in techniques in terms of the design, management and maintenance of assets.

Technical Committee (TC) D.3, Road Bridges, has divided into three working groups to satisfy the strategic plan themes dealing with the management and design of bridge stock. This report presents the contribution of Working Group 1 of TC D.3.

1.1. PURPOSE

A successful bridge design satisfies the requirements of strength, durability, functionality, aesthetics and economics over its design life. In fulfilling these requirements, bridges also need to be designed so that they can be efficiently and effectively inspected and maintained during its lifetime. This requires that the aspects of inspections and maintenance are seen as an integral consideration in the design phase and not treated as an afterthought. All elements of a bridge must be designed such that a bridge owner is able to inspect and maintain them, as well as to consider elements of the bridge that will need to be replaced during its lifetime. In this context, the focus of this investigation is on bridge design toward improved inspection and maintenance.

The principle of designing bridges while having in mind the future inspections and maintenance has often been overlooked in the past. On these occasions, the focus of the design was placed firstly on fulfilling just the "initial requirements" of the bridge (mainly structural safety and serviceability) and secondly in minimizing the initial capital cost. This approach has, in many instances, resulted in costly future maintenance which far exceeded the initial capital savings of not taking into account the aspects of inspection and maintenance.

As a result, there is now a greater emphasis in design on sustainable bridge practices and to consider future performance of bridges with regard to inspections, maintenance and replacement of bridge elements. Although this principle has been universally accepted, it is still not yet very well defined or documented. Design codes, which are an inseparable part of the design process, are noticeably light on this subject and such considerations are normally left up to the individual experience of designers. Furthermore, feedback from inspection and maintenance teams of road bridges is also an invaluable source of information on this subject which needs to be captured. Thus, there is a need to document experiences and practices in this regard, with the aim of making future inspections and maintenance a standard design consideration.

The aim of the investigation presented in this report was to collate and assess design and detailing practices from various countries that are specifically directed toward facilitating the undertaking of future inspections, maintenance and/or the replacement of bridge elements. The output of this investigation is the production of this technical report which reviews the different practices and concludes with a consolidated set of best practice guidelines and recommendations on the subject. It is hoped that this will be of great value to bridge designers and bridge owners alike, in order to draw attention to the importance of and to assist in designing for future inspections and maintenance.

1.2. Scope

Bridge design toward improved inspection and maintenance is addressed through appropriate considerations and provisions in conceptual design, detail design and access provisions.

Conceptual design provisions relate to the choice of structural form, materials, component or element dimensions, or other conceptual design aspects that improve the bridge's life-cycle performance thereby reducing inspection and maintenance demands. Detail design provisions relate to elements or components of a bridge, such as bearings, expansion joints, drainage, etc. that when considered and installed correctly, will facilitate the ease of inspections, maintenance and/or the replacement of bridge elements. Access provisions are to provide inspectors and maintenance teams with a safe and easy working environment. Experience has shown that where access is difficult, the efficiency of the inspector is impaired and the maintenance is costly.

The scope of the investigation presented in this report thus focusses on the conceptual design considerations, detailed design considerations and safe access provisions that are specifically directed toward facilitating the undertaking of future inspections, maintenance and/or the replacement of bridge elements.

1.3. Limitations

The type of inspections considered in this investigation are typically defined as the principal bridge inspections that take place normally every 4 to 5 years. It involves the visual condition assessment of every element of the bridge, and in this context, the inspector is expected to be appropriately qualified and to be within touching distance of every bridge element (or as a minimum to have reasonably good visual sight of every bridge element).

The maintenance regime considered in this investigation is typically defined as the standard, preventive or proactive maintenance that would normally be specified in a maintenance manual. This type of maintenance is normally undertaken on bridge elements for which the expected design life is shorter than the design life of the bridge as a whole. Examples of such bridge elements are bearings, joints, corrosion protection, etc. Specifically excluded from this definition is the corrective, repair and rehabilitation maintenance, or bridge renovation (strengthening, upgrading, etc.) which would not normally have been envisaged at inception of the design.

The types of bridges considered in this study are conventional concrete, steel or composite bridges. Cable stayed, cable suspended, masonry arch and timber bridges are generally not considered, however some of the examples presented in this report are from these bridge types as the principle may be equally applicable to all types of bridges.

1.4. Methodology

The methodology used in this investigation was to seek out and gather information from member countries of TC D.3 on experiences and practices on the subject of designing toward improved future inspections and maintenance. This was accomplished through a survey based on a specifically developed questionnaire and case study template that invited the member countries to describe their experiences and practices in this regard and to share examples. The responses received were then compared and analysed and the output of this investigation is the production of the following technical report, containing a consolidated set of best practice guidelines and recommendations on the subject.

2. REQUIREMENTS OF INSPECTIONS, MAINTENANCE AND REPLACEMENT OF BRIDGE ELEMENTS

The following chapter gives a brief outline of the general context into which the present investigation is placed. A concise compilation of the basic principles, terms and interrelations in the broad field of bridge inspection and maintenance is presented. Based on this overview, a set of fundamental requirements are stated, which relate to the future inspection, maintenance, and replacement of bridge elements and shall be considered upfront in the original design of a bridge.

The general objectives of bridge inspection and maintenance are:

- the preservation of sufficient safety (comprising structural, road, operational, road user and environmental safeties)
- the securing of sufficient serviceability
- the conservation of the basic elements
- the conservation of both the cultural and the economic values of the construction
- to manage the risks during the bridge service life

The inspection of bridges involves activities related to:

- the supervision (including periodical targeted surveillances and inspections, if needed also check measurements or monitoring)
- the implementation of urgent safety measures if needed
- the examination (including condition surveys, condition evaluations and subsequent recommendations of intervention measures)
- the planning and execution of intervention measures

The maintenance of bridges involves intervention measures ranging:

- from regular and simple, foreseen and preventive measures as stated in the maintenance plan which shall ensure sufficient serviceability, including for instance the replacement of bridge elements with reduced service life, and eventually extending to unforeseen repairs of smaller damage
- to more extensive rehabilitation measures in order to reinstall sufficient safety and serviceability
- or even broad modification measures in order to adjust the bridge to new requirements

As a premise for planned bridge maintenance, at least the following set of fundamental documents should be established in the design phases and be included in the construction documents:

- the utilization agreement between owner and planner (including general objectives for the utilization of the bridge, consideration of external environment and third party requirements if needed, operational and maintenance requirements, safety objectives, and other relevant basic requirements) or alternatively, an analogous utilization plan
- the construction supervision plan
- a monitoring plan, including details of the provisions for inspection access
- the maintenance plan, including details of the provisions for maintenance access and any site and environmental conditions as applicable.

As stated in Chapter 1.3, the present report is limited to the consideration of those activities of the maintenance of bridges, which can and shall be foreseen in due form within the original design. These are the monitoring – and therein especially the principal inspections done every 4 to 5 years – and the intervention measures according to the original maintenance plan established within the execution of the design.

The following report attempts to illustrate by what means the original design of the bridge shall already implement design provisions that are intended to facilitate the future inspections, maintenance and/or replacement of bridge elements with reduced service life (e.g. bearings, expansion joints, kerbs, parapets, railings, surfacing and waterproofing, drainage etc.).

In particular, the following basic principles shall be applied:

- Both the conceptual design of the bridge (including structural configuration, material choices, dimensions and clearances, instrumentation, equipment etc.) and the subsequent detail design shall incorporate all the provisions that are suitable for facilitating the future inspections, maintenance and/or replacement of bridge elements with reduced service life.
- A comprehensive and well-thought-out provision for the accessibility of all those bridge elements that will have to be visually inspected within hand-distance is of major importance for the future quality and cost of the maintenance. These considerations will interact both with the geometric configuration and the accessibility equipment required for the relevant bridge elements.

3. QUESTIONNAIRE AND CASE STUDY – DEVELOPMENT AND REVIEW OF RESPONSES

3.1. Development Of The Questionnaire And Case Study Template

A questionnaire and case study was developed to gather the practices and examples from PIARC member countries of TC D.3. The questionnaire and case study was divided into four parts:

Part 1: Conceptual Design Provisions

This part of the questionnaire inquired about conceptual design provisions existing in member countries that were aimed at improving the bridge's life-cycle performance thereby reducing inspection and maintenance demands. There were 6 questions in this part.

Part 2: Detail Design Provisions

This part of the questionnaire inquired about elements or components of a bridge, such as bearings, expansion joints, drainage, etc. that when considered and installed correctly, facilitates the ease of inspections, maintenance and/or the replacement of bridge elements. There were 8 questions in this part.

Part 3: Safe Access Provisions

This part of the questionnaire aimed to assess the safe access provisions in member countries that are installed on bridges to facilitate the undertaking of inspections, maintenance and/or the replacement of bridge elements. There were 12 questions in this part.

Part 4: Case Study

The case study aimed to obtain from member countries examples where appropriate conceptual design, detail design and safe access provisions (like those stated above in Parts 1, 2 and 3) were successfully considered and implemented toward facilitating the undertaking of the inspections, maintenance and/or the replacement of bridge elements.

For each question, examples of responses were provided to aid in the understanding of the question taking into account the potential for differences in interpretation due to the different nationalities polled. Respondents were also asked to provide references for their answers if the answer was established in documented design codes, standards, procedural manuals, guidelines and/or national legislation. Due to time constraints, the questionnaire and case study was produced only in English. However, from the responses received, this did not prove to be a deterrent in responding.

Refer to Appendix A for the questionnaire and case study developed.

3.2. Overview of Responses

In response to Parts 1 to 3 of the questionnaire, 17 responses were received from 15 different countries (given that USA and Romania have sent 2 responses each), while 10 responses from 10 different countries were received for the case study (Part 4). Table 1 below summarises the organizations responding to the questionnaire and case study.

Country	Person	Organization	Description of Organization	Questionnaire	Case Study
Austria	Martin KIRCHMAIR	ASFINAG	ASFINAG is responsible for planning, construction, maintenance, operation, funding and tolling of motorways and expressways all over Austria with a road network in operation of 2,178 km. ASFINAG is an efficiently operating user-financed builder and operator of motorways and expressways. Employees in the group: 2,700 Motorway operation and maintenance facilities: 43 Monitoring centres: 9 Locations: Wien, Graz, Innsbruck, Salzburg, Ansfelden Financing: Vehicles < 3.5 t: toll stickers + special tolls, Trucks > 3.5 t: mileage-dependent toll	Yes	No
Belgium-Wallonia	Pierre GILLES	Public Service of Wallonia	Road administration	Yes	Yes
Canada-Quebec	Bernard PILON	Quebec ministry of Transportation	Responsible for different transportation related aspects in the	Yes	Yes

Country	Person	Organization	Description of Organization	Questionnaire	Case Study
			province of Quebec in Canada.		
China	Bo LIU	CCCC Highway Consultants Co. Ltd.	Solely-invested subsidiary of State-owned enterprises. Founded in 1954, known as Highway Planning and Design Institute (HPDI) under the Ministry of Transportation. Core businesses- are design for roads, tunnel and bridges, traffic planning etc.	Yes	No
Germany	Ralph HOLST	Federal Highway Research Institute (BASt)	Technical Research Institute which belongs to the Federal Ministry of Transport and Digital Infrastructure (BMVI).	Yes	No
Hungary	Istvan MOLNAR	Hungarian Public Road Non-profit Pte. Ltd Co.	This company is responsible for national road network (operating, maintenance, rehabilitation).	Yes	Yes
Japan	Yoichi SATO	Japan Bridge Association	A member of National Committee of TC D3 in Japan.	Yes	Yes
Norway	Borre STENSVOLD	Norwegian Public Roads Administration	Headquarter (The Directorate of Public Roads) and five regions responsible for inspections, maintenance and reconstructions. In total the organization has about 7,600 employees. The	Yes	Yes

Country	Person	Organization	Description of Organization	Questionnaire	Case Study
			organization is responsible for appr. 10,500 km of national roads and 44,000 km of county roads inclusive 17,573 bridges.		
Portugal	Paulo BARROS	Brisa	Highway operator and transport infrastructure company.	Yes	Yes
Romania-Timisoara	Adrian BOTA	Politehnica University Timisoara	Faculty For Civil Engineering, Bridge Department.	Yes	No
Romania-Bucharest	Corina CHIOTAN	Technical University of Civil Engineering Bucharest	Technical University of Civil Engineering Bucharest is a technical university in Romania. Within there are Railways, Roads and Bridges Faculty, forming students in this area.	Yes	No
South Africa	Mohamed PARAK	South African National Roads Agency Limited	SANRAL was established as an independent statutory company registered in terms of the Companies Act. The South African Government, represented by the Minister of Transport, is the sole shareholder an owner of SANRAL. SANRAL's mandate is to finance, improve, manage and maintain the national road network of South Africa.	Yes	Yes

Country	Person	Organization	Description of Organization	Questionnaire	Case Study
South Korea	Heungbae GIL and Hyunho CHOI	Korea Expressway Corp.	Government-owned Public Corporation. Founded in 1969 by the Law (KEC Act). 6,003 Employees : Civil Engineers 1,172. Annual Budget : 9.5 billion USD (FY 2016).	Yes	Yes
Spain	Gonzalo ARIAS HOFMAN	Ministerio de Fomento	Ministerio de Fomento is responsible for planning, construction, maintenance and operation of national road network in Spain, as well as planning and supervise of toll motorways, managed by private contractors. Total length of the road network in operation, including free and toll roads, is 24.185 km.	Yes	Yes
Switzerland	Manuel ALVAREZ	Federal Roads Office (Fedro)	FEDRO is both Owner and Operator of the Swiss Federal Highway Network.	Yes	No
USA-FHWA	Joseph HARTMANN	Federal Highway Administration (FHWA)	FHWA is a national level safety and regulatory agency within the Federal government. FHWA provides funding, oversight, training and technical assistance for the design, construction, inspection, maintenance and rehabilitation of highway infrastructure	Yes	No

Country	Person	Organization	Description of Organization	Questionnaire	Case Study
			to our State government partners.		
USA-Wisconsin	Scot BECKER	Wisconsin Department of Transportation	The Wisconsin Department of Transportation is a governmental agency of the U.S. State of Wisconsin responsible for planning, building and maintaining the state's highways.	Yes	Yes

Table 1: Summary of Organizations responding to questionnaire.

Tables 2 to 4 below reveal how Parts 1 to 3 of the questionnaire were answered. A full summary of all the answers are given in Appendix B. Despite the answers given, a review of the answers indicates that these may be different in some instances due to an explicit interpretation of the questions.

Table 2: Summary of how Part 1 of the questionnaire was answered regarding Conceptual Design Provisions.

	Does your country have Conceptual Design provisions or examples of good practice for bridges intended to facilitate the undertaking of the inspections, maintenance and replacement of bridge elements with regard to:					
	Structural configurations	Material Choices	Dimensions / Clearances	Instrumentation	Other	References
Austria	Yes	Yes	Yes	No	Yes	Yes
Belgium-Wallonia	No	No	No	No	No	No
Canada-Quebec	Yes	Yes	Yes	No	No	Yes
China	Yes	Yes	Yes	Yes	Yes	Yes
Germany	Yes	Yes	Yes	No	No	Yes
Hungary	Yes	Yes	Yes	Yes	No	Yes
Japan	Yes	Yes	Yes	No	Yes	Yes
Norway	Yes	Yes	Yes	No	No	Yes
Portugal	Yes	Yes	Yes	Yes	Yes	Yes
Romania-Timisoara	Yes	Yes	Yes	No	No	Yes
Romania-Bucharest	Yes	Yes	Yes	No	No	No
South Africa	Yes	Yes	Yes	No	Yes	Yes
South Korea	Yes	Yes	Yes	Yes	No	Yes
Spain	No	No	No	No	No	No
Switzerland	Yes	Yes	Yes	No	No	Yes
USA-FHWA	No	No	No	No	No	No

USA-Wisconsin	Yes	Yes	Yes	No	No	Yes
Yes	*14*	*14*	*14*	*4*	*5*	*13*
No	*3*	*3*	*3*	*13*	*12*	*4*
Total	*17*	*17*	*17*	*17*	*17*	*17*

Table 3: Summary of how Part 2 of the questionnaire was answered regarding Detail Design Provisions.

	Does your country have Detail Design provisions or examples of good practice for bridges intended to facilitate the undertaking of inspections, maintenance and replacement of bridge elements with regard to:							
	Bearings	Expansion joints	Kerbs, parapets, railings	Surfacing, waterproofing	Drainage	Hollow spaces, voids	Pre-stressing	Other
Austria	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Belgium-Wallonia	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Canada-Quebec	Yes	Yes	Yes	Yes	Yes	Yes	No	No
China	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Germany	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hungary	Yes	No	No	No	No	Yes	No	No
Japan	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Norway	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Portugal	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Romania-Timisoara	No	No	No	No	No	No	No	No
Romania-Bucharest	No	No	No	No	No	No	No	No
South Africa	Yes	Yes	Yes	No	Yes	Yes	No	Yes
South Korea	Yes	Yes	No	Yes	No	Yes	Yes	Yes

	Does your country have Detail Design provisions or examples of good practice for bridges intended to facilitate the undertaking of inspections, maintenance and replacement of bridge elements with regard to:							
	Bearings	Expansion joints	Kerbs, parapets, railings	Surfacing, waterproofing	Drainage	Hollow spaces, voids	Pre-stressing	Other
Spain	Yes	No	No	No	No	Yes	No	No
Switzerland	Yes	Yes	Yes	No	Yes	Yes	Yes	No
USA-FHWA	No	No	No	No	No	No	No	No
USA-Wisconsin	Yes	Yes	No	Yes	Yes	No	No	No
Yes	*14*	*12*	*9*	*8*	*11*	*11*	*7*	*5*
No	*3*	*5*	*8*	*9*	*6*	*6*	*10*	*12*
Total	*17*	*17*	*17*	*17*	*17*	*17*	*17*	*17*

Table 4: Summary of how Part 3 of the questionnaire was answered regarding Safe Access Provisions.

	Does your country have Safe Access provisions or examples of good practice for bridges intended to facilitate the undertaking of inspections, maintenance and replacement of bridge elements with regard to:											
	Platforms,	Connections for	Permanently	Climbing or	Ladders, stairs,	Fall arrest,	Lugs, connection	Hatches, opening,	Lighting	Ventilation	Parking	Other
Austria	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Belgium-Wallonia	No	No	No	No	No	No	No	No	No	No	No	No
Canada-Quebec	Yes	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
China	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Germany	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	No
Hungary	No	No	No	No	No	No	No	No	No	No	No	No
Japan	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	Does your country have Safe Access provisions or examples of good practice for bridges intended to facilitate the undertaking of inspections, maintenance and replacement of bridge elements with regard to:											
	Platforms,	Connections for	Permanently	Climbing or	Ladders, stairs,	Fall arrest,	Lugs, connection	Hatches, opening,	Lighting	Ventilation	Parking	Other
Norway	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Portugal	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes
Romania-Timisoara	No	No	No	No	No	No	No	No	No	No	No	No
Romania-Bucharest	No	No	No	No	No	No	No	No	No	No	No	No
South Africa	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes
South Korea	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	No	No
Spain	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No
Switzerland	-	-	-	-	-	-	-	-	-	-	-	-
USA-FHWA	No	No	No	No	No	No	No	No	No	No	No	No
USA-Wisconsin	No	No	No	No	No	Yes	No	No	No	No	Yes	No
Yes	*10*	*5*	*7*	*6*	*10*	*10*	*6*	*10*	*7*	*6*	*5*	*5*
No	*6*	*11*	*9*	*10*	*6*	*6*	*10*	*6*	*9*	*10*	*11*	*11*
Total	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*16*

Sections 3.3 to 3.5 that follow below discusses in further detail the individual responses to the questionnaire from each country.

3.3. PART 1: CONCEPTUAL DESIGN PROVISIONS

The majority of respondents (62%) to Part 1 of the questionnaire have confirmed that their country does take into account future inspections, maintenance and replacement of bridge elements during the conceptual design phase. Many of the design practices in this regard are found in design codes, standards and guidelines, however there were a small minority of countries (24%) where such practices are based on individual experience and common best practice. Below follows a brief review of each countries practice with respect to conceptual design for improved inspections, maintenance and replacement of bridge elements. The reader is referred to Appendix C for examples of the practices in this regard.

Austria has a technical regulation for the planning and design of bridges which make provision for bridge inspection and repair in the design phase. Structural configurations, choice of material, dimensions/clearances and other conceptual design aspects are guided by these regulations.

Belgium-Wallonia indicated that they do consider aspects of inspections, maintenance and replacement of bridge elements at conceptual design stage. However, the answers were given in the negative which indicates that such practices are possibly not yet regulated in codes and standards but rather good design practice.

Canada-Quebec indicated that structures that minimise the use of expansion joints and bearings are favoured. Structures less than 20m in length are designed as integral and deck slabs are made continuous where possible. The choice of materials depend on the environmental exposure and where required weathering steel, which is sometimes painted, is used. Galvanised reinforcement is used in most deck slabs and concrete mixes do take durability into account. With regard to dimensions and clearances, voids must be accessible for inspection and the minimum dia. used is 800mm. There are also minimum concrete slab dimensions and steel web thicknesses. These requirements are guided by the Canadian Highway Bridge Design Code.

China does not have explicit documentation that deal specifically with inspections, maintenance and replacement of bridge elements. However guidance is found in general bridge design standards and codes. These latter standards and codes require that the use of expansion joints and bearings are minimised, protective coatings, weathering steel and ultra-high-performance concrete is used for applicable environmental exposure conditions and that dimensions and clearances at bearings permit the future inspection and replacement of the bearings. China also have extensive instrumentation requirements for structural health monitoring of technologically complex and large scale bridges.

Germany does have guidelines and typical details for the design of engineering structures and make use of weathering steel and protective coatings where needed and ultra-high-performance concrete for improved durability. They also indicated that the use of elastomeric bearings are preferred over other types of bearings as they are easier to replace. They also provide for a minimum space of 300mm between the soffit of the superstructure and the top of the substructure for jacking for bearing replacement.

Hungary has a common bridge design code and detailed material specific design codes. For bridge lengths less than 20m, they design integral structures and prefer continuous superstructures over simply supported. They also have concrete specifications appropriate to the environmental exposure and use protective coatings for steel structures. Elastomeric bearings are also preferred, similar to Germany. For steel bridges, Hungary specifies that the distance between the end diaphragm beam and the abutment breast wall must be a minimum of 500mm. They also have minimum thicknesses of deck slabs (200mm) and steel plates (8mm). For large structures bridge instrumentation shall be implemented.

Japan has a technical standard which provides for the specifications for the design of highway bridges. This standard provides broad principles to consider when designing a bridge, amongst them being “fitness for the purpose of use, safety of structures, durability, securing of construction quality, reliability and ease of maintenance, compatibility with the environment, and economy”. The requirements for choice of material as guided by these standards are that steel shall be resistant to atmospheric corrosion, specifications for admixtures and additives to improve quality of concrete shall be used, minimum concrete strengths shall be specified which relate to the water/cement ratio which in turn relate to concrete durability, and provide specifications for pre-grouted prestressing steel for protection and bonding of the tendons. With regard to dimensions and clearances, minimum thicknesses of steel elements considering the corrosive environment are detailed, minimum thicknesses of concrete dimensions in bridge decks and minimum thicknesses of orthotropic steel plates are given. Bridge instrumentation are installed in large structures but these are rather to test new technologies instead of for improvement of inspections and maintenance.

In Norway, the administration’s specifications provide standards for the design of bridges and the inspection of bridges. These relate to geometric requirements regarding accessibility of hollow box-girder bridges, accessibility for inspection and replacement of bearings and expansion joints as well as accessibility for piers and pylons. With regard to materials, weathering steel is used in certain environmental exposure conditions and ultra-high-performance concrete and/or stainless steel reinforcement is used along the coastline where the concrete is exposed to chloride penetration. Self-compacting concrete is also used when casting concrete underwater. The specifications also provide for the checking of the designs by the directorate for large and complex structures and for structures built within design-and-build contracts.

Portugal has internal guidelines and favour the design of integral and continuous structures where possible to minimise the use of bearings and expansion joints. All steel structures must have protective coatings and minimum clearances at abutments and piers for inspection and replacement of bearings are specified. Bridge instrumentation is installed in certain structures and these are used to monitor earthquake actions, scour, temperature, humidity, creep and shrinkage, concrete degradation and structural displacements.

In Romania, there exists a procedural manual for the undertaking of the bridge inspections. It is expected that the designer be aware of the requirements in the manual and ensure the bridge is designed accordingly. There are also norms that guide the design of bridges with regard to materials and dimensions and integral and continuous structures are favoured.

In South Africa, there are procedural codes and typical details guiding the design of bridges. Many of the requirements in the design are also guided by health and safety regulations and the bridge must be designed accordingly. The latter relates to, for example, minimum sizes of openings and voids (which must not be less than 800mm) and the maximum embankment slope which is safe for maintenance crew. With regard to structural configurations, integral bridges and continuous structures are favoured and bridges that are less than 60m in length must be designed as integral where possible. Concrete is the most common material used for bridge construction and there exists in South Africa durability specifications for the use of concrete depending on the environmental exposure. If steel is used, it must be galvanised or painted, or both, again depending on the environmental exposure. Galvanised reinforcement is also specified for use in parapets.

In South Korea, integral and semi-integral bridges are specified for bridges less than 100m in length. The requirements for steel and concrete structures are dictated by the design life requirements of the structure (100 years for bridges). For a steel structure, a fatigue design must be undertaken and for durability specifications applied for concrete structures. Ultra-high-performance concrete is also used in some cases. South Korea have a minimum thickness of a deck slab of 220mm and the minimum clearance at an abutment or pier must be 200mm for bearing inspection and replacement. Bridge instrumentation is required for long span bridges with spans greater than 200m.

Spain indicated that they do not have any regulated codes and standards dealing specifically with conceptual design for inspections, maintenance and replacement of bridge elements. They did indicate though that the choice of material used is dictated by the design life requirements of the structure, which is 100 years for bridges in accordance with the Eurocode EN 1990.

Switzerland has listed various national standards applicable to the subject matter. They favour the use the integral bridges wherever possible. Alternatively, inspection chambers are required at abutments if expansion joints and bearings are used. With regard to the choice of material used, they have durability specifications for concrete, and frequently make use of weathering steel for flyovers/overpasses and protective coatings in other instances. Occasionally, ultra-high-performance concrete and galvanised reinforcement (for example in parapets) is used when the need arises. Switzerland also require that all voids must be accessible for inspection and that bridge instrumentation is only specified in exceptional cases.

For USA, the Federal Highway Administration (FHWA) may promote best practice when it comes to design, however the responsibility for the detail specifications with regard to the subject matter reside with the individual states. The response from the State of Wisconsin indicated that they prefer to eliminate joints and bearings by making use of integral abutments. They also specify structural approach slabs to eliminate typical roadway approaches from settling and cracking. They also make use of stainless steel or epoxy reinforcement in bridge decks and parapets and in some cases ultra-high-performance concrete for bridge decks especially where there is higher traffic volume. Wisconsin also takes into account the limitations of their inspection equipment, for example the maximum height of a parapet or fence is specified according to the capability of the under bridge inspection unit (UBIU). They also have minimum dimensions for steel plates. The above provisions are guided by the Wisconsin bridge design manual and AASHTO LFRD (What is this abbreviation) bridge specifications.

The review of the responses has revealed that most countries have design codes, standards, regulations, specifications and or guidelines that inform the conceptual design in some way. These relate to, amongst others, the typology, choice of material and dimensions or clearances of elements of a bridge. It is unclear whether the provisions in these documents are intended to directly improve inspections, maintenance and replacement of bridge elements. However it is evident that these provisions are based on best practice and will nonetheless have the desired effect, either directly or indirectly. For those countries that indicated that they do not have conceptual design provisions relating to the subject matter, this was perhaps a misunderstanding of the question and a shortcoming in the way the question was posed. It is evident from the examples of these countries that they do indeed consider the future performance of a bridge with regard to inspections, maintenance and replacement of bridge elements at the conceptual design phase, and that they may have applied an explicit interpretation of the word "provisions", as in having codes and standards that deal directly with the subject matter, and thus responded in the negative.

The responses indicate that the most common conceptual design provisions for improved inspections, maintenance and replacement of bridge elements is to design structures that minimise the use of bearings and expansion joints. The design of integral, semi-integral and continuous structures is thus favoured. Other common provisions are durability specifications for concrete and the use of weathering steel or protective coatings on steel depending on the environmental exposure conditions. In terms of dimensional clearances, most countries allow space at abutments and piers and between the substructure and superstructure for the inspection, maintenance and replacement of bearings. Most countries also have minimum element thicknesses of slabs and steel plates and minimum dimensions for hollow spaces (800mm).

Some of the less common provisions are countries which use ultra-high-performance concrete (that reduces the amount of reinforcing required), stainless or galvanised reinforcing steel and weathering steel for highway overpasses only. One country also does not permit the use of void formers in deck slabs as this has led to long term maintenance problems. Bridge instrumentation for structural health monitoring is also used less frequently and mainly applied for larger structures for research purposes or earthquake/wind monitoring.

Based on the responses to the survey, the recommended practices to consider in conceptual design with regard to inspections, maintenance and replacement of bridge elements are given in Section 4 of this report.

3.4. Part 2: Detailed Design Provisions

The majority (57%) of the road authorities responded to have detailed design provisions for improved inspections, maintenance and replacement of bridge elements. The following is a brief review of these provisions for each country. The reader is referred to Appendix D for examples of the practices in this regard.

In Austria, the technical design provisions such as "Planning Basics-Providing for Bridge Inspection and Repair" are used to inform the detailed design for inspection and maintenance. In these provisions, minimum dimension and/or clearances for inspection and replacement of bearings and expansion joints at abutments and piers are specified. Typical details for wearing surface and drainage are also provided.

In Belgium, to provide access to the bearings and the expansion joints at the abutments, an inspection gallery/chamber is specified. The depth of a transversal beam at the abutment is less than half of the depth of the main beam height to easily access to the bearings. The details of the expansion joint chamber are also designed to protect the post tensioning anchorages from leakage of the joint. The space is also adequate on both ends of the beam or girder to provide jacks for friction tests and to replace tendons. As for pre-stressing systems, Belgium does not use transversal tendons in the deck slab.

In Canada-Quebec, the Ministry of Transportation has detailed design provisions for inspection and maintenance. For bearings, adaptor plates are used to have replaceable bearings. Diaphragms and end elements of the bridge are designed to be able to lift the bridge (permanent weight only). When expansion joints are installed at abutments, the inspection chambers are designed mainly to prevent the splashing of the backwall due to leaking joints. If the chamber was not constructed, a gutter (trough) is used underneath the rubber strip. To have a better resistance to abrasion and scaling, 50MPa concrete is specified for kerbs and barriers (as opposed to 35 MPa for bridge decks). As a waterproofing membrane for bridge decks, thermo-fusible membranes are used because it is more robust to withstand the paving operations. For drainage, decks require a certain number of drains depending on the slope and width. The drains are standard 200 x 200 mm square hollow shapes made of galvanized steel and have weep-holes on their side at the elevation of the top of the concrete surface to drain the accumulation of water at the concrete/asphalt interface. The interior of steel hollow box girders are also painted white which enhances the light and also shows crack better.

China provided a number of good practice examples for improved inspection and maintenance. A reserved jacking place is designed on top of the pier for bearing replacement. Other good examples are modified mastic asphalt as surface waterproofing which extend the service life of the waterproofing from 12 to 20 years, expansion joints which are installed in 1m modular units so servicing and replacement does not require the closure of the entire roadway and concealed drainage pipes inside the pier.

In Germany, German Standard “DIN 1076 (Highway structures-Testing and Inspection)”, Guideline “RI-EBW-PRÜF”, “RIZ-ING“ (Drawings of Details for Design); “RE-ING” and “RAB-ING” (Guidelines for the Design of engineering structures), and “ZTV-ING” (additional technical conditions of contracts) are used for detailed designs for bridge inspection.

Hungary does not have specific design provisions to improve inspection of bridge members but follows “Design Code of Highway Bridges, Hungary” for bridge design.

In Japan, “Specifications for Highway Bridges” requires that the bridge members shall be designed considering the ease of construction, maintenance, and repair. The specifications require waterproofing membranes to be installed for asphalt pavement to prevent water from permeating the deck slab, a quick drainage system on the bridge deck and expansion joints with durability and water tightness. Detailed design provisions for members are also provided through a series of manuals and standards. “Manual for Bearings of Highway Bridges” specifies a number of requirements for bridge bearings. The space below the girder on the front side of the bearing is preferred to be at least 400mm considering the practicality of installation and maintenance. Jack-up reinforcement in the form of web and flange stiffeners should also be provided near the bearing for maintenance. At expansion joints, the design of the abutment gallery/chamber is such that the leakage from a joint does not come into contact with the post tensioning anchorages and the space is sufficient for the inspection, maintenance and replacement of the cables. For guardrail designs, “Standards for Installation of Guardrails” is used. The Standards specifies that the materials with sufficient strength, durability and maintainability must be used. It also requires that anti-rust treatment and anti-corrosive treatment be applied to metal guardrails. For pre-stressing systems, “Recommendations for Design Standard for External Cable Structure Method and Precast Segment Method” is used. It species that anchorage and deviators for external cables should be designed considering cable replacement. The design of the anchor bolts for steel parapets using base plates to ensure the easy replacement of the post and rails if the anchor bolts are not damaged in an impact.

In Norway, “V441 Inspection Manual for Bridges” by NPRA (Norwegian Public Road Administration) is used to inspect bridge members and evaluate damage levels. If replacement of damaged members is required, “N400 Design Manual” by NPRA is utilized for detailed design provisions and “R762 Work Guidelines” is used for replacement work.

Portugal’s largest highway management concessionaire, Brisa – Auto-estradas de Protugal, S.A., usually follows their own project guidelines. The guideline specifies a drainage system for expansion joints, clearance for hydraulic jacks considering bearing replacement, deck surface drainage, accessibility requirements for hollow-box girders, and requirements for additional ducts for external post-tensioning systems. The guideline also has provision for seismic dampers and monitoring systems. A good example from Portugal was the provision of street lighting in the central reserve which permits the use of the under bridge inspection vehicle on the outer edges.

In Romania, there are neither specific codes nor specifications with detailed design provisions for inspection and maintenance.

In South Africa, the Code of Procedure for the Planning and Design of Highway Structures in South Africa (C.O.P) stipulates detailed design requirements for improved inspection and maintenance of bridge members. When mechanical bearings are used, upper and lower adaptor plates are required to facilitate the removal and replacement of bearings. Materials chosen for bearings must be carefully selected to guard against environmental corrosion and the use of details that allow dirt and moisture to be trapped must be avoided. Expansion joints are required to be terminated in the kerb or parapet with the ends turned up. As parapets, steel parapets/railings shall only be used where the loss due to theft is highly unlikely. Sidewalks are designed to have sufficient provision for future services. Sand filled sidewalks covered with paving slabs is not permitted due to maintenance issues associated with theft, vandalism and disregard from installers of services. Concrete filled sidewalks is preferred with inspections slots spaced at 30m intervals. Particular attention must be paid to details at expansion joints for the sidewalks. With regard to bridge deck drainage, direct discharge pipes (downspouts/scuppers) from decks are preferred with a minimum size of 75mm. For drainage behind abutments and retaining walls, weepholes with a minimum size of 50mm diameter is installed. Bearing sills and abutment galleries are designed to facilitate drainage and the clearing of debris in the event of a joint leakage. One of the unique design details relate to the embankment under bridges. These embankments must not have a horizontal landing directly under the soffit at the top of the bank in order to discourage the homeless from sleeping under the bridge and the possible lighting of fires under the bridge.

In South Korea, a number of provisions and design guidelines for the detailed design of bridge members are available. To improve inspection and maintenance of bearings, the minimum clear dimensions of 200mm to place hydraulic jacks between the girder and the abutment is provided and jack-up stiffeners for the steel girders are installed. As a concrete wearing surface, a latex modified concrete (LMC) overlay system is mainly used for expressway bridges in Korea as it has a shorter curing time. To minimize the detrimental effects of water spray on bridge piers, drainpipes near the pier are extended to the ground. To help inspection of the inside of hollow box girders, the minimum size of access manholes and ventilation holes are specified in the design guidelines.

In Spain, there are no specific codes nor specifications with detail design provisions for inspection and maintenance. However, there are numerous examples of accesses to hollow-box girders or deck-slab voids.

In Switzerland, design provisions from Federal Road Office (FEDRO) Standard: ASTRA 12004 "Détails de construction de ponts (2011)" is mainly used for detail designs of bridge members. An inspection chamber is installed at abutments with expansion joints and/or bearings. The minimum dimensions of the inspection chamber are 1m wide and 2m high. Drainage of expansion joints and separate drainage of the inspection chamber are required. The requirements for the minimum clear dimension between the deck and abutment is 200mm. Switzerland requires that a bearing plan is submitted that considers design, installation, maintenance and replacement of bearings during its lifetime. Railings are required to be installed on "levitating" ground plates, which are anchored into the underlying concrete. The use of hydrophobic coatings for kerbs and parapets is not prescribed but becoming frequent, especially when retrofitting existing bridges. Voids inside the members generally need to be ventilated, drained and accessible through manholes with the minimum diameter of 800mm. Drainage pipes must be polyethylene or stainless steel and must be external and not cast-in to the concrete. It is also considered good practice to prohibit the employment of non-accessible voids and also of accessible voids of small dimensions less than 800mm.

For USA, the Federal Highway Administration (FHWA) may promote best practice when in comes to design, however the responsibility for the detail specifications with regard to the subject matter reside with the individual states. The Wisconsin Department of Transportation (WISDOT) use “WISDOT Bridge Design Manual and Standard” and “AASHTO LRFD Bridge Design Specifications” for detail designs. A minimum of 4 inches (101.6mm) is provided from edge of abutment/pier face to masonry plate or a bearing pad. Where applicable, laminated elastomeric bearings are used instead of steel bearings. WISDOT tries to reduce the number of expansion joints in the bridges. When the thermal movement is greater than 4 inches (101.6mm), modular expansion joint systems are recommended. Polymer overlays are placed on the deck to seal deck and provide an improved ride and surface/skid resistance. To prevent splashing of superstructures, downspouts are extended a minimum of 6 inches (152.4mm) below the bottom of an adjacent prestressed steel girders and the minimum of 1 foot (304.8mm) for steel girders.

The review of responses shows that most road agencies do have specific detail design provisions to facilitate inspections, maintenance, and replacement of bridge elements in documented formats. The review also shows that there are common, as well as unique design provisions.

Most road agencies have a provision for minimum spaces between the bottom of the girders and top of the piers/abutments to replace and inspect bearings. Some of the agencies, especially the ones in Europe, have an inspection gallery or chamber that is also designed at the abutment to facilitate inspection and maintenance of the bearing.

Road agencies are also found to have unique design provisions to deal with specific inspection and maintenance issues. To improve durability of the deck, China employs modified mastic asphalt as surface waterproofing. Korea is using a latex modified concrete (LMC) overlay system for the same reason. To improve the resistance to abrasion and scaling for kerbs and barriers, Canada-Quebec uses 50 MPa concrete. In South Africa, steel parapets/railings are only to be used where the loss due to theft is highly unlikely. Also, a concrete filled sidewalk is preferred with inspections slots spaced at 30m intervals. In Switzerland, the use of hydrophobic coatings for kerbs and parapets is becoming frequent, especially when retrofitting the existing bridges.

Based on the responses to the survey, the recommended practices to consider in detail design with regard to inspections, maintenance and replacement of bridge elements are given in Section 4 of this report.

3.5. Part 3: Safe Access Provisions

The answers in the questionnaire to Part 3: Safe Access Provisions toward improved inspections, maintenance and replacement of bridge elements varied greatly. In addition, this part of the questionnaire was poorly answered. In many of the responses, the space allocated for the answer was left blank without the respondent indicating either a "Yes" or "No". In these cases, the answer inferred was "No" and although the result shows that safe access provisions are not provided from the majority of countries (55%), it is assumed that the countries have more practises and regulations than what is mentioned below. The basis of this assumption is the increasing need to make construction safe from a health and safety point of view and thus these provisions would need to be provided.

Based on the answers, an attempt was also made to determine whether the provisions and practices were founded in existing regulations/standards, best practice, and/or engineering judgment. Table 5 below is an attempt to determine the basis of the replies to this part of the questionnaire, which also proved difficult.

	Determine if the design and detailing practices were founded in regulations/standards, best practice, engineering judgment or none.	Number of Safe Access provisions founded in: Regulations / Standards	Best Practice / Engineering Judgment	None
a)	Platforms, landings, walkways, catwalks, etc.	3	7	6
b)	Connections for inspection platforms	3	7	6
c)	Permanently installed moveable platforms	3	7	6
d)	Installations on embankments or inclined elements of the bridge (such as arches) for assisting climbing or descending	3	7	6
e)	Ladders, stairs, hoists, lifts, step irons, etc.	3	7	6
f)	Fall arrest systems, handrails, etc.	3	7	6
g)	Lugs for rope access, harness connections	3	7	6
h)	Hatches, openings, ports, manholes, etc.	3	7	6
i)	Lighting in closed spaces	3	7	6
j)	Ventilation in closed spaces	3	7	6
k)	Parking for bridge inspector	2	7	7
l)	Other safe access provisions	2	7	7

Table 5: Determination of the basis of the answers to Part 3 of questionnaire.

Notwithstanding the above, some good examples are mentioned in the answers and these should be considered for revision of national standards towards achieving best practice. Herewith follows a brief review of some of the practices in this regard and the reader is also referred to Appendix E for examples of the practices.

Austria has a provision dealing with Bridge Inspections and Repair. Although no details were provided, it is assumed that the requirements for the provision of safe access facilities is contained in this document.

Belgium-Wallonia have previously installed permanent moveable platforms on their long bridges (300m to 500m). However the maintenance of this platform proved to be too costly and now prefer to make use of temporary mobile platforms to access the soffit of the superstructure.

Canada-Quebec provide for platforms and walkways underneath certain long span bridges of great height or length and with grab bars for attaching harnesses. They also provide for ladders and stairs inside tall hollow piers. All hatches and openings must be equipped with locks to prevent vandalism and not allow the entry of birds and bats inside the bridge.

China mentioned quite an extensive list of safe access facilities installed on some of their bridges. Although the examples given relate to long span cable stayed and suspension bridges, most of the provisions listed would be equally applicable to conventional concrete or steel bridges. A unique practice in China is the provision of a staircase on the embankment at the abutment to assist the inspector to ascend or descend the slopes.

In Germany, safe access provisions are provided where required. These are normally for large and high bridges and are typically platforms, stairs and ladders with handrails. Lifting points are provided at the top of tall towers for the raising of equipment. A unique practice is the provision of a walkway outside the main traffic barrier for inspection and service crew on large bridges of high traffic volumes.

Japan mentioned that in the structural design phase they were obliged to consider the following (other countries probably have similar obligations).

"The structural design must be carried out by considering the following matters:

- If damage to one member can result in a collapse or other fatal situation for the bridge, remedial measures must be installed to avoid that situation.
- Maintenance equipment require to conduct in-service inspections, maintenance work, etc. must be installed.
- Maintenance for members that are likely to be replaced during the in-service period of the bridge must be carefully planned in advance so that these members can be replaced reliability and easily."

Although no details were provided, the principle requirements for the provision of safe access facilities is contained in this document [33].

Norway provides safe access provisions where required. These are typically for big truss bridges, free cantilever box girder bridges, suspension and cable stayed bridges. They do not provide any installations on embankments to assist climbing and descending or parking for the inspector. Ventilation is also only provided inside steel box girders.

Portugal does have guidelines dealing with safe access provisions in the form of "Brisa's own project guidelines". Although no details were provided, it is assumed that these are contained in these guidelines.

South Africa provides safe access provisions where required. These are typically for large long span and high bridges where conventional access from the ground is not possible. A unique practice in South Africa is the provision of security personnel to accompany the bridge inspector. Although this is not a standard provision, it is sometimes used in areas where there is a risk of personal danger to the inspector.

Spain have provisions specific to individual bridges as necessary. Where required, these provisions are designed on a case by case basis.

USA-Wisconsin also does not have specific provisions and these are provided where required. Lighting and ventilation is installed in some of their steel box girders. Eye-bolt hooks are also installed on the front face of abutments on top of mechanically stabilised earth walls as harness connection points for the inspector.

Some countries mentioned that some of the questions in this part of the questionnaire are considered in the design phase (for example manholes, lighting, ports/hatches, locks, etc.) and therefore were not mentioned here.

Table 6 below is a summary of some of the more common answers, i.e. more than two countries presented the same practice.

Table 6: Common answers for safe access provisions.

Practices for:	
Walkway underneath the bridge deck	Germany, China and Canada mentioned a walkway underneath the deck for the inspection crew and some maintenance activities. It is only for truss bridges and trusted carriageways on suspension bridges.
Bearings	Portugal and USA mentioned a path for inspection of bearing shelf including the bearings alongside the abutments and South Africa and Korea mentioned the same for piers. South Africa mentioned that they have access chamber on top of the piers for checking and repairing of bearings.
Stairs and lift	Canada, China, Norway, Korea and Spain mentioned stairs or a lift in towers/piers for the inspection crew.
Movable platforms	Germany, Belgium, Canada, China, Norway and Spain mentioned moveable platforms underneath the bridge. However, Belgium mentioned that they no longer use permanently installed moveable platforms because they are not cost efficient any more. Norway have reduced the number of movable platform of same reasons.
Fall arrest systems	Portugal, China, Norway, Korea, Canada and Spain mentioned general provision for fall arrest systems and handrails, especially on ladders. It is only installed on large bridges.
Grab bar and eye bolts	Canada mentioned that they install grab bars along girder webs (in order to attach harnesses) and South Africa, China, Norway mentioned they use eye bolts for the same purpose.
Manholes	Germany, China, Norway and Japan mentioned manholes in box girders and some other places. There are general provisions for hatches where public shall have no access.
Lighting	Germany, Belgium, Portugal, China, Norway, Korea and Spain mentioned that there is lighting in hollow box girders or closed spaces.

Table 7 is a summary of some of the more unique answers, i.e. only one or two countries presented these practices.

Table 7: Unique answers for safe access provisions.

Practices for:	
Catwalk on the cables	China and Norway mention catwalk on the cables on suspension bridges are frequently used
Walkway beside the traffic way	Germany and China mentioned a walkway outside the main traffic barrier, the parapet, as a rescue path and for inspection crew. It is only for bridges of large dimensions, heavy traffic volume and high speed traffic, i.e. multi-traffic lane motorway bridges.
Locks on hatches and openings	Canada mentioned that hatches and openings must be equipped with locks to prevent vandalism and birds to enter.
Parking spaces	Germany, and China mentioned that there is parking space for bridge inspectors and space for inspection devices.
Steps on embankment	China and Korea mentioned that they have steps on embankment to assist inspectors

Based on the responses to this part of the survey, the recommended practices to consider for the provision of safe access with regard to inspections, maintenance and replacement of bridge elements are given in Section 4 of this report.

4. RECOMMENDATIONS AND CONCLUSION

4.1. Recommended Practices

This section presents a consolidated set of best practice guidelines with regard to designing bridges for improved inspection and maintenance. The recommendations presented here are general in nature and may not be applicable in each and every instance. Designers should use their engineering judgement before adopting any of the practices recommended below.

The recommended practices are summarised in Tables 8, 9 and 10 below in terms of conceptual design practices, detail design practices and safe access respectively.

Table 8: Recommended practices for conceptual design toward improved inspection and maintenance.

Structural configurations	• The use of integral, semi-integral or continuous deck slabs is recommended to minimise the use of bearings and expansion joints. Some countries specify fully integral structures for bridge lengths less than 20m, some up to 60m and some up to 100m. The limitations are dependent on specific conditions. • The use of inaccessible permanent void forms in deck slabs is cautioned. This has led to problems being encountered during construction and long-term maintenance. • Use of structural approach slabs to prevent settlement of the approach fills is recommended.
Material choice	• Durability specifications shall be used for concrete dependent on environmental exposure conditions. • Weathering steel shall be used, dependent on environmental exposure conditions, and painted at expansion joints. In some instances, where the exposure conditions do not demand it, weathering steel may also be used if future access is restricted (for example over busy freeways). • Protective coatings to exposed steel elements shall be used where needed. • The use of ultra high performance concrete with reduced steel reinforcing is advantageous for certain conditions. • The use of galvanised or stainless steel reinforcing in bridge decks where de-icing salts are used is recommended. • The use of galvanised or stainless steel reinforcing in concrete parapets may be used appropriate to the environmental exposure condition.
Minimum dimensions or clearances	• Generally 150mm minimum should be allowed between the bearing shelf and underside of bridge deck for inspections, maintenance and replacement of bearings. This is typical for rubber-type bearings. For other bearing types, some countries use 300mm up to 400mm. • The recommended minimum size of internal voids/hollow spaces is 800mm dia. or 800mm high. • The minimum dimension of an access gallery/chamber at an abutment or expansion joint must be at least 500mm wide where access to post tensioning anchorages for friction testing or tendon replacement is required. This may be reduced to 200mm where no tendon replacement is expected. • The minimum thickness of concrete deck slabs should generally not be less than 200mm.

	• The minimum thickness of steel plates should be determined in accordance to environmental exposure conditions, amongst other factors. • The minimum sizes of manholes, openings and voids must take cognisance of health and safety regulations. • The maximum height of bridge railings and parapets must take into account the limitations of under bridge inspection vehicles. The minimum height should be determined by the level of containment required. Wind or noise barriers are excluded from these recommendations and alternative accesses must be considered.
Bridge instrumentation	• Limited use of instrumentation was noted for supplementing inspection information, however the potential for wider implementation is growing. • Instrumentation is more widely used for larger structures to monitor earthquake or wind effects and for research purposes.
Other	• Services fixed to bridges must not impair the undertaking of inspections and maintenance.

Table 9: Recommended practices for detail design toward improved inspection and maintenance.

Bearings	• Where steel bearings are used, top and bottom adaptor plates shall be installed to facilitate replacement. • Allowances must be made on the bearing shelf for placement of jacks. • Cross beam/transversal beam/diaphragm shall be less then the height of the longitudinal beam to permit access to the bearings. These beams shall be designed to permit the jacking of the bridge. • Jack up stiffeners and reinforcement shall be installed on main steel girders and cross beams to permit the jacking of the bridge. • A bearing plan and report shall be submitted with every design. The plan shall cover the design, installation, maintenance and replacement of the bearings during its lifetime.
Expansion joints	• Access galleries/chambers are recommended for inspections and maintenance of joints, especially for large bridges where multi-element joints are used. • Access galleries/chambers must cater for drainage from joint leakage and the design of the chamber must protect prestressing anchorages from joint leakage and the back wall (abutment breast wall) from splashing. • The placement of expansion joints shall be minimised as far as practical. • Expansion joints shall be installed in modular unit lengths so the replacement of the joint does not require the closure of the entire roadway. • The ends of joints must terminate with upturned ends in kerbs or parapets. • A drainage gutter shall be installed under the joint.
Kerbs, parapets, railings	• The design of the anchor bolts for steel parapets and railings shall ensure that the deck will not be damaged in an impact. It is recommended to make use of sacrificial bolts (provided that the containment level is not compromised) and elevated base plates (not in contact with the deck). • High strength concrete (>50MPa) shall be used for concrete kerbs and parapets to resist abrasion and delamination from impacts. • Concrete parapets shall be used where there is a risk of vandalism and theft.

	• No paving blocks shall be used on sidewalks and walkways on bridges in areas with a high risk of vandalism. These shall be surfaced with concrete/asphalt to prevent vandalism and theft. • Hydrophobic coatings may be used on concrete kerbs for protection against corrosion from de-icing salts.
Surfacing and waterproofing	• Appropriate waterproofing membranes or polymer overlays may be used to prevent water permeating into the deck where de-icing salts are used. The choice of waterproofing should not impair the bond with the surfacing layer/wearing course nor adversely affect the riding quality. • Modified mastic asphalt or latex modified concrete is recommended for bridge deck surfacing. These have increased service life and reduced curing time respectively. • Concrete pavers to float the deck surface shall be used which provides improved riding surface and reduces low spots for ponding.
Drainage	• Deck scuppers/down spouts shall be a minimum of 75mm dia. • Deck scuppers shall protrude more than 150mm beyond the deck slab or beam/girder, which ever is the lower. • Deck drainage shall take into account the water flowing at the interface between the surfacing layer/wearing course and the top of the deck/waterproofing layer. • Deck scuppers shall have direct discharge where possible, taking into account environmental restrictions where applicable. Piping systems shall be avoided and all drainage ducts shall be external (not cast in). • To minimize the detrimental effects of water spray on bridge piers from scuppers, drainpipes near the pier shall be extended to the ground. • Drip notches shall be used.
Hollow-box girders, deck slab voids, hollow piers/abutments	• Voids in bridge decks, hollow box girders and piers must be accessible for inspection. The recommended minimum size is 800mm dia. or 800mm high. • All voids must be drained. Special attention must be paid to draining the voids in composite box girders. • The interior of steel hollow box girders must be ventilated and lit. The internal areas may be painted white which reflects the light better and improves the identification of cracks.
Pre-stressing systems	• No anchorages shall be in the top of deck slabs. • Additional ducts shall be allowed for external post tensioning. • For non-grouted internal post tensioning, phased replacement of cables must be considered.
Other	• Stone pitching on embankments in front of abutments shall be used and a horizontal landing in front of the abutment may not be permitted to prevent the lighting of fires under bridges and vandalism. • Street lighting is recommended to be installed in the median/central reserve to facilitate the use of under bridge inspection vehicles on the outer edges.

The provision of safe access equipment is based on practical considerations and safe working practices. As such, many of the provisions are common practice and straightforward and will not be repeated here. The recommendations listed in Table 10 below therefore does not list obvious provisions which should be self-evident. In all cases where there are installations attached to bridges (example platforms, connection points, etc.), the design and maintenance of these elements must be designed and installed according to the required regulations.

Platforms, landings, walkways, catwalks	• A walkway outside the main parapet on some bridges is used. This has two purposes. One is for the inspection crew and the second as a rescue area for road users. It can only be justified for long bridges, high-speed traffic and heavy traffic volume on the bridges. • For long truss bridges and other large bridges with the truss underneath the deck, a pedestrian walkway on the truss will be a great advantage for the inspection crew. It is estimated that the cost-benefit ratio to be relatively low for a walkway placed in the truss. • Permanent platforms for inspection and replacing bearings on large bridges where the bearings are inaccessible should be assessed.
Permanently installed moveable platforms	• Permanently installed moveable platforms underneath the deck for the inspection crew may no longer be cost efficient. This should be evaluated before including costly moveable platforms. The use of under-bridge lifts or inspection vehicles could be assessed instead of permanently installed moveable platforms.
Installations on inclined elements such as embankments	• Stair cases, stepping laths or toe-boards shall be installed on embankments to assist the inspector to ascend or descend embankments at bridges.
Ladders, stairs, hoists, lifts, step irons	• In towers/piers, the use of stairs/lift should always be assessed.
Fall arrest systems, handrails	• Should be installed when there is a risk of falling from height.
Hatches, openings, ports, manholes	• The use of fibre reinforced polymer plates is beneficial as it reduces the weight of hatch doors and openings. • Hatch doors shall be provided with locks to prevent vandalism and shall not permit the entry of birds and bats.
Lighting in closed spaces	• Shall be installed where needed. • It was reported that the maintenance of the internal lighting may become costly and in one instance the lighting was abandoned in favour of hand held torches or head lamps.
Ventilation in closed spaces	• Shall be installed for steel hollow box girders.
Parking for bridge inspector	• A solution for parking space on the road or on the road crossing under the bridge should be evaluated.
Other	• For inspection of bridges, security personnel should accompany the inspector in areas where crime is prevalent.

Table 10: Recommended provisions for safe access toward improved inspection and maintenance.

4.2. Conclusion

The aim of this investigation was to seek out and gather from member countries of TC D.3 provisions and practices with regard to the design of bridges toward improved future inspection, maintenance and replacement of bridge elements. This was accomplished through a survey based on a specifically developed questionnaire and case study template that invited the member countries to describe their experiences and practices in this regard and to share examples. 17 responses were received from 15 different countries to the questionnaire. The responses received were then compared and analysed and the output of this investigation is a review of each country's provisions and practices and the production of a consolidated set of best practice guidelines and recommendations on the subject.

Implementation of the practices presented in this report may in some instances add to the initial capital cost of the bridge. This cost increment may or may not be significant in terms of the overall cost of the bridge or project, depending on the size of the bridge or project. However, in many instances, omitting to take into account future inspections and maintenance in the design and construction of bridges has resulted in large future costs which far exceeded the initial capital savings of not taking these aspects into account. Besides the actual cost of the inspection and maintenance, social costs are also experienced from delays due to the provision of safe access for repairs, for example. Thus, it is hoped that the investigation presented in this report draws awareness and provides some guidelines on the design and construction of bridges toward improved future inspections, maintenance and replacement of bridge elements.

As a concluding comment, the techniques and technologies for inspection and maintenance will change over time. For example, in the last 15-20 years, there have been better and more functional under-bridge lifts that can easily place the inspection and maintenance crew in a good position to inspect, take samples and even to undertake some maintenance work. Advancement in material technology also provides more durable elements requiring less maintenance interventions during its life time. This may in the future obviate the need for maintenance access to some bridge elements. In addition, the use of instrumentation for structural health monitoring may replace the need for some inspections.

The most recent development, however, is the use of unmanned aerial vehicles (drones), which can reach nearly inaccessible locations without the need for an access platform. The use of drones for inspections is gaining popularity in many countries. It does not replace the bridge inspector, but provides high quality imagery to inaccessible areas for the inspector to interpret. Its use does come with extensive regulatory requirements (each country will be different) and also needs to be manned by an experienced and certified operator. The use of drones for inspections also requires pre- and post-processing effort and thus currently the only time saved is the time spent on site. In the future though, its use may be expanded and it may also be possible to take some types of measurements with this technology but not for undertaking any maintenance works. In the years to come, the presence of the inspector on site may also not be required. Drone technology has been used in some countries (for example Norway) and it may in the future replace many of the access facilities mentioned in this report.

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APPENDIX A: QUESTIONNAIRE AND CASE STUDY TEMPLATE

PIARC TECHNICAL COMMITTEE D.3 : BRIDGES – WORKING GROUP 1

BRIDGE DESIGN TOWARD IMPROVED INSPECTION AND MAINTENANCE

TC D.3 Working Group 1 is concentrating on the issue of improved inspection and maintenance for bridges. This issue aims to assess the design and detailing practices from member countries that are specifically directed toward facilitating the undertaking of the inspections, maintenance and replacement of bridge elements. Furthermore, Working Group 1 seeks to collate from member countries case studies of bridges where the future inspection, maintenance and replacement of bridge elements were successfully considered in the design and implemented in the construction. The ultimate goal of Working Group 1 is to produce a set of best practice guidelines or recommendations to be considered in design and construction of bridges toward facilitating the undertaking of the inspections, maintenance and replacement of bridge elements.

To this end, Working Group 1 has developed a questionnaire and case study to gather the practices and examples from member countries. The questionnaire and case study is divided into four parts:

Part 1: Conceptual Design Provisions

Part 2: Detail Design Provisions

Part 3: Safe Access Provisions

Part 4: Case Study

The parts are defined further in the sections that follow.

It is important to define at this juncture the inspection and maintenance regimes and the types of bridges to be considered for this study. The inspection regime to be considered is typically defined as the *principal* bridge inspection that takes place normally every 4 to 5 years. It involves the visual condition assessment of every element of the bridge, and in this context, the inspector is expected to be appropriately qualified and to be within touching distance of every bridge element (or as a minimum to have reasonably good visual sight of every bridge element). The maintenance regime to be considered is typically defined as the *standard, preventative* or *proactive* maintenance that would normally be specified in a maintenance manual. This type of maintenance is typically undertaken on bridge elements for which the expected design life is shorter than the design life of the bridge as a whole. Examples of such bridge elements are bearings, joints, corrosion protection, etc. Specifically excluded from this definition is the *corrective, repair* and *rehabilitation* maintenance or bridge *renovation* (strengthening, upgrades, etc.) which would not have been envisaged at inception. Lastly, the type of bridges to be considered are conventional concrete, steel or composite bridges. Cable stayed, cable suspended, masonry arch and timber bridges are excluded.

Your input is very important to the success of this project. The work required to complete the questionnaire and case study is understood and acknowledged; every effort has been made to make them as user friendly and labour effective as possible. The questionnaire and case study have been produced only in English, as an exception and due to unforeseen time constraints.

The collective aims are very important to all bridge specialists and will have particular importance for both developing countries and countries in transition. The compiled questionnaires and case studies will be included in the final report of which you will receive a copy. I humbly request you to take the time to contact the people best placed to respond to these questions and submit responses that best represent your country's practice to enable our Working Group to continue PIARC's Vision to be one of the world leaders in the exchange of knowledge.

Please complete all forms electronically in Word and return the completed questionnaire and case study to the undersigned by 30 June 2017.

Thanking you in anticipation.

Mohamed PARAK (South Africa), parakm@nra.co.za, Leader – Working Group 1, TC D.3 Bridges

PIARC TECHNICAL COMMITTEE D.3 : BRIDGES – WORKING GROUP 1

QUESTIONNAIRE & CASE STUDY

Description of your organisation:

Country:	
Name of Organization:	
Description of Organization:	
Your name:	
Your e-mail address:	

Part 1: Conceptual Design Provisions toward Improved Inspection and Maintenance

This part of the questionnaire inquires about conceptual design provisions existing in the member countries that aim at designing toward facilitating the undertaking of inspections, maintenance and replacement of bridge elements.

Please give concise answers to the questions. If needed, further details should be given in Part 4: Case Study.

1. Does your country specify structural configurations for bridges intended to facilitate the undertaking of the:
   a) inspections? Yes/No
   b) maintenance? Yes/No
   c) replacement of bridge elements? Yes/No

   If "Yes" was answered to any of the above, please indicate examples of such configurations below. Examples can be the elimination of bearings and joints in integral bridges, the reduction of connections or secondary elements in steel bridges, the advantages or disadvantages of internal versus external post tensioning systems, specific design features intended to increase the service life, or any other examples.

2. Does your country specify material choices for bridges intended to facilitate the undertaking of the:
   a) inspections? Yes/No
   b) maintenance? Yes/No
   c) replacement of bridge elements? Yes/No

   If "Yes" was answered to any of the above, please indicate examples of such material choices below. Examples can be the reduction of corrosion protection requirements by using weathering steel, the use of protective coatings, the use of Ultra High Performance Concrete (UHPC) for elements with specific exposures, the use of self-compacting concrete, the use of galvanized reinforcement in concrete parapets, durability specifications for concrete, specific design features intended to increase the service life, or any other examples.

3. Does your country specify certain minimum dimensions or clearances for particular bridge elements intended to facilitate the undertaking of the:
   a) inspections? Yes/No
   b) maintenance? Yes/No
   c) replacement of bridge elements? Yes/No

   If "Yes" was answered to any of the above, please indicate examples of such specifications below. Examples can be minimum thicknesses of concrete slabs/webs/parapets, minimum thicknesses of steel plates, minimum dimensions for which voids will be allowed, minimum clearances related to the provision of required space for jacking at bearings, requirements for access to voids, slopes of embankments for safe ascending/descending, design for specific inspection equipment such as Under Bridge Inspection Units (UBIU), or any other examples.

4. Does your country have provisions for bridge instrumentation intended to facilitate the undertaking of the:
   a) inspections? Yes/No
   b) maintenance? Yes/No
   c) replacement of bridge elements? Yes/No

   If "Yes" was answered to any of the above, please indicate examples of such specifications below. Examples should be related to specific installations contemplated at design stage and not to monitoring of damage and deterioration originated by poor design or maintenance. Examples can be the instrumentation for monitoring of earthquake actions, of scour on foundations, of strains in integral bridges, of humidity in closed voids or ducts, or any other examples.

5. Does your country specify any other conceptual design aspects intended to facilitate the undertaking of the:
   a) inspections? Yes/No
   b) maintenance? Yes/No
   c) replacement of bridge elements? Yes/No

   If "Yes" was answered to any of the above, please indicate examples of such specifications below.

6. If you have answered "Yes" to any of the above questions, please indicate a reference to the specific documents like design codes, standards, procedural manuals, guidelines and/or national legislation (as applicable) where the conceptual design provisions that you mentioned above are specified. Please also indicate if these provisions are not yet documented but are still implemented on the basis of design experience or best practice that exists in your country/organisation.

Part 2: Detail Design Provisions toward Improved Inspection and Maintenance

This part of the questionnaire inquires about detail design provisions existing in the member countries that aim at designing toward facilitating the undertaking of inspections, maintenance and replacement of bridge elements.

Please give concise answers to the questions. If needed, further details should be given in Part 4: Case Study.

7. Does your country have detail design provisions or examples of good practice toward facilitating the undertaking of the inspections, maintenance and replacement of:
    - Bearings (including provisions for the adjacent abutments/piers/decks) Yes/No?

    If "Yes" was answered above, please describe the general provisions or examples below.
    Examples can be adaptor plates to facilitate the replacement of bearings, minimum clear dimensions for jacking, deck stiffening elements for jacking, or any other examples.
    Please include if available a reference to the specific design codes, standards, procedural manuals and/or guidelines.

8. Does your country have detail design provisions or examples of good practice toward facilitating the undertaking of the inspections, maintenance and replacement of:
    - Expansion joints
      Yes/No?

    If "Yes" was answered above, please describe the general provisions or examples below.
    Examples can be inspection chambers at abutments, minimum clear dimensions between the deck and abutment, provisions for drainage of expansion joints, or any other examples.
    Please include if available a reference to the specific design codes, standards, procedural manuals and/or guidelines.

9. Does your country have detail design provisions or examples of good practice toward facilitating the undertaking of the inspections, maintenance and replacement of:
    - Kerbs, parapets, railings
      Yes/No?

If “Yes” was answered above, please describe the general provisions or examples below.
Examples can be the use of fuse anchorages (predetermined breaking point) to preserve the deck from damage, the use of hydrophobic coatings for kerbs and parapets, or any other examples.
Please include if available a reference to the specific design codes, standards, procedural manuals and/or guidelines.

10. Does your country have detail design provisions or examples of good practice toward facilitating the undertaking of the inspections, maintenance and replacement of:
    - Surfacing and waterproofing

      Yes/No?

If “Yes” was answered above, please describe the general provisions or examples below.
Examples can be the use of waterproofing systems with extended service life, supplementary layers for protection of the waterproofing system, more durable materials for deck surfacing, or any other examples.
Please include if available a reference to the specific design codes, standards, procedural manuals and/or guidelines.

11. Does your country have detail design provisions or examples of good practice toward facilitating the undertaking of the inspections, maintenance and replacement of:
    - Drainage

      Yes/No?

If “Yes” was answered above, please describe the general provisions or examples below.
Examples can be the material choice for the drainage ducts or their location and layout, or any other examples. This may include drainage related to the deck surface, drainage of bearing shelves, drainage of internal voids, drainage behind abutment/retaining walls or road prism drainage on the approaches to the bridge.
Please include if available a reference to the specific design codes, standards, procedural manuals and/or guidelines.

12. Does your country have detail design provisions or examples of good practice toward facilitating the undertaking of the inspections, maintenance and replacement of:
    - Hollow-box girders, deck slab voids, hollow piers/abutments
      Yes/No?

    If "Yes" was answered above, please describe the general provisions or examples below.
    Examples can be either accessibility requirements including size, ventilation, lighting or sealing requirements for voids in hollow-box girders, deck slabs, piers or abutments, or any other examples.
    Please include if available a reference to the specific design codes, standards, procedural manuals and/or guidelines.

13. Does your country have detail design provisions or examples of good practice toward facilitating the undertaking of the inspections, maintenance and replacement of:
    - Pre-stressing systems
      Yes/No?

    If "Yes" was answered above, please describe the general provisions or examples below.
    Examples can be accessibility or visibility requirements for post-tensioning anchorages, prescriptions for the use of external post-tensioning systems or of post-tensioning systems with electrically insulated prestressing tendons, or any other examples.
    Please include if available a reference to the specific design codes, standards, procedural manuals and/or guidelines.

14. Does your country have detail design provisions or examples of good practice toward facilitating the undertaking of the inspections, maintenance and replacement of:
    - Other bridge elements
      (for example seismic dampers, built-in monitoring systems, etc.)
      Yes/No?

    If "Yes" was answered above, please describe the general provisions or examples below.
    Please include if available a reference to the specific design codes, standards, procedural manuals and/or guidelines.

Part 3: Safe Access Provisions toward Improved Inspection and Maintenance

This part of the questionnaire aims to assess the safe access provisions in member countries that are installed on bridges facilitating the undertaking of inspections, maintenance and replacement of bridge elements.

Please give concise answers to the questions. If needed, further details should be given in Part 4: Case Study.

15. Does your country have safe access provisions or examples of good practice toward facilitating the undertaking of the inspections, maintenance and replacement of bridge elements regarding:

    a) Platforms, landings, walkways, catwalks, etc. Yes/No?

    b) Connections for inspection platforms Yes/No?

    c) Permanently installed moveable platforms Yes/No?

    d) Installations on embankments or inclined elements of the bridge (such as arches) for assisting climbing or descending Yes/No?

    e) Ladders, stairs, hoists, lifts, step irons, etc. Yes/No?

    f) Fall arrest systems, handrails, etc. Yes/No?

    g) Lugs for rope access, harness connections Yes/No?

    h) Hatches, openings, ports, manholes, etc. Yes/No?

    i) Lighting in closed spaces Yes/No?

    j) Ventilation in closed spaces Yes/No?

    k) Parking for bridge inspector Yes/No?

    l) Other safe access provisions Yes/No?

    If “Yes” was answered to any of the above, please describe in the table below the general provisions or examples for the items a) through l). Please include if available a reference to the specific design codes, standards, procedural manuals and/or guidelines.

a)	
b)	
c)	
d)	
e)	
f)	
g)	
h)	
i)	
j)	
k)	
l)	

Part 4: Case Study

The case study aims to obtain from member countries examples where appropriate **conceptual design**, **detail design** and **safe access provisions** (like those stated above in Parts 1, 2 and 3) toward facilitating the undertaking of the inspections, maintenance and/or replacement of bridge elements were successfully considered and implemented.

<table>
<tr><td colspan="2">4.1 Conceptual Design Provisions toward Improved Inspection and Maintenance
Give examples below (from a bridge or bridges) of how the conceptual design of the bridge intended to facilitate the undertaking of inspections, maintenance and/or replacement of bridge elements. Kindly include in the cells below pictures, drawings and other material as necessary that demonstrate the following conceptual design aspects, as well as the name and description of the bridge.</td></tr>
<tr><td rowspan="4">Structural configuration</td><td>Description of structural configuration:</td></tr>
<tr><td>(Pictures, drawings and other material as necessary)</td></tr>
<tr><td>Name of the bridge and year of construction:</td></tr>
<tr><td>Brief description of the bridge:</td></tr>
<tr><td rowspan="4">Material choice</td><td>Description of material choice:</td></tr>
<tr><td>(Pictures, drawings and other material as necessary)</td></tr>
<tr><td>Name of the bridge and year of construction:</td></tr>
<tr><td>Brief description of the bridge:</td></tr>
<tr><td rowspan="4">Dimensional specifications</td><td>Description of dimensional specifications:</td></tr>
<tr><td>(Pictures, drawings and other material as necessary)</td></tr>
<tr><td>Name of the bridge and year of construction:</td></tr>
<tr><td>Brief description of the bridge:</td></tr>
<tr><td></td><td>Description of bridge instrumentation:</td></tr>
</table>

Bridge instrumen-tation	
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Other conceptual design aspects	Description of other:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:

4.2 Detail Design Provisions toward Improved Inspection and Maintenance

Give examples below (from a bridge or bridges) of how the detail design of the bridge intended to facilitate the undertaking of inspections, maintenance and/or replacement of bridge elements. Kindly include in the cells below pictures, drawings and other material as necessary that demonstrate the following detail design aspects, as well as the name and description of the bridge.

Bearings	Description for bearings:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Expansion Joints	Description for expansion Joints:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:

Kerbs, parapets and railings	Description for kerbs, parapets and railings:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Surfacing and waterproofing	Description for surfacing and waterproofing:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Drainage	Description for drainage:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Hollow-box girders, deck slab voids, hollow piers /abutments	Description for voids:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Pre-stressing systems	Description for pre-stressing systems:
	(Pictures, drawings and other material as necessary)

	Name of the bridge and year of construction:
	Brief description of the bridge:
Other detail design aspects	Description for other:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:

4.3 Safe Access Provisions toward Improved Inspection and Maintenance Give examples below (from a bridge or bridges) of how the following safe access provisions of the bridge intended to facilitate the undertaking of inspections, maintenance and/or replacement of bridge elements. Kindly include in the cells below pictures, drawings and other material as necessary that demonstrate the following safe access provisions, as well as the name and description of the bridge.	
Platforms, landings, walkways, catwalks, etc.	Description for platforms, landings, walkways, catwalks, etc.:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Connections for inspection platforms	Description for connections for inspection platforms:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Permanently installed	Description for permanently installed moveable platforms:

moveable platforms	*(Pictures, drawings and other material as necessary)*
	Name of the bridge and year of construction:
	Brief description of the bridge:
Installations on embank-ments or inclined elements of the bridge for assisting climbing or descending	Description for installations on inclined surfaces:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Ladders, stairs, hoists, lifts, step irons, etc.	Description for ladders, stairs, hoists, lifts, step irons, etc.:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Fall arrest systems, handrails, etc.	Description for Fall arrest systems, handrails, etc.:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Lugs for rope access, harness connections	Description for lugs for rope access, harness connections:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:

	Brief description of the bridge:
Hatches, openings, ports, manholes, etc.	Description for hatches, openings, ports, manholes, etc.:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Lighting in closed spaces	Description for lighting in closed spaces:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Ventilation in closed spaces	Description for ventilation in closed spaces:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
Parking for bridge inspector	Description for parking for bridge inspector:
	(Pictures, drawings and other material as necessary)
	Name of the bridge and year of construction:
	Brief description of the bridge:
	Description for other safe access provisions :

Other safe access provisions	*(Pictures, drawings and other material as necessary)*
	Name of the bridge and year of construction:
	Brief description of the bridge:

APPENDIX B: SUMMARY OF RESPONSES

Country	Questionnaire	Case Study	Conceptual Design	Detail Design	Safe Access	Case Study	Comments
Austria	Yes	No	*1. Structural Configurations* : Given in references. *2. Material Choices* : Dictated by intended Service Life of structure (100 years for bridges) according to Eurocode. *3. Dimensions:* Example given of minimum dimensions at abutment and piers for access to bearings and joints. *4. Instrumentation* : None. *5. Other* : Many other conceptual provisions available in references. *6. References* : Technical regulation for Providing for Bridge Inspection and Repair, Eurocode and company-specific standard.	*7. Bearings* : Yes, minimum dimensions at abutment and piers for access to bearings and joints. *8. Expansion joints* : Yes, minimum dimensions at abutment and piers for access to bearings and joints. *9. Kerbs, parapets, railings* : Yes, contained in technical regulations. *10. Surfacing, waterproofing* : Two-layer bridge sealing system used. *11. Drainage* : Yes *12. Hollow spaces, voids* : No. *13. Prestressing* : Yes contained in Eurocode 2, no details provided. *14. Other* : No other special measures to improve inspection, maintenance and replacement.	*15a. Platforms, landings, walkways, etc* : *15b. Connections for platforms* : *15c. Moveable platforms* : *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : *15f. Fall arrest, handrails* : *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : *15i. Lighting* : *15j. Ventilation* : *15k. Parking* : *15l. Other* : All access provisions contained in Bridge Inspection and Repair standard. No details given.	Bridge design undertaken according to codes and standards which are based on best practice. No special measures over and above are introduced to improve inspections and maintenance. No case studies given. Questionnaire contains examples of the following: Dimensional clearances at abutments and piers. Two-layer bridge waterproofing. Bridge drainage. Steel edge beam.	
Belgium-Wallonia	Yes	Yes	Belgium-Wallonia indicated that they do consider aspects of inspections, maintenance and replacement of bridge elements at conceptual design stage. However, the answers were given in the negative indicating perhaps a misunderstanding in the question or that such considerations are not yet documented design standards/provisions but rather good design practice.	*7. Bearings* : Space details at abutments for bearings access/jacking. *8. Expansion joints* : Chamber access details at abutment and protection of post tensioning anchorage from joint leakage (FIB Bulletin 33). *9. Kerbs, parapets, railings* : The rapture is not allowed to occur in the anchorage of the parapet. *10. Surfacing, waterproofing* : None. *11. Drainage* : Transverse and longitudinal drainage channels in waterproofing connected to scupper. *12. Hollow spaces, voids* : Must be accessible for inspections. *13. Prestressing* : No transverse tendons in deck slab, no anchorages in deck slab and space behind anchorages for friction test or replacement of tendons. *14. Other* : None.	*15a. Platforms, landings, walkways, etc* : *15b. Connections for platforms* : *15c. Moveable platforms* : For some long bridges (300 - 500m), permanent moveable platforms installed. However the maintenance of the platform proved too costly and it is now preferred to use mobile platforms. *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : *15f. Fall arrest, handrails* : *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : *15i. Lighting* : *15j. Ventilation* : *15k. Parking* : *15l. Other* :	Space details for bearings and expansion joints. Abutment chamber and drainage under expansion joint and protection of PS anchorage from leakage (FIB bulletin 33). Permanently installed moveable platform. Lighting in closed spaces.	
Canada-Quebec	Yes	Yes	*1. Structural Configurations* : Voids must be accessible, integral/continuous structures favoured where joints/bearings are minimized, provisions made for jacking for bearing replacement. *2. Material Choices* : Weathering steel used and also painted for certain exposures, galvanised rebar used in most deck slabs, concrete mix designs for durability requirements. *3. Dimensions* : Hollow box girders must be accessible to inspections, minimum dia. of void 800mm, minimum slab and steel web dimensions. *4. Instrumentation* : None. *5. Other* : Services fixed to bridge must not impair inspections. *6. References* : Canadian bridge design code and manual.	*7. Bearings* : Adaptor plates used and diaphragms designed for jacking. *8. Expansion joints* : Chamber and gutter detail to prevent splashing of back wall when joints leak *9. Kerbs, parapets, railings* : High strength (50MPa) concrete specified for kerbs and barriers to resist abrasion. GFRP bars used in barrier design (experimental). *10. Surfacing, waterproofing* : Thermofusible waterproofing membrane used on bridge decks, screeding machine used to obtain improved profile on deck (no ponding, better ride quality). *11. Drainage* : Scuppers must protrude more than 150mm from bottom of deck, scuppers have weepholes at deck concrete level to drain water seeping underneath asphalt onto of membrane. *12. Hollow spaces, voids* : Do not use deck slab voids. Interiors of steel hollow box girders are lit and painted white which reflects the light better and makes the cracks more visible. *13. Prestressing* : None. *14. Other* : None.	*15a. Platforms, landings, walkways, etc* : Permanent walkway installed for large bridges. *15b. Connections for platforms* : *15c. Moveable platforms* : *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : Permanent ladders in hollow piers of great height. *15f. Fall arrest, handrails* : In some cases, not normally done. *15g. Lugs, connection points for rope access* : Grab bars installed on girder webs for attachment of harnesses. *15h. Hatches, openings, manholes, etc* : These must be equipped with locks to prevent vandalism and must not permit birds/bats to enter. *15i. Lighting* : *15j. Ventilation* : *15k. Parking* : *15l. Other* :	Integral bridge example. Weathering steel. Openings in steel box girders. Bearing adaptor plates. Abutment chambers and expansion joint chambers. Screeding machine on deck. Waterproofing membrane. Deck scuppers. Access doors. Interior painted white of steel hollow box girder. Inspection walkways on deck soffit. Ladders for hollow piers. Access door to hollow piers.	
China	Yes	No	*1. Structural Configurations* : Minimisation of expansion joints and bearings in favour of continuous slab and integral structures. *2. Material Choices* : Use of protective coatings, weathering steel and high-performance concrete encouraged. *3. Dimensions:* Specified for jacking and bearing replacements. *4. Instrumentation* : For large scale bridges, structural monitoring measures are implemented. *5. Other* : None *6. References* : General guidelines on good bridge design found in relevant design codes, but not specific to inspections, maintenance and replacement.	*7. Bearings* : Allowance of space on top of piers and abutments for jacking and bearing replacement. *8. Expansion joints* : Expansion joints are installed in modular unit lengths of 1m so replacement of expansion joint does not require the closure of the entire road. *9. Kerbs, parapets, railings* : None. *10. Surfacing, waterproofing* : Modified Mastic Asphalt is used in certain bridges which extend the service life from 12 to 20 years over conventional asphalt. *11. Drainage* : Drainage pipes are concealed in the piers. *12. Hollow spaces, voids* : Internal stair case provided in hollow piers. *13. Prestressing* : None. *14. Other* : Inspection and access platforms on long span bridges.	*15a. Platforms, landings, walkways, etc* : Provided along bottom chord of truss bridge, along main cable of suspension bridge (with non slip surface), at the anchorages of main cables, along the side of the roadway of long span bridges to inspect roadway surfacing and cable anchorages, at bearings. *15b. Connections for platforms* : Provided on top of towers for attaching and lifting equipment and rope access. *15c. Moveable platforms* : Permanently installed moveable inspection gantries provided along soffits of long span bridges mainly of steel construction. *15d. Climbing or descending* : Stairs provided at embankments. *15e.Ladders, stairs, hoists, etc* : Stairs, ladders, lifts provided internally or externally at piers, towers. *15f. Fall arrest, handrails* : Handrails provided at all platforms, ladders, stairs. *15g. Lugs, connection points for rope access* : Provided on top of towers for attaching and lifting equipment and rope access. *15h. Hatches, openings, manholes, etc* : Provided at end of deck girder. *15i. Lighting* : *15j. Ventilation* : Provided on side of concrete box girder. *15k. Parking* : Provided *15l. Other* :	Good examples of bridge instrumentation. Example of pier with space for jacking for bearing replacement. Example modular unit expansion joint. Concealed drainage pipes. Internal stair case for hollow piers. Inspection and access platforms on long span bridges. Safe access section has good examples of all provisions mentioned.	Although safe access provisions relate mainly to long span cable stayed or suspension bridges, it may be equally applicable to more conventional bridges as per the scope of the questionnaire.

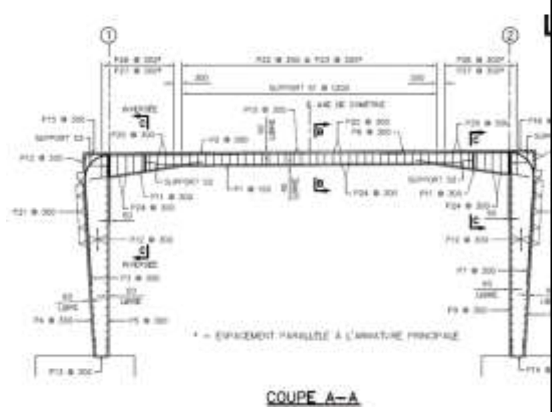
Country	Questionnaire	Case Study	Conceptual Design	Detail Design	Safe Access	Case Study	Comments
Germany	Yes	No	*1. Structural Configurations* : *2. Material Choices* : Weathering steel in some cases, protective coatings compulsory for steel bridges, use of ultra high performance concrete in some cases, use of elastomeric bearings in some cases. *3. Dimensions* : Minimum 300mm between bridge deck and bearing shelf, minimum vertical clearances for road overpasses/underpasses. *4. Instrumentation* : None. *5. Other* : None. *6. References* : German standards, typical details and design guidelines.	*7. Bearings* : Jacking points at abutments. *8. Expansion joints* : *9. Kerbs, parapets, railings* : *10. Surfacing, waterproofing* : *11. Drainage* : *12. Hollow spaces, voids* : *13. Prestressing* : In certain bridges, the unbonded prestressing must be able to be replaced. *14. Other* : All provisions made, details available in reference RI-EBW-PRUF	*15a. Platforms, landings, walkways, etc* : Inspection paths at abutments and on the parapets. *15b. Connections for platforms* : *15c. Moveable platforms* : Permanently installed on some long bridges. *15d. Climbing or descending* : Normally not provided. *15e.Ladders, stairs, hoists, etc* : Provided where required in some piers and hollow box girders. *15f. Fall arrest, handrails* : Installed on platforms, stairs, ladders where required. *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : In hollow box girders *15i. Lighting* : In hollow box girders. *15j. Ventilation* : *15k. Parking* : Space for UBIU or cherry picker allowed for where space permits. *15l. Other* :	None provided.	
Hungary	Yes	Yes	*1. Structural Configurations* : Integral bridges for lengths < 20m, continuous decks preferred over simply supported. *2. Material Choices* : Concrete specifications and cover for different environmental exposures and conditions (e.g.. de-icing salts), protective coatings for steel bridges, elastomeric bearings preferred. *3. Dimensions* : Minimum 500mm between end diaphragm and abutment breast wall for steel bridges, concrete slab 200mm minimum, steel plates 8mm minimum. *4. Instrumentation* : For complex large span bridges, instrumentation shall be implemented. *5. Other* : None. *6. References* : Design codes for Hungary and various other detailed codes.	*7. Bearings* : Jacking positions to be designed, bearings must be inspectable. *8. Expansion joints* : *9. Kerbs, parapets, railings* : *10. Surfacing, waterproofing* : *11. Drainage* : *12. Hollow spaces, voids* : Must be accessible for inspection. *13. Prestressing* : *14. Other* : No details provided.	*15a. Platforms, landings, walkways, etc* : *15b. Connections for platforms* : *15c. Moveable platforms* : *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : *15f. Fall arrest, handrails* : *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : *15i. Lighting* : *15j. Ventilation* : *15k. Parking* : *15l. Other* : No details provided.	Case study provided of a planned monitoring system to be installed in a new cable stayed bridge. The monitoring system will include the following sensors: Meteorological monitoring Cable force monitoring Temperature monitoring Bearing movement monitoring Vibration monitoring.	
Japan	Yes	Yes	*1. Structural Configurations* : Japan's Specification for Highway Bridges give principles to consider when designing a bridge that refer to inspections, maintenance and replacement. *2. Material Choices* : Steel shall be resistant to atmospheric corrosion (possibly meaning weathering steel), specifications for admixtures and additives to improve quality of concrete, minimum concrete strengths specified which relate to W/C ratio which relate to concrete durability, specifications for pregrouted prestressing steel for protection of prestressing steel and bonding. *3. Dimensions* : Minimum thickness of steel members considering the corrosive environment, minimum thicknesses of concrete dimensions in bridge decks, minimum thickness of orthotropic steel plate. *4. Instrumentation* : In some bridges, instrumentation is installed but these are to test new technologies rather than for inspections, maintenance and replacement. *5. Other* : Contained in the principles given in the specifications. *6. References* : Specifications for Highway Bridges.	*7. Bearings* : Principles for the design of bearings include considering inspection, maintenance and replacement. 400mm is generally allowed between top of support and underside of deck. Reinforcement in the form of stiffeners to webs to be provide in main girders and cross beams for jacking. Connections between cross beam and main girder to be able to withstand jacking loads. *8. Expansion joints* : Principles for the design of expansion joints include considering inspection, maintenance and replacement. *9. Kerbs, parapets, railings* : Steel rails are to be protected against corrosion, concrete shall use high strength fibres to prevent abrasion and delamination from impacts. *10. Surfacing, waterproofing* : Waterproofing layer shall be applied to prevent water permeating into deck concrete. *11. Drainage* : Principles of designing for deck drainage indicate that "quick drainage" shall be considered and maintenance method and equipment available shall be considered in the design. *12. Hollow spaces, voids* : None. *13. Prestressing* : Principles given for design of external cables for maintenance. The design of anchorages and deviators shall be designed such that the cable is able to be replaced. *14. Other* : None.	*15a. Platforms, landings, walkways, etc* : *15b. Connections for platforms* : *15c. Moveable platforms* : *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : *15f. Fall arrest, handrails* : *15g. Lugs, connection points for rope access* : Casting of lugs are necessary for hanging scaffolding in consideration of future painting and maintenance. *15h. Hatches, openings, manholes, etc* : *15i. Lighting* : *15j. Ventilation* : *15k. Parking* : *15l. Other* : No details given. However, Japan's Specification for Highway Bridges give principles to consider when designing a bridge that refer to inspections, maintenance and maintenance equipment to be used and items that need replacement.	Example of minimising steel usage in deck cross sections for reduced maintenance. Example of minimising number of precast concrete beams in deck cross section. The use of precast concrete produced in factories improves concrete quality and durability and reduces maintenance. Use and popularity of weathering steel in Japan as a material choice demonstrated in graph. Example given of concrete mix design to improve resistance against chloride penetration and alkali-silica reaction using increased proportions of blast-furnace slag. Example of use of ultra-high strength fibre reinforced concrete used with no reinforcing bars. The design of the anchor bolts for steel parapets tries to ensure that these will not be damaged in an impact and thus permits the easy replacement of the post and rails. The space at abutment galleries are designed to prevent leaking water from expansion joint to come into contact prestress cable anchorages. The space at girder/beam ends are designed for the inspection and replacement of the cables at the anchorages. Anchorages in the upper deck is not allowed. The space at top of piers are designed to permit the replacement of the bearings. Example given of an FRP plate used to replace a steel plate for a hatch opening which was too heavy.	
Norway	Yes	Yes	*1. Structural Configurations* : Specifications for geometries, dimensions, access, and design checking of certain bridges by NPRA for long term maintenance and performance. *2. Material Choices* : Weathering steel, high performance concrete and stainless steel for certain environments. Self-compacting concrete for underwater casting. *3. Dimensions* : Minimum dimensions for accessibility to hollow-box girders, bearings, expansion joints and hollow spaces of piers and pylons. *4. Instrumentation* : None. *5. Other* : Flow calculations for replacement of superstructure. *6. References* : NPRA design specifications and inspection manuals.	*7. Bearings* : Provisions contained in inspection and design manuals. *8. Expansion joints* : Provisions contained in inspection and design manuals. *9. Kerbs, parapets, railings* : Provisions contained in inspection and design manuals. *10. Surfacing, waterproofing* : Provisions contained in inspection and design manuals. *11. Drainage* : Provisions contained in inspection and design manuals. *12. Hollow spaces, voids* : Provisions contained in inspection and design manuals. *13. Prestressing* : Provisions contained in inspection and design manuals. *14. Other* :	*15a. Platforms, landings, walkways, etc* : Provided on large truss, cantilever, cable-stayed and suspension bridges. *15b. Connections for platforms* : Provided on large cable-stayed and suspension bridges. *15c. Moveable platforms* : Provided on large cable-stayed and suspension bridges. *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : Ladders and stairs inside cantilever and truss bridges. Lifts inside pylons of suspension bridges. *15f. Fall arrest, handrails* : Mainly handrails provided. *15g. Lugs, connection points for rope access* : Inside cantilever bridges. *15h. Hatches, openings, manholes, etc* : In hollow box girders. *15i. Lighting* : Inside closed spaces. *15j. Ventilation* : Inside steel box girders *15k. Parking* : *15l. Other* :	Hardanger Bridge: suspension bridge, 1.3km long main span. For Material choice, main and hanger cables are hot dip galvanised. Instrumentation monitors humidity inside of steel box girder and wind, rain and temperature monitors. Warning lights for ship and air traffic also installed. Bearings, expansion joints and parapets/railings details given. Polyurethane coating used for waterproofing under 80mm asphalt. Deck scuppers installed. Inside of hollow box steel girder and pylon is dehumidified. Deck steel is painted with protective coating. Side spans and pylons constructed from concrete. Rails are installed on the soffit for the permanent inspection platform. Platforms, stairs, ladders, elevators are installed inside pylons. Lugs installed on outside of pylons for climbing equipment. Railings installed and latchways for fall arrest. Lighting installed inside hollow spaces. Openings with hatches installed.	

Country	Questionnaire	Case Study	Conceptual Design	Detail Design	Safe Access	Case Study	Comments
Portugal	Yes	Yes	*1. Structural Configurations* : Integral/continuous structures favoured. *2. Material Choices* : Protective coatings to steel, and coatings to rehabilitated concrete. *3. Dimensions* : Clearances at abutments/piers for bearing inspection/replacement. *4. Instrumentation* : Installed for certain bridges. *5. Other* : None. *6. References* : Internal guidelines.	*7. Bearings* : Internal guidelines. *8. Expansion joints* : Must have a drainage system. *9. Kerbs, parapets, railings* : Must not allow climbing over or passing through. *10. Surfacing, waterproofing* : None. *11. Drainage* : Provisions for deck drainage, bearing shelf, internal voids, at abutments. *12. Hollow spaces, voids* : Provisions for accessibility in hollow spaces. *13. Prestressing* : Additional ducts allowed for external post tensioning. For non-grouted internal post tensioning, phased replacement of cables must be considered. *14. Other* : Access to built-in monitoring systems must be considered.	*15a. Platforms, landings, walkways, etc* : In access to abutments and landing in front of abutments. *15b. Connections for platforms* : *15c. Moveable platforms* : *15d. Climbing or descending* : In front of abutments. *15e.Ladders, stairs, hoists, etc* : Ladders inside hollow piers and on abutments. *15f. Fall arrest, handrails* : Handrails and harness connection points for ladders, platforms, etc. *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : For access to hollow spaces. *15i. Lighting* : Inside hollow spaces. *15j. Ventilation* : *15k. Parking* : *15l. Other* : Sidewalks on bridges.	Example of integral bridge. Protective coating to concrete bridge. Clearance at abutment for bearing inspection replacement. Example of instrumentation to monitor concrete degradation and structural displacements. Example of drip channel. Piers adapted to receive platform for bearing replacement. Anti slide cover on expansion joint. Parapets with additional height protection for railway. Waterproofing membrane. Example of deck drainage. Lighting located in central reserve to facilitate the use of UBIU on outer edges. Walkway in front of abutments. Example of ladder, handrail, lighting.	
Romania-Timisoara	Yes	No	*1. Structural Configurations* : No specifications, but rather left to the experience of the designer, for example continuous structures preferred, design of jacking points for bearings replacement. *2. Material Choices* : Contained in PD165/2012 Norm, durability specifications for concrete. *3. Dimensions* : Contained in PD165/2012 Norm. *4. Instrumentation* : None. *5. Other* : None *6. References* : Procedural manual for inspections which inform technical guidelines for design, also contained in PD165/2012 Norm.	*7. Bearings* : *8. Expansion joints* : *9. Kerbs, parapets, railings* : *10. Surfacing, waterproofing* : *11. Drainage* : *12. Hollow spaces, voids* : *13. Prestressing* : *14. Other* : No detail provided.	*15a. Platforms, landings, walkways, etc* : *15b. Connections for platforms* : *15c. Moveable platforms* : *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : *15f. Fall arrest, handrails* : *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : *15i. Lighting* : *15j. Ventilation* : *15k. Parking* : *15l. Other* : No detail provided.	No detail provided, old version of template used.	
Romania-Bucharest	Yes	No	*1. Structural Configurations* : Integral/continuous bridges, design of cross-beams for jacking to replace bearings. *2. Material Choices* : Durability specifications for concrete. *3. Dimensions* : Contained in national standards from European Norms. *4. Instrumentation* : None. *5. Other* : None. *6. References* : None.	*7. Bearings* : *8. Expansion joints* : *9. Kerbs, parapets, railings* : *10. Surfacing, waterproofing* : *11. Drainage* : *12. Hollow spaces, voids* : *13. Prestressing* : *14. Other* : No detail provided.	*15a. Platforms, landings, walkways, etc* : *15b. Connections for platforms* : *15c. Moveable platforms* : *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : *15f. Fall arrest, handrails* : *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : *15i. Lighting* : *15j. Ventilation* : *15k. Parking* : *15l. Other* : No detail provided.	No detail provided, old version of template used.	
South Africa	Yes	Yes	*1. Structural Configurations* : Integral bridges for lengths < 60m, continuous decks preferred, void formers in voided deck slabs not permitted, only internally bonded post tensioning used. *2. Material Choices* : Durability specifications for concrete, steel must be galvanised or coated or both depending on exposure, galvanised reinforcement used in parapets. *3. Dimensions* : Minimum clearances and space at bearings for jacking and replacement, minimum embankment slopes, minimum sizes of access openings and voids for Health and Safety reasons. *4. Instrumentation* : None. *5. Other* : *6. References* : Procedural design codes, typical details, Health and Safety regulations.	*7. Bearings* : Adaptor plates for bearings and materials selected to suit the environmental exposure conditions. *8. Expansion joints* : Expansion joint ends must terminate with upturned ends in the kerbs/parapets. *9. Kerbs, parapets, railings* : Concrete parapets/railings proffered due to risk of theft of steel elements. Sidewalks to cater for provision of future services. No paving slabs/blocks permitted for sidewalk surfaces due to theft/vandalism. *10. Surfacing, waterproofing* : None. *11. Drainage* : Direct discharge scuppers, no internal or external piping systems to be used. Deck voids, bearing shelves to cater for drainage and drip notches on deck edges. *12. Hollow spaces, voids* : Abutment galleries to be provided for large bridges where multi-element joints specified to facilitate inspection/maintenance/replacement of joints and bearings. *13. Prestressing* : Only internally bonded post tensioning used. *14. Other* : Stone pitching on embankments in front of abutments and a horizontal landing in front of the abutment is not permitted due to homeless people vandalism.	*15a. Platforms, landings, walkways, etc* : *15b. Connections for platforms* : *15c. Moveable platforms* : *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : *15f. Fall arrest, handrails* : *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : *15i. Lighting* : *15j. Ventilation* : *15k. Parking* : *15l. Other* : Personal security for inspectors and maintenance people sometimes used in dangerous areas. Other example given in Case Study.	Example of integral bridge. Durability Concrete specification given. Space requirements on piers for jacking for bearing replacement. Adaptor plates. Upturned ends of expansion joints. Direct discharge deck scuppers and drip-notch. Abutment galleries. Access chamber on pier head to inspect bearing and undertake maintenance. Platforms, Ladders, handrails, openings inside inclined legs of concrete arch. Abseil rope hooks for external inspection of high piers. Manholes, openings, etc. inside hollow concrete box girder.	
South Korea	Yes	Yes	*1. Structural Configurations* : Integral and semi-integral bridges for lengths < 100m. Minimisation of bearings by design monolithic connections between pier and deck. *2. Material Choices* : Fatigue design of steel bridges and durability requirements for concrete bridges dictated by design life requirements (100 years), use of ultra high performance concrete in some cases, latex modified concrete as wearing course is used. *3. Dimensions* : Minimum thickness of deck slab is 220mm, minimum clearance for bearing replacement 200mm. *4. Instrumentation* : Large span bridges (>200m) require instrumentation for earthquake monitoring. *5. Other* : *6. References* : None.	*7. Bearings* : Space allowances for jacking and bearing replacement, strengthening with stiffeners for jacking, installation of platforms where not enough space on pier/abutment for jacking. *8. Expansion joints* : Drainage trough installed under expansion joint for leakage. *9. Kerbs, parapets, railings* : None. *10. Surfacing, waterproofing* : Latex modified concrete as wearing course is used with reduced curing time for bridges in operation. *11. Drainage* : Minimum slope of drainage pipes to be 3%. Drainage cover at embankment slopes to prevent overflow. Drainage scuppers near piers must be piped to prevent staining/corrosion of pier face. *12. Hollow spaces, voids* : Minimum sizes for manholes and hollow boxes specified. Ventilation installed for steel box girders. *13. Prestressing* : Currently undertaking research to develop a "smart strand" that monitors stress levels. *14. Other* : Bridge health monitoring (instrumentation) installed on long span cable supported bridges.	*15a. Platforms, landings, walkways, etc* : Inspection platforms at abutments and piers. *15b. Connections for platforms* : *15c. Moveable platforms* : Bridge inspection lift used when height < 6.5m and under bridge inspection vehicle used when height > 6.5m. *15d. Climbing or descending* : Steps at abutments *15e.Ladders, stairs, hoists, etc* : *15f. Fall arrest, handrails* : *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : *15i. Lighting* : Installation of lighting inside of hollow spaces became a maintenance issue on its own. Now head lamps are rather used in these spaces. *15j. Ventilation* : Installed every 20m inside hollow steel box girders, 150mm dia. *15k. Parking* : *15l. Other* :	Platforms and walkway around pier head.	

Country	Questionnaire	Case Study	Conceptual Design	Detail Design	Safe Access	Case Study	Comments
Spain	Yes	Yes	*1. Structural Configurations* : None. *2. Material Choices* : Dictated by service life of bridges (100 years) as given in Eurocode. *3. Dimensions* : Vertical clearances to road below > 5.5m. *4. Instrumentation* : None. *5. Other* : None. *6. References* : None.	*7. Bearings* : *8. Expansion joints* : *9. Kerbs, parapets, railings* : *10. Surfacing, waterproofing* : *11. Drainage* : *12. Hollow spaces, voids* : *13. Prestressing* : *14. Other* : Details are specific to each bridge and no codes/specifications guiding the design of these items for inspection, maintenance and replacement.	*15a. Platforms, landings, walkways, etc* : *15b. Connections for platforms* : *15c. Moveable platforms* : *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : *15f. Fall arrest, handrails* : *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : *15i. Lighting* : *15j. Ventilation* : *15k. Parking* : *15l. Other* : Details are specific to each bridge and no codes/specifications guiding the design of these items for inspection, maintenance and replacement.	Interesting example of bearing configuration to assist replacement, with 2 elastomeric bearings under deck and 2 between the deck and upper side of abutment. Needs to be explained. Access openings into hollow box girders at ends. Platforms and access walkways on inclined legs of arch. Permanent moveable platform for cable stayed bridge, first used during construction of spans and now used for maintenance. Lift on exterior of pylon for cable stayed bridge. Ladder internally. Lighting inside concrete hollow box.	
Switzerland	Yes	No	*1. Structural Configurations* : Integral bridges used whenever possible. If bridge contains expansion joints and bearings, then inspection chambers required. *2. Material Choices* : Durability specifications for concrete, use of weathering steel, protection coatings, UHPC and galvanised rebar where needed. *3. Dimensions* : Space requirements for bearing replacements, all voids must be accessible for inspections. *4. Instrumentation* : Only in exceptional circumstances. *5. Other* : None. *6. References* : Various national standards listed.	*7. Bearings* : Requirement of a bearing plan to be submitted that considers design, installation, maintenance and replacement of bearings during its life. Min clearance of 200mm between bearing shelf and deck soffit. *8. Expansion joints* : Inspection chambers required at abutments for joint with minimum dimensions. Expansion joint must have separate drainage and chamber must have separate drainage. *9. Kerbs, parapets, railings* : Railings must be installed using "levitating" ground plates, to permit easy replacement of the post and rails? Hydrophobic coatings for kerbs and parapets is now common. *10. Surfacing, waterproofing* : None. *11. Drainage* : Polyethylene and stainless steel material. Cannot be cast-in. Voids must be drained. Drainage ducts outside of hollow box girders preferred. *12. Hollow spaces, voids* : Voids must be accessible and ventilated. Minimum manhole size 800mm dia. *13. Prestressing* : Internal grouted post tensioning common, with three corrosion protection categories, namely tendons inside steel ducts, tendons inside plastic ducts and tendons that re electrically insulated. *14. Other* : None.	*15a. Platforms, landings, walkways, etc* : *15b. Connections for platforms* : *15c. Moveable platforms* : *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : *15f. Fall arrest, handrails* : *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : *15i. Lighting* : *15j. Ventilation* : *15k. Parking* : *15l. Other* : No details given.	No details given.	
USA-FHWA	Yes	No	*1. Structural Configurations* : *2. Material Choices* : *3. Dimensions* : AASHTO LRFD Bridge Design Specifications *4. Instrumentation* : *5. Other* : *6. References* : The responsibility for these provisions mostly reside with the individual States.	*7. Bearings:* *8. Expansion joints:* *9. Kerbs, parapets, railings:* *10. Surfacing, waterproofing:* *11. Drainage:* *12. Hollow spaces, voids:* *13. Prestressing:* *14. Other:* No detail provided.	*15a. Platforms, landings, walkways, etc* : *15b. Connections for platforms* : *15c. Moveable platforms* : *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : *15f. Fall arrest, handrails* : *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : *15i. Lighting* : *15j. Ventilation* : *15k. Parking* : *15l. Other* : No details given.	No details given.	
USA-Wisconsin	Yes	Yes	*1. Structural Configurations* : Use of integral structures, use of approach slabs to prevent settlement of approaches. *2. Material Choices* : Stainless steel or epoxy coated rebar in bridge decks and parapets, UHPC in some cases. *3. Dimensions* : Maximum height of fence/parapet for UBIU access, minimum dimensions of steel plates given in design specifications. *4. Instrumentation* : Instrumentation provided on some research projects, but non for inspections, maintenance and replacements. *5. Other* : None. *6. References* : WISDOT Bridge Manual and Standards, ASHTO LRFD Bridge Design Specifications	*7. Bearings* : Minimum dimensions specified for jacking space. Laminated elastomeric bearings proffered over steel bearings. *8. Expansion joints* : Modular joints used for greater movements. Expansion joints are always minimised. *9. Kerbs, parapets, railings* : None. *10. Surfacing, waterproofing* : Polymer overlays to seal deck. *11. Drainage* : Downspout of deck drainage to extend minimum distances below bottom deck girder. *12. Hollow spaces, voids* : These spaces are avoided if possible in the design. *13. Prestressing* : Attempts to join cut prestressed strands using GRABB-IT Cable splice. *14. Other* : None.	*15a. Platforms, landings, walkways, etc* : *15b. Connections for platforms* : *15c. Moveable platforms* : *15d. Climbing or descending* : *15e.Ladders, stairs, hoists, etc* : *15f. Fall arrest, handrails* : Eye-bolt lugs installed in front of abutment face for hooking harness in front of abutments to perform inspections. *15g. Lugs, connection points for rope access* : *15h. Hatches, openings, manholes, etc* : *15i. Lighting* : Installed in some cases. *15j. Ventilation* : Installed in some cases. *15k. Parking* : *15l. Other* :	Detail of standard approach slab. Use of stainless steel rebar. Use of laminated elastomeric bearings. Polymer overlays for overlays. Detail of downspout from deck drainage to extend beyond bottom of girder. Detail of eye-bolt lugs installed in front of abutment face for hooking harness in front of abutments to perform inspections.	

APPENDIX C: EXAMPLES OF CONCEPTUAL DESIGN PROVISIONS

Canada-Quebec



Example of fully integral structure for span less than 20m.

The use of weathering steel which is painted at the expansion joints.

China

Monitoring item	Reason of monitoring	Commonly used apparatus	Photos
Wind field	The wind field over the bridge deck has significant influence to vehicle driving and structural safety. As for river and sea crossing cable supported bridges, the wind speed and direction would be measured in general.	Anemometer	
Environmental temperature& humidity	Mainly monitor the air temperature and humidity inside steel box girder, and alsoassist to monitor the working condition of dehumidifier, so as to assist and guide the maintenance and repair works of steel box girders.	Temperature &humidity instrument	
Structure temperature	Use to analyse the effect of structural temperature field to the structural static response, so thatstatic testing & identification method can be based on for reflection of the structural referencestatus,which is in turn used for provision of information on structural analysis at a regular basis.	Structural temperature measurement gauge	
Vibration properties	Bridge dynamic property parameters (frequency, vibration mode, modal damping coefficient) are signs for the quality deteriorations of bridge structural elements.	Accelerometer	
Spatial displacement	Bridge pier settlement and tower deformation etc. are the most intuitive response of the bridge safety.	GPS	
Deck girder deformation	The main deck girder deformation will varyfollowing the load distribution and load magnitude, and its downward displacement is an important index to reflect the loading condition.	Pressure Transmitter	
Deck girder displacement	The main deck girder longitudinal deformation is realized through main girder displacements at the bearing and expansion joint positions. If the deck girder longitudinal deformation is abnormal, then there will be hazard to the bridge safety.	Pull rope displacement meter	
Stay cable vibration and cable force	After bridge completion, the stay cables are easy to be damaged due to fatigue and corrosion, and their lives are sometimes shorter than that of other bridge structural elements. Thus, should timely master the stay cable internal forces and their variation characteristics for judgement of structural safety, and determine whether cable replacement is needed.	Stay cable accelerometer	
Structure strain	The structural damage status will lead to stress over limit or stress abnormal redistribution. Through strain monitoring to master the stress conditions due external loadings like vehicle load, wind load, temperature field and earthquake etc. Whether the stress level at measurement positions are safe or not, it can be judged directly.	Optical fiber grating strain gauge	

Monitoring item	Reason of monitoring	Commonly used apparatus	Photos
Concrete corrosion	For bridge structure in marine environment, especially various types of reinforced or prestressed concrete structures in water splash zone or water level fluctuation zone, they are easily to be corroded by high chloride content inside seawater.	Corrosion meter	
Riverbed scouring	Riverbed scouring will cause a variation in pile free length, and hence obviously change the pile structure bearing capacity.	Ultrasonic scouring measurement meter	
Vehicle loading	Vehicle loading is the major load to be sustained by the bridge. It would not only cause structural fatigue issue, but also lead to inadequate bearing capacity and collapse.	Vehicle loading system	
Bearing reaction	Bearing is an important boundary condition of the bridge. The bridge bearing working condition would closely relate to whether the bridge can properly function. Thus, its behaviour shall be monitored if the condition is permitted.	Bearing reaction meter	

Commonly used health monitoring systems in China.

Japan

3.1 Steel Materials

(1) The steel materials shall have certain mechanical properties such as strength, elongatio[n] and toughness, chemical composition, limitations on harmful ingredients, geometric[al] dimensions such as thickness and warping, and quality.

(2) The steel materials given in Tables 3.1.1 and 3.1.2 are deemed to satisfy (1).

Table 3.1.1 Steel Materials (JIS)

Steel type	Standard		Steel material symbol
1) Steels	JIS G 3101	Rolled steels for general structure	SS400
	JIS G 3106	Rolled steels for welded structure	SM400, SM490, SM490Y SM520, SM570
	JIS G 3114	Hot-rolled atmospheric corrosion resisting steels for welded structure	SMA400W, SMA490W SMA570W

Specifications for hot-rolled atmospheric corrosion resisting steels for welded structure.

Table 3.2.1 Standards or Stipulations of Materials for Concrete

Material type	Standard or stipulation		Remarks
1) Cement	JIS R 5210	Portland cement	Normal, High-early-streng[th]
	JIS R 5211	Portland blast-furnace slag cement	
2) Water	JIS A 5308 Appendix C	Water used for kneading ready mixed concrete	
3) Aggregate	JIS A 5308 Appendix A	Aggregate for ready mixed concrete	
4) Additive	JIS A 6204	Chemical admixtures for concrete	
5) Admixture	JIS A 6201	Fly ash for use in concrete	
	JIS A 6206	Ground granulated blast-furnace slag for concrete	

Materials specification for concrete mixture

Table 3.2.2 Minimum Specified Compressive Strength of Concrete (N/mm^2)

Member type		Minimum specified compressive strength
Plain concrete member		18
Reinforced concrete member		21
Prestressed concrete member	Pretensionning method	36
	Post-tensionning method	30

Minimum specified compressive strength for concrete.

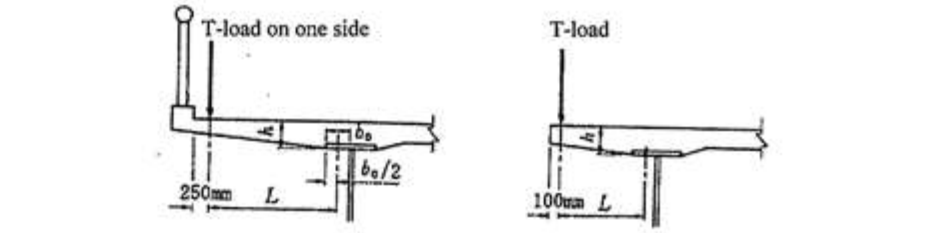
Table 9.2.4 Minimum Deck Thickness of Roadway

(mm)

Deck type	Span direction of deck		
	Perpendicular to vehicle running direction		Parallel to vehicle running direction
Simple deck	$40L + 110$		$65L + 130$
Continuous deck	$30L + 110$		$50L + 130$
CantileverCantilever deck	$0 < L \leq 0.25$	$280L + 160$	$240L + 130$
	$L > 0.25$	$80L + 210$	

where

L: Span (m) of deck with respect to T-load shown in Clause 9.2.3

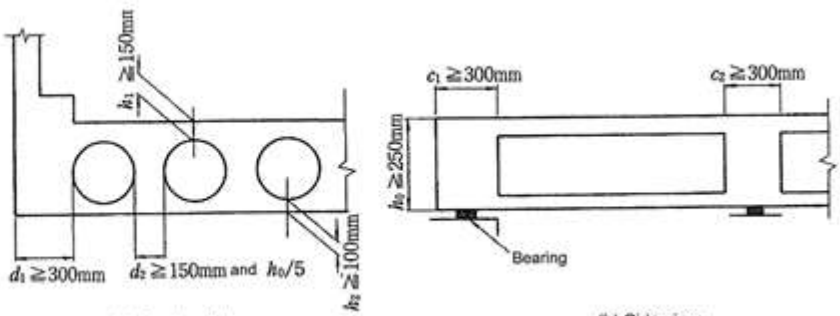


(a) Main reinforcement perpendicular to vehicle running direction

(b) Main reinforcement parallel to vehicle running direction

Figure 9.2.3 Minimum Total Thickness of Cantilever Deck h

Minimum thicknesses of concrete deck.

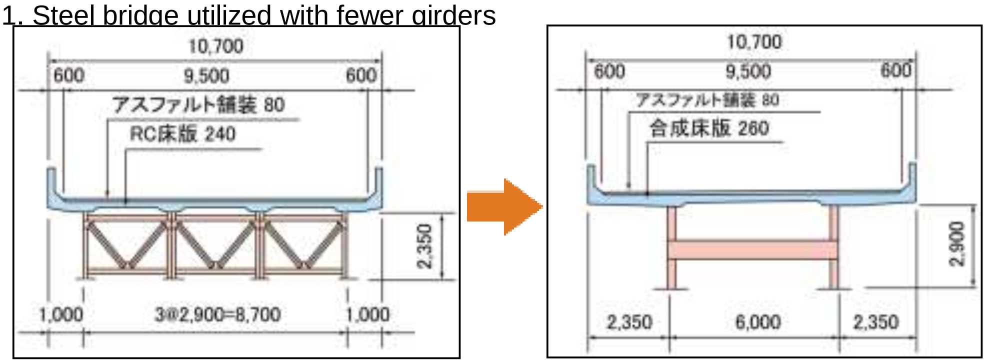


(a) Sectional view

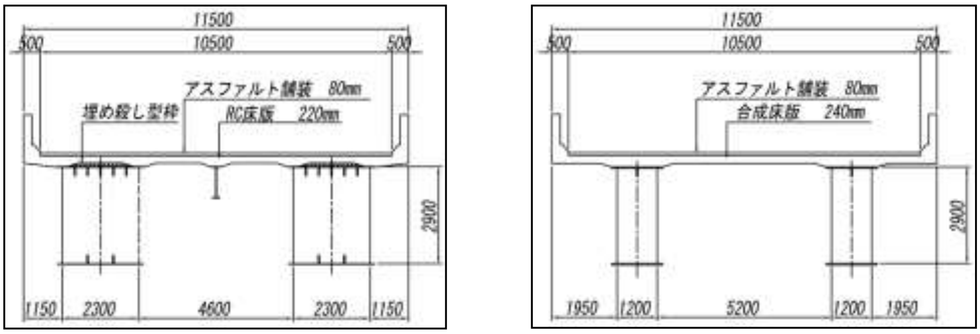
(b) Side view

Minimum dimensions of hollow slab bridges.

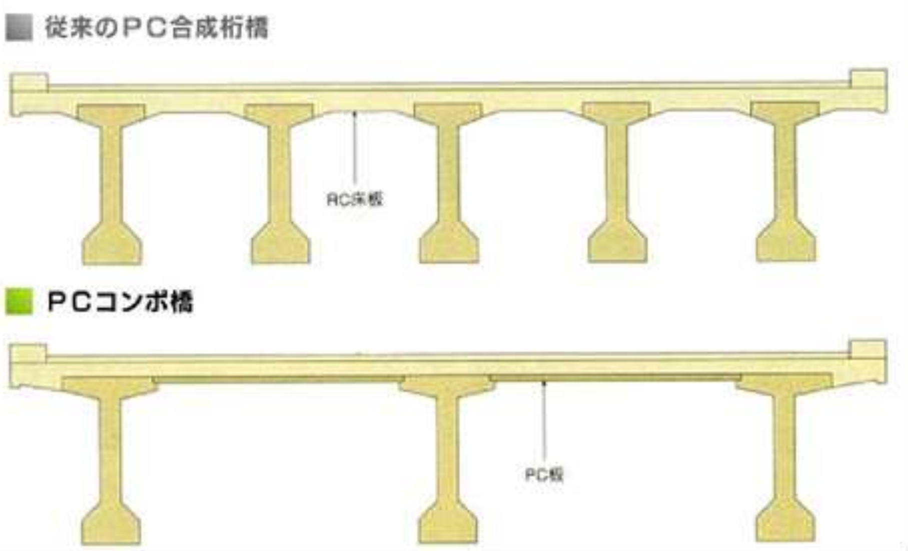
1. Steel bridge utilized with fewer girders



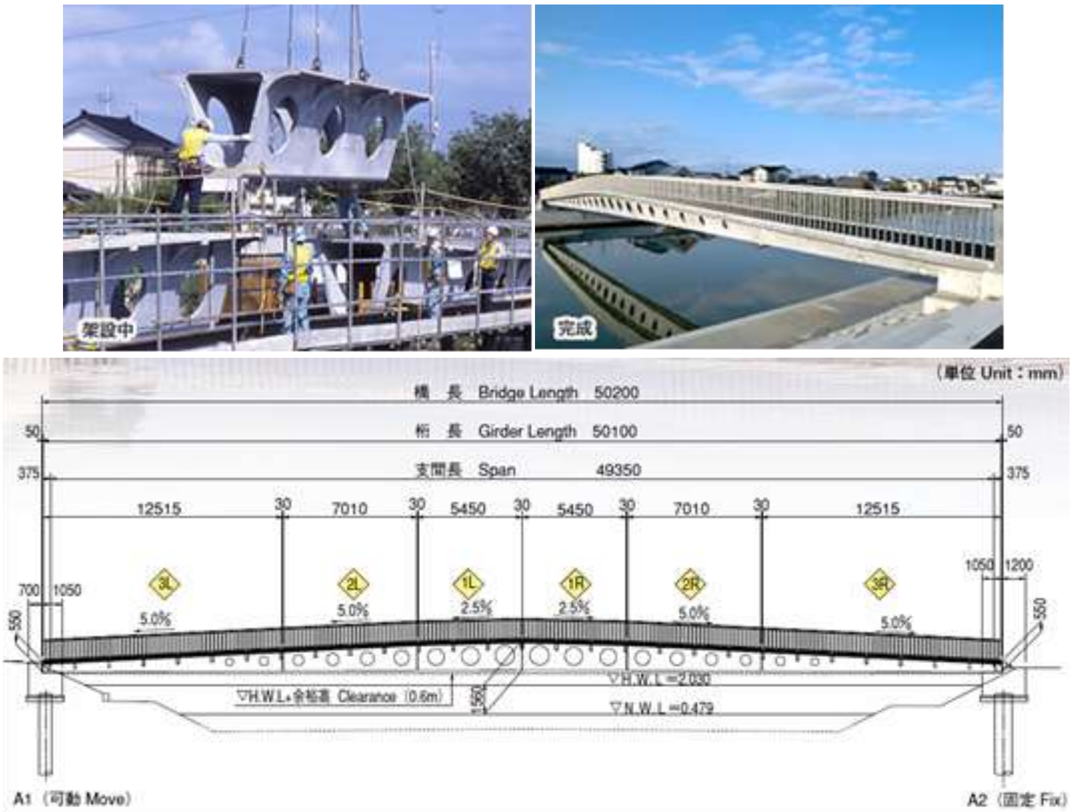
2. Narrow section steel box girder



Examples of fewer steel elements used in girders.

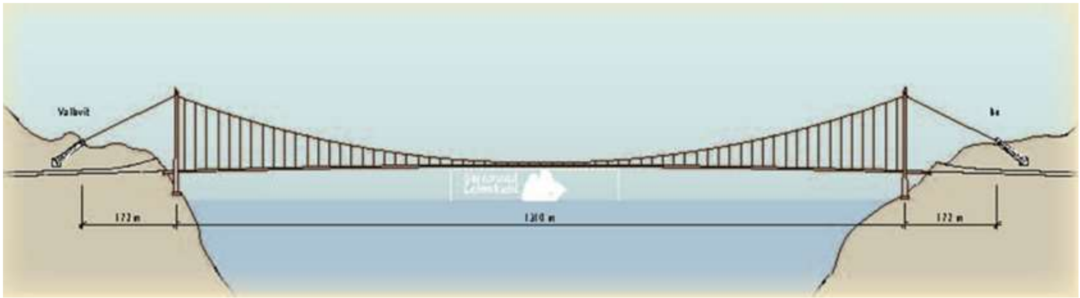


Example of reducing number of girders with embedded form for concrete and composite floor slab with cast-in-place concrete.



Example of ultra-high-strength fiber reinforced concrete which is 180 MPa compressive strength and no reinforcing bars.

Norway



The Hardanger Bridge, description of material choice:

Pylons: Concrete B45 SV-30/SV-40

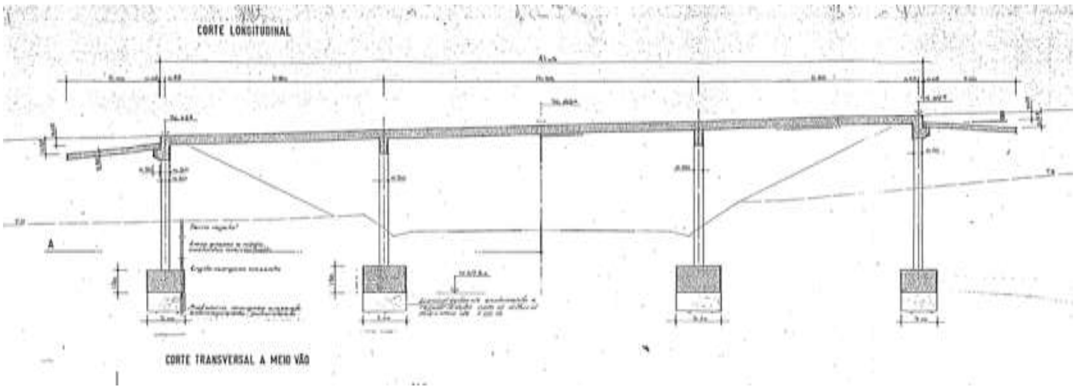
Side spans: Concrete B45 SV-40

Steel box girder: S355N/NL - NS-EN 10025-3, S

Main cables: 2x 10032 hot-dip galvanized wires with a diameter of 5.30 mm, tensile strength 1570 MPa.

Hangers: Locked coil cables with a diameter of 68 mm made from hot-dip galvanized wires with tensile strength 1570 MPa

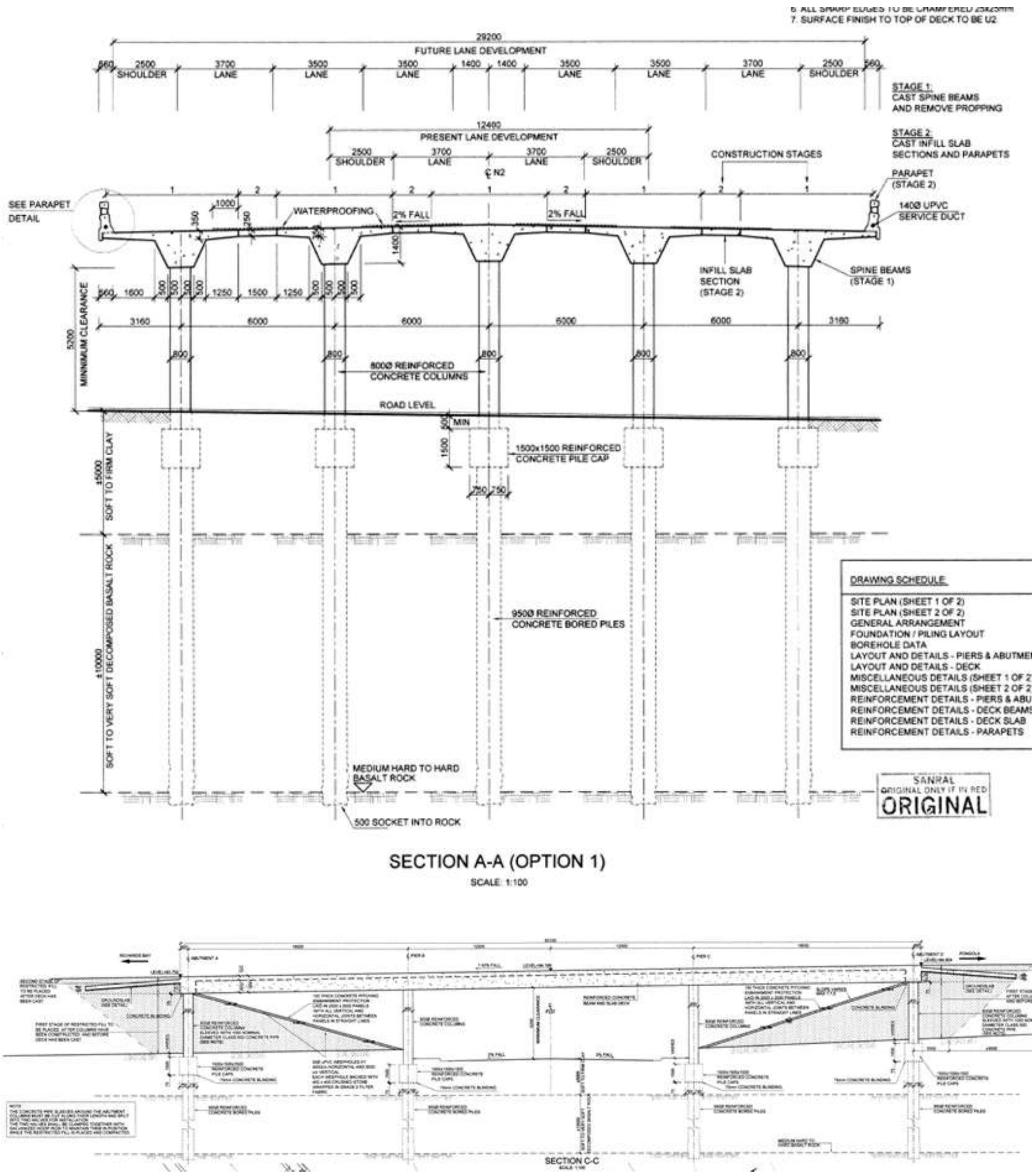
Portugal



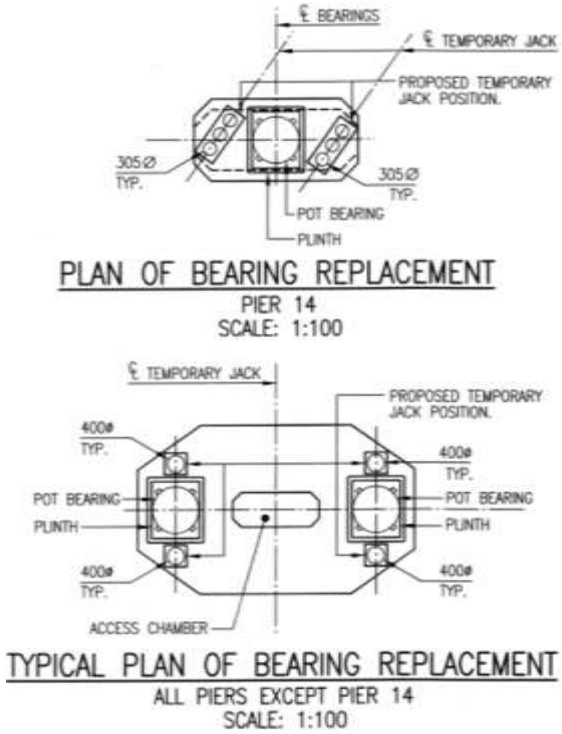
Example of a three-span monolithic (integral) structure.

Example of protective coating of concrete.

South Africa

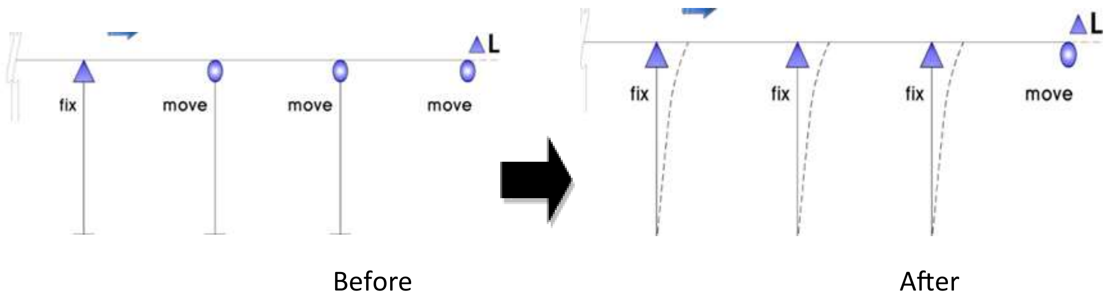


Example of an integral structure.



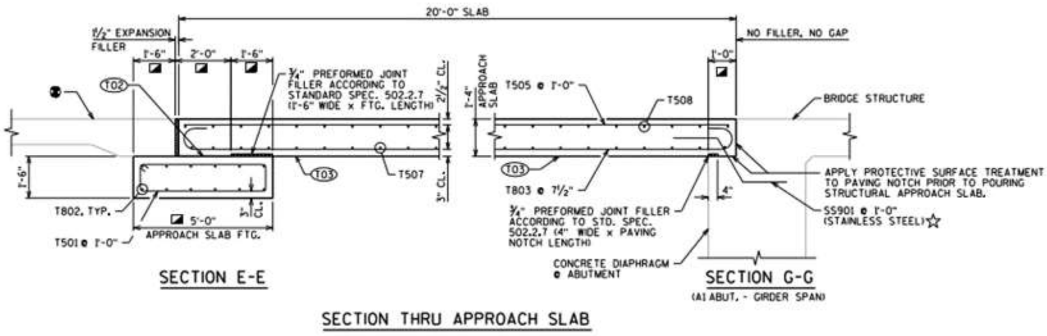
Example of clearance allowances on piers for jacking.

South Korea



Example of minimizing the use of bearings.

USA-Wisconsin



Example of structural approach slab standard detail.

The use of stainless steel rebar in deck slabs.

APPENDIX D: EXAMPLES OF DETAIL DESIGN PROVISIONS

Austria

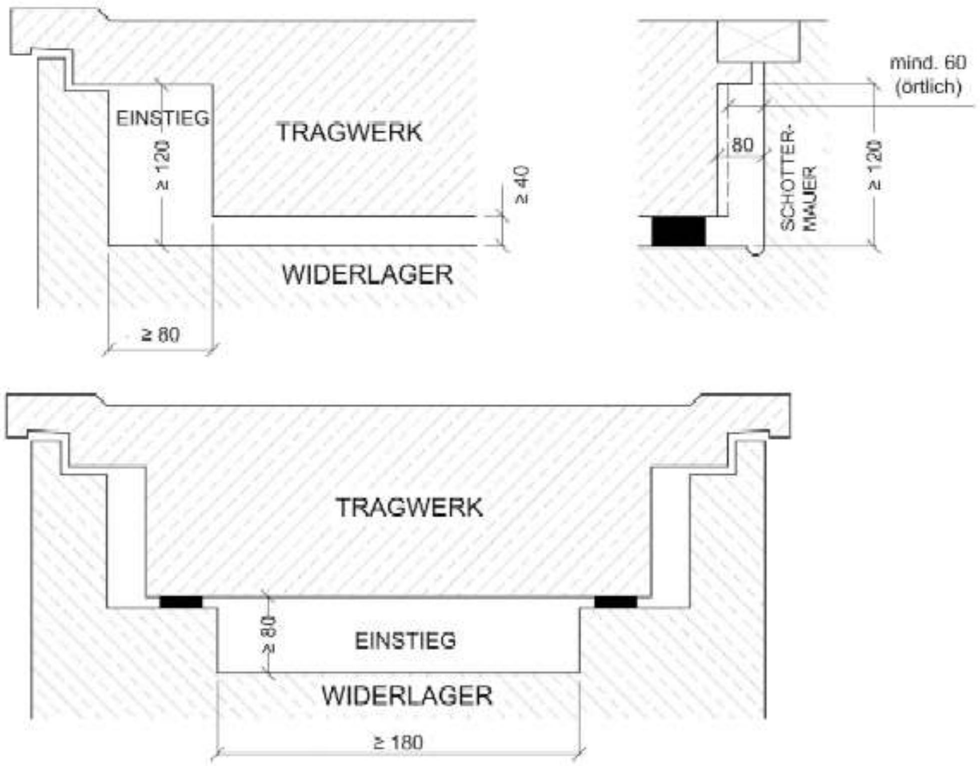


Abbildung 2: Ausführung für Einstiege im Widerlagerbereich (alle Maße in [cm])

Example of minimum dimensions at the abutment.

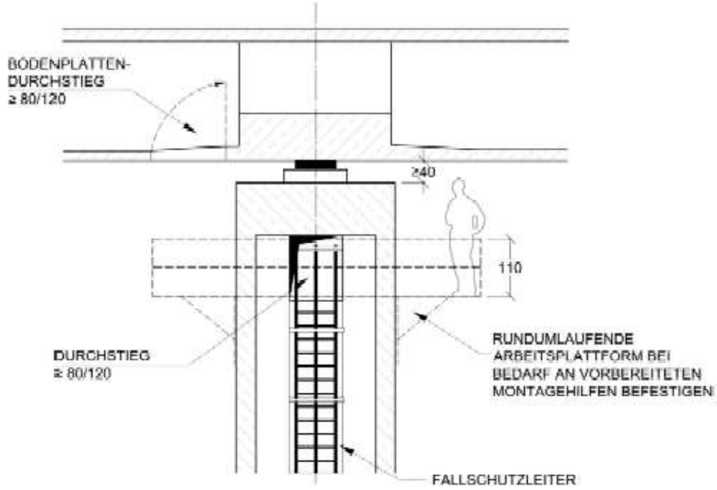


Abbildung 3: Ausführung von Durchstiegsöffnungen bei Pfeilern (alle Maße in [cm])

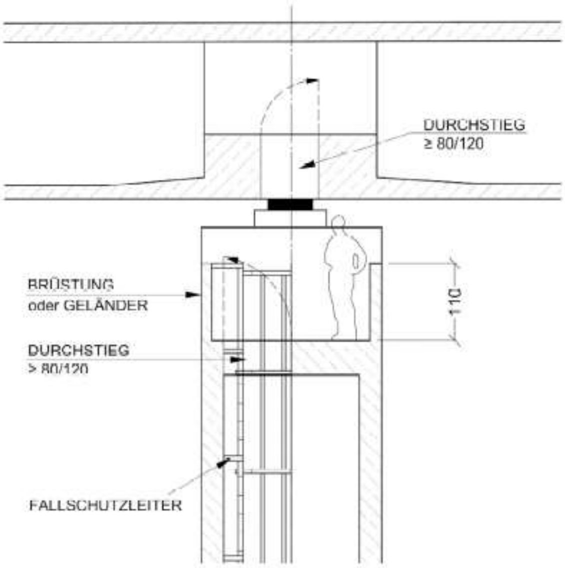
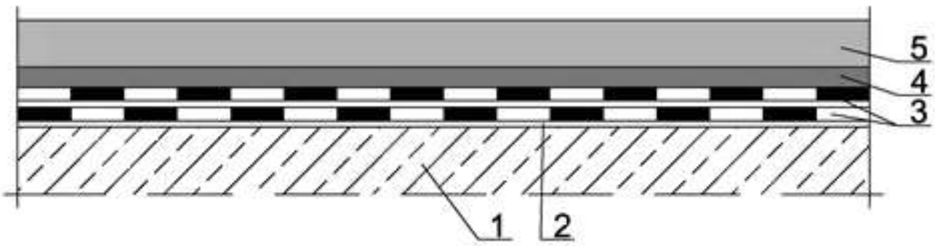


Abbildung 4: Ausführung von direkten Durchstiegsöffnungen bei Pfeilern (alle Maße in [cm])

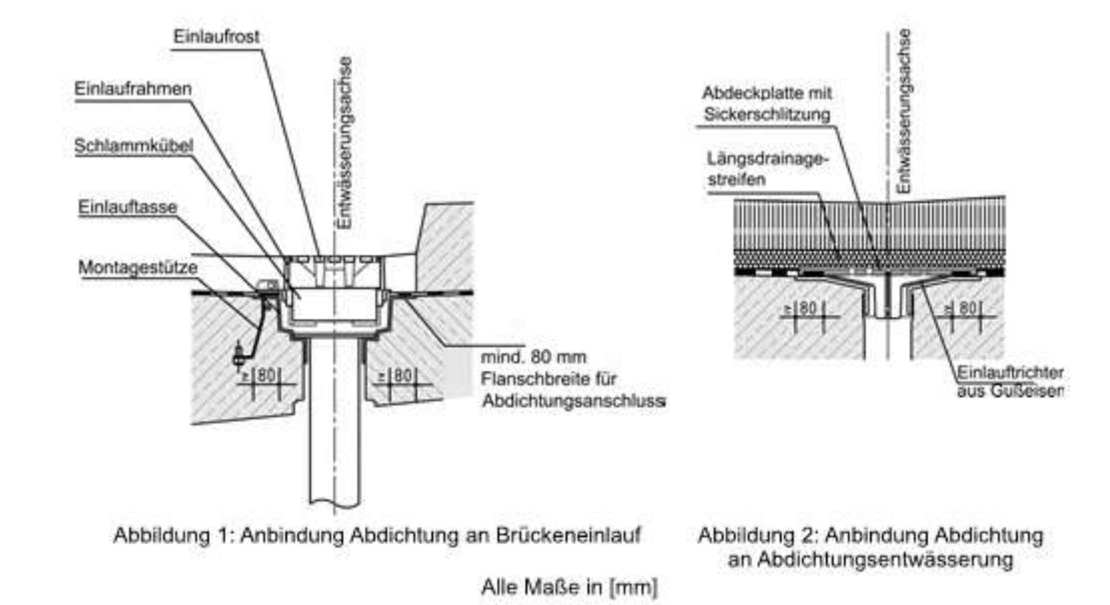
Example of space provisions at piers.



Legende: 1 Rohtragwerk 2 Primer 3 Abdichtung
4 Schutzschicht 5 Zwischen- und/oder Deckschicht

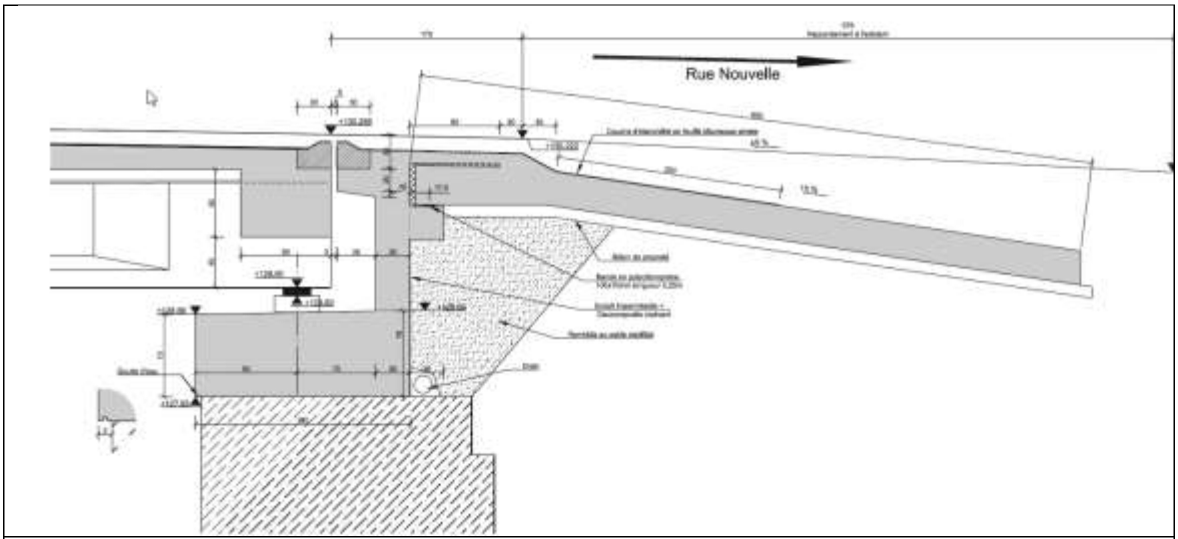
Abbildung 1: Aufbau einer zweilagigen Brückenabdichtung

Example of a two-layer bridge waterproofing system.



Typical details of a bridge drainage system.

Belgium-Wallonia



Example of space details at abutment for bearing access.

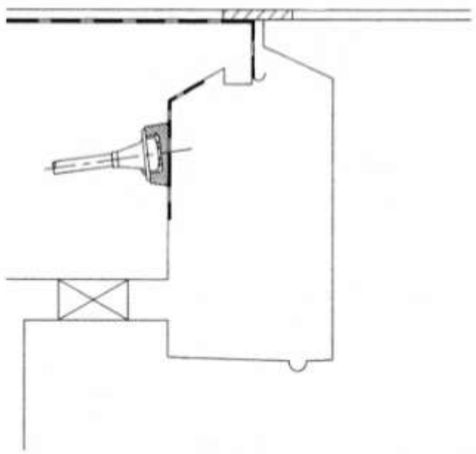
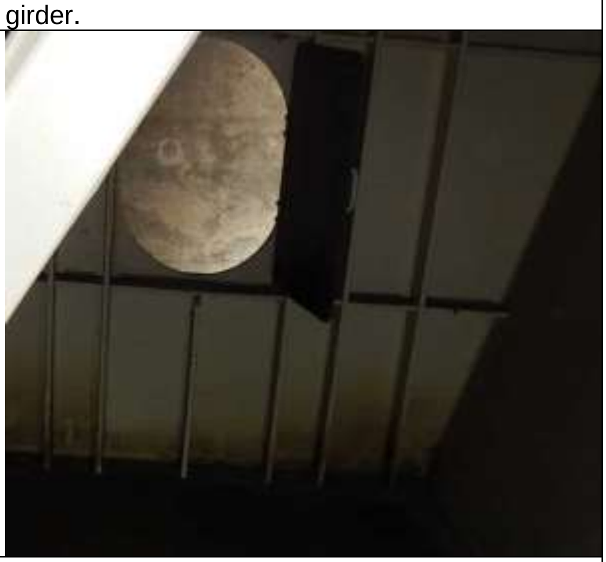


Fig.1.2 Buried anchorage for internal tendons at end of deck with abutment gallery, or beneath expansion joints, [7]

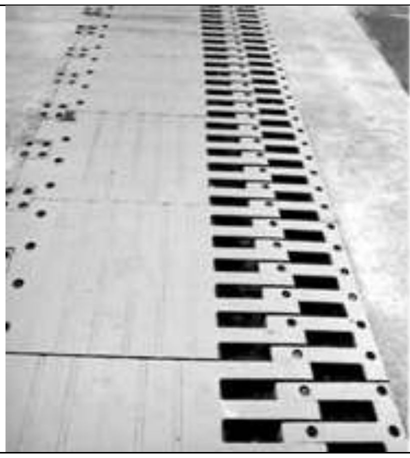
Details of expansion joint drainage and protection of post tensioning anchorages from leakage at the joint. Space also allows for replacement of tendons.

Canada-Quebec

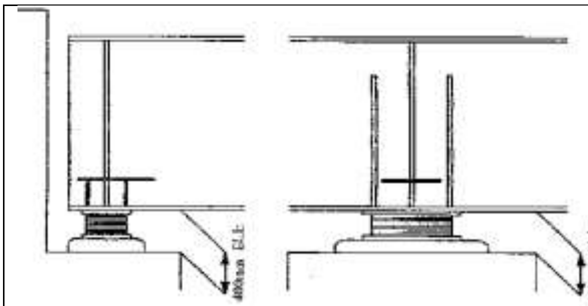
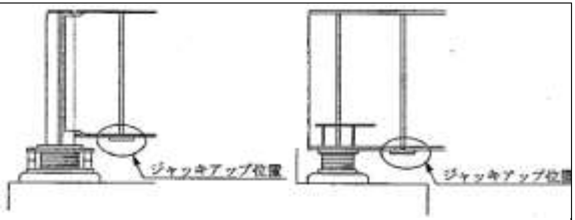
	
Example of abutment chamber drainage.	Expansion joint drainage.

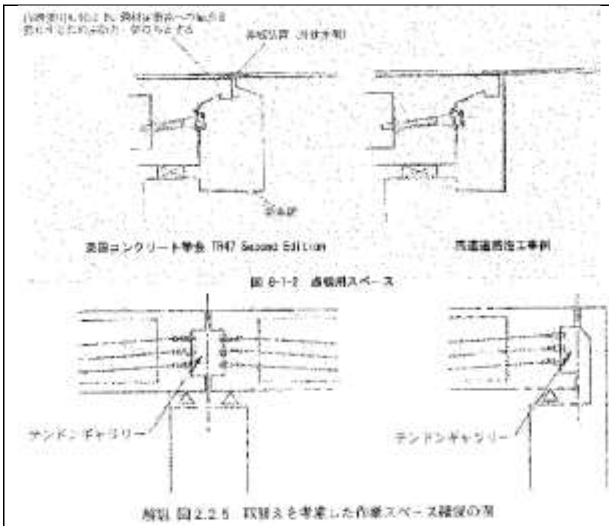
	
Thermo-fusible waterproofing membrane.	Concrete machine used for finishing surface of bridge decks.
	
Deck scupper with weepholes at concrete level.	Deck scupper extends beyond bottom level of girder.
	
Interior steel hollow box girder painted white.	Interior steel hollow box girder painted white.

China

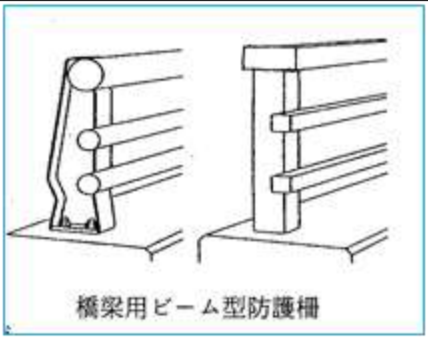
	
Reserved jacking place on top of pier.	Example of expansion joint installed in 1m modular lengths
	
Example of concealed drainage pipes.	Example of concealed drainage pipes.

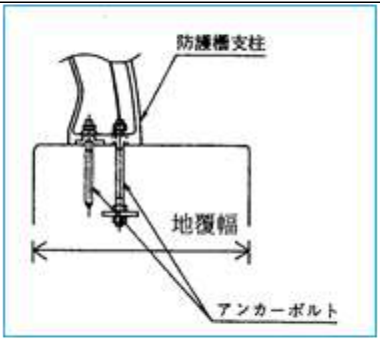
Japan

	
Clearance under the bearing	Example of jack-up reinforcement



Details of expansion joint drainage and protection of post tensioning anchorages from leakage at the joint. Space also allows for replacement of tendons.

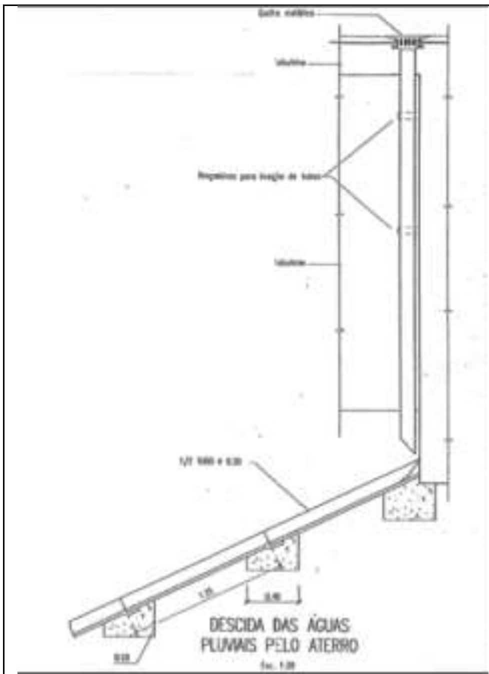




Details of base plate type anchoring for posts of parapets which permit replacement of post and rails only provided anchor bolts are not damaged.

Portugal

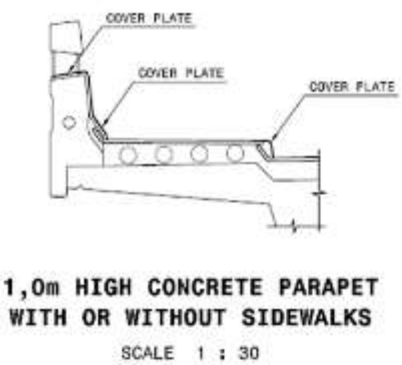
	
Top of piers adapted to receive platform for maintenance work on bearings.	Waterproofing membrane of deck surface.

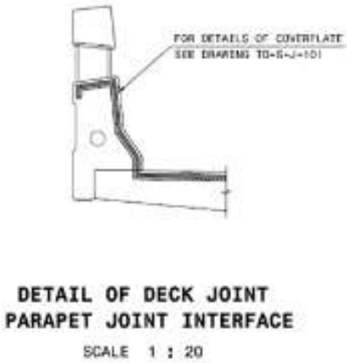


Example of drainage from deck.

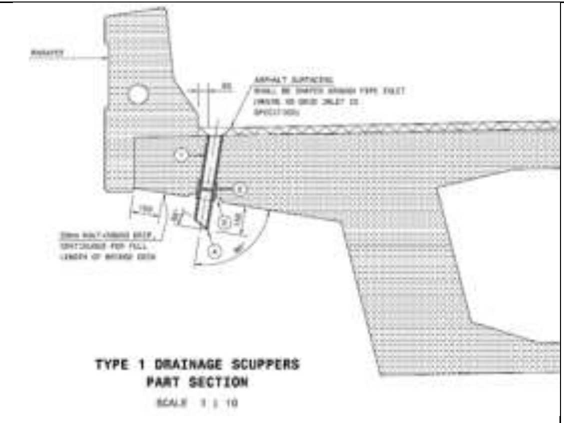
Lighting provided in central reserve which permits use of under bridge inspection vehicle.

South Africa

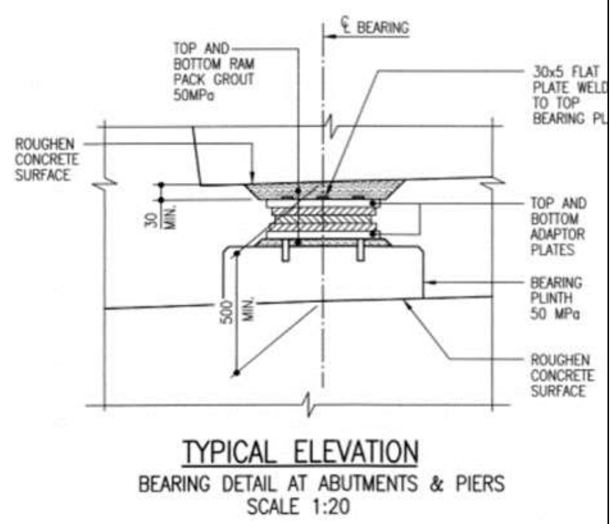




Expansion joints turned up or continue into parapets/kerbs at ends



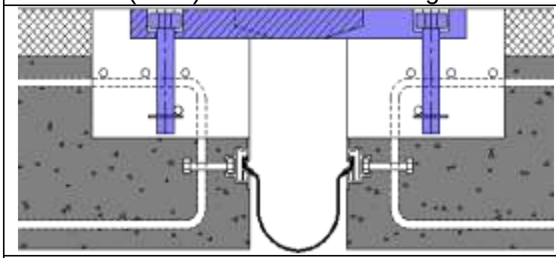
Direct discharge deck scupper and half-round drip notch.



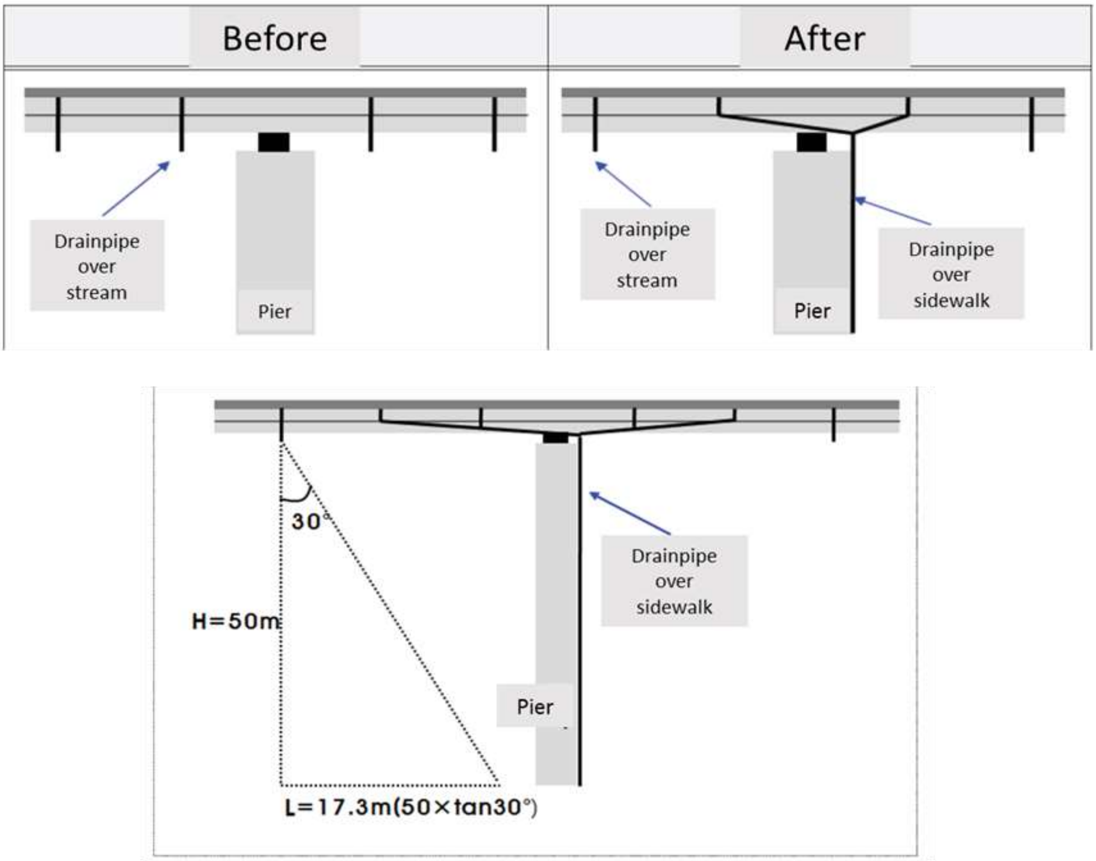
Upper and lower adaptor plates to facilitate bearing removal and replacement.

South Korea

Deteriorated asphalt overlay shown on the left and repaired on the right with latex modified concrete (LMC) with reduced curing time.

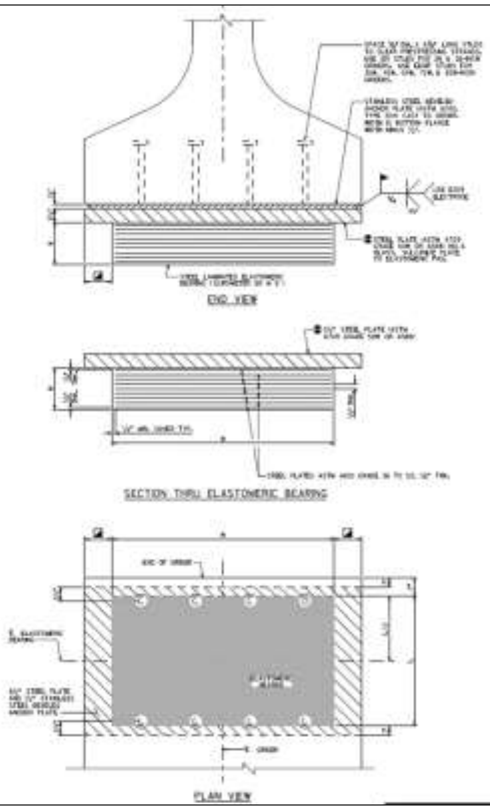


To prevent leakage, a drainage trough is installed under the finger type expansion joint.

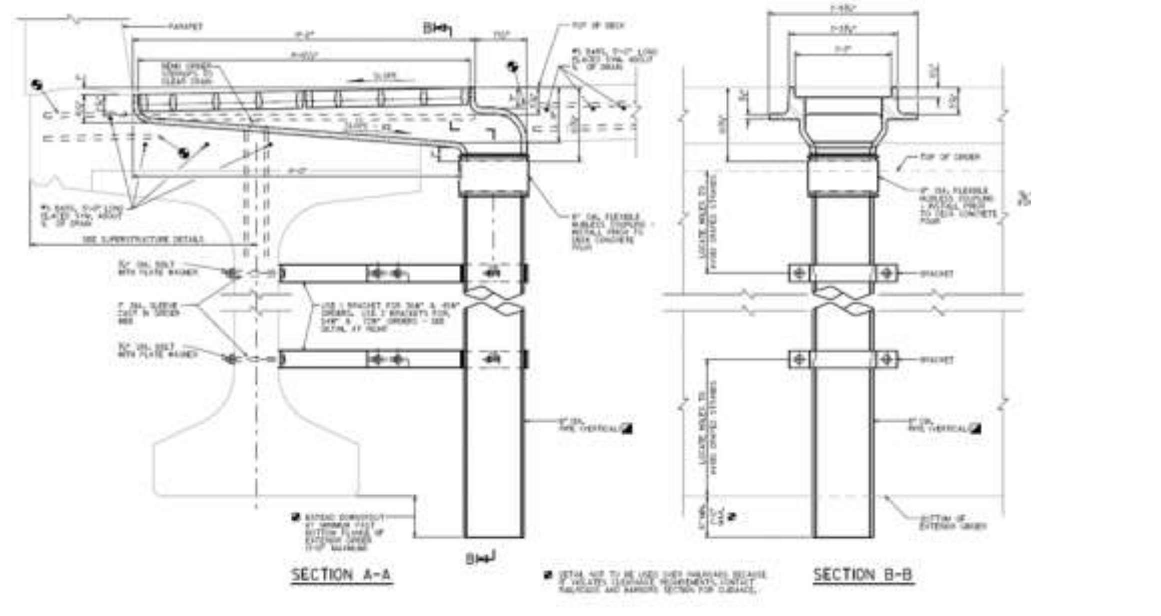


To minimize the detrimental effects of water spray on bridge piers, drainpipes near the pier are extended to the ground.

USA-Wisconsin



Use Laminated Elastomeric bearing instead of steel bearings where applicable.



Extension of downspout past bottom soffit of girder.

Polymer overlay.

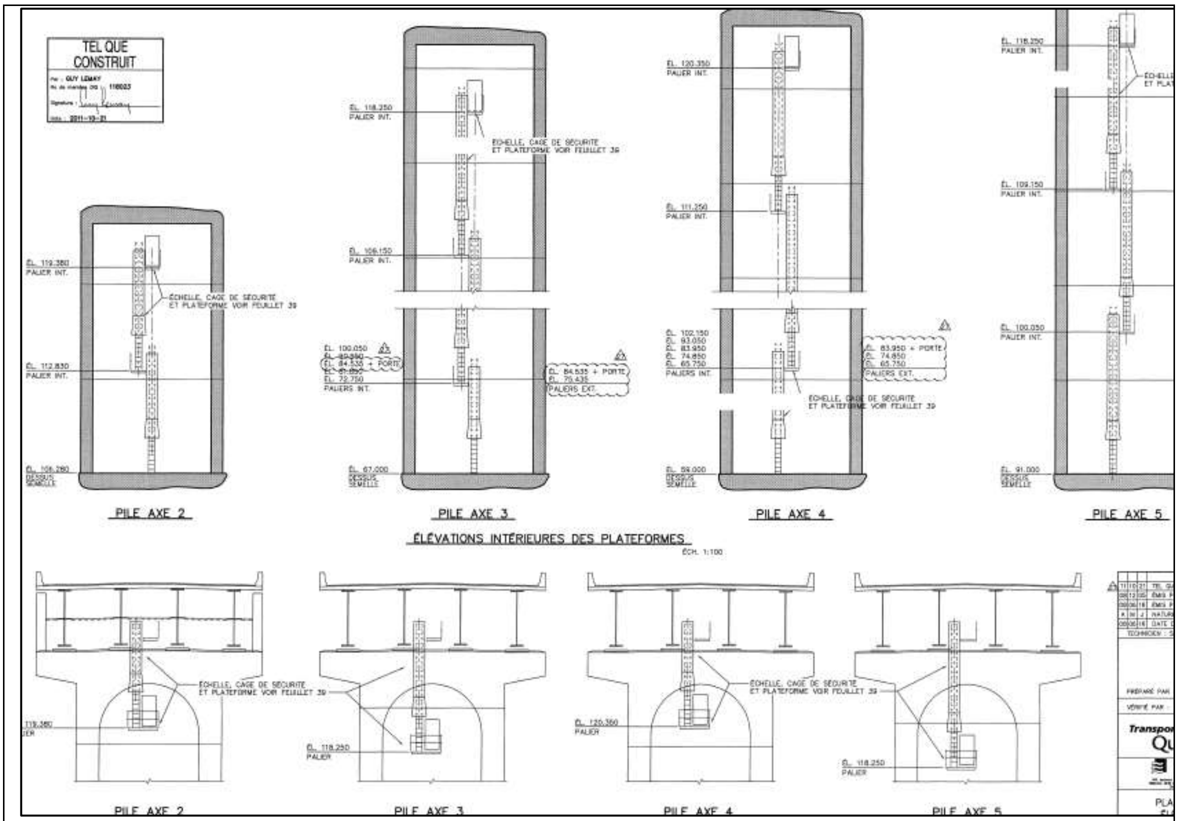
APPENDIX E: EXAMPLES OF SAFE ACCESS PROVISIONS

Belgium-Wallonia

	
Description for permanently installed moveable platforms.	Description for lighting in closed spaces.

Canada-Quebec

Inspection openings in hollow concrete elements – inspection walkway for girders and access to piles since the bridge is long and high above the terrain.



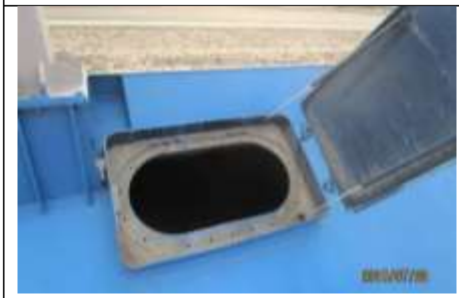
Plans for access openings and ladders for access to the interior of hollow piles.

Access ladder and door detail.

China

	
Item a: ---Inspection access platform.	Item b: Interior ladder.
	
Item b: Interior elevator.	Item b: Platform interior.
	
Item b: Exterior ladder.	Item c: Underbridge inspection gantry.

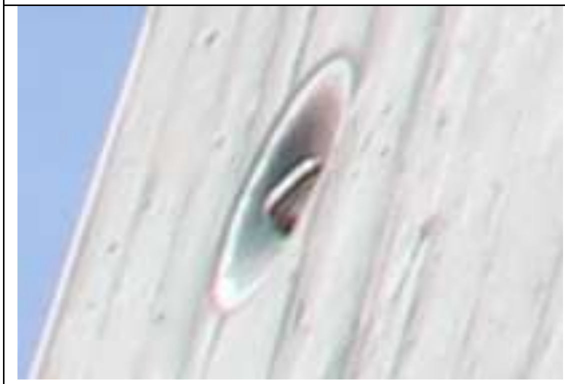
	
Item c: Underbridge inspection gantry.	Item d: Embankment access staircase.
	
Item e: Underbridge inspection gantry.	Item e; Truss bottom chord inspection access.
	
Item e: Main cable inspection walkway.	Item e: Ladder for anchorage chamber.

	
Item-f: Fall protection system at cat ladder.	Item-g: Support structure at top of tower.
	
Item h: Man hole.	Item j: Ventilation inside box girder.
	
Item k: Parking area.	Item i: Inspection access at deck top level.
	
Item i: Bearing inspection platform.	Item i: Expansion joint inspection access.

Japan

	
The original hatch to enter the inside of the tower shaft was made of steel plate, however, it was heavy to open and it might be corroded due to sea salt. The material for hatch was replaced by FRP plate.	

Norway

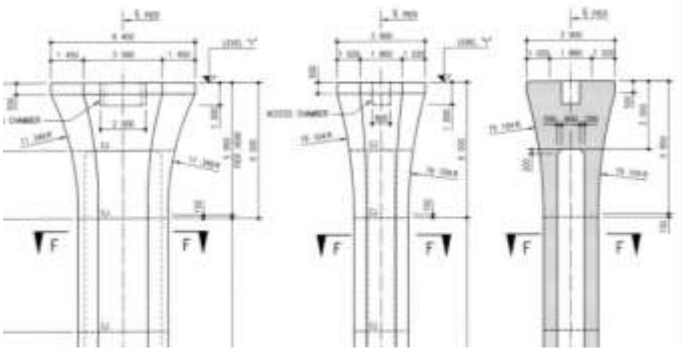
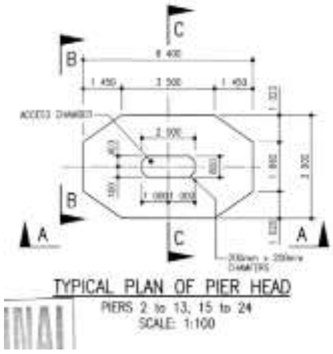
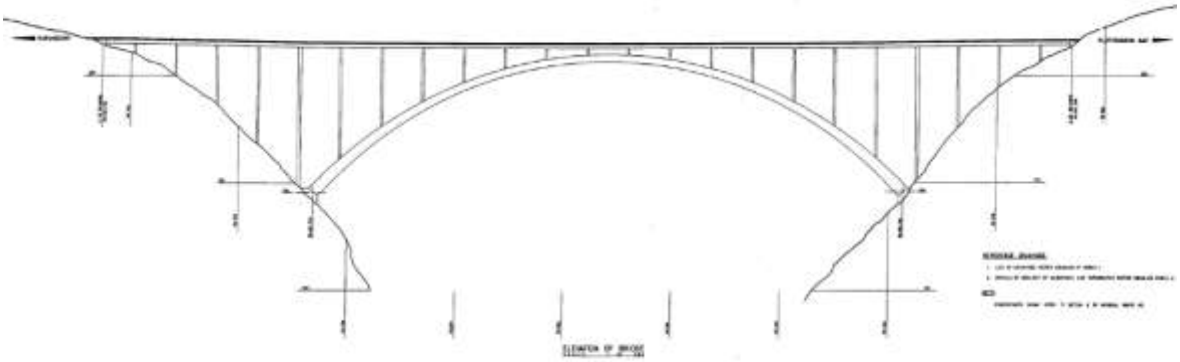
	
Access platform for outer surfaces box girder.	Railings on both side of main cables. Latch-way system installed on railings.
	
Details for fastening of climbing equipment at vertical sides of pylon legs. Railings and latchway system at main cables.	

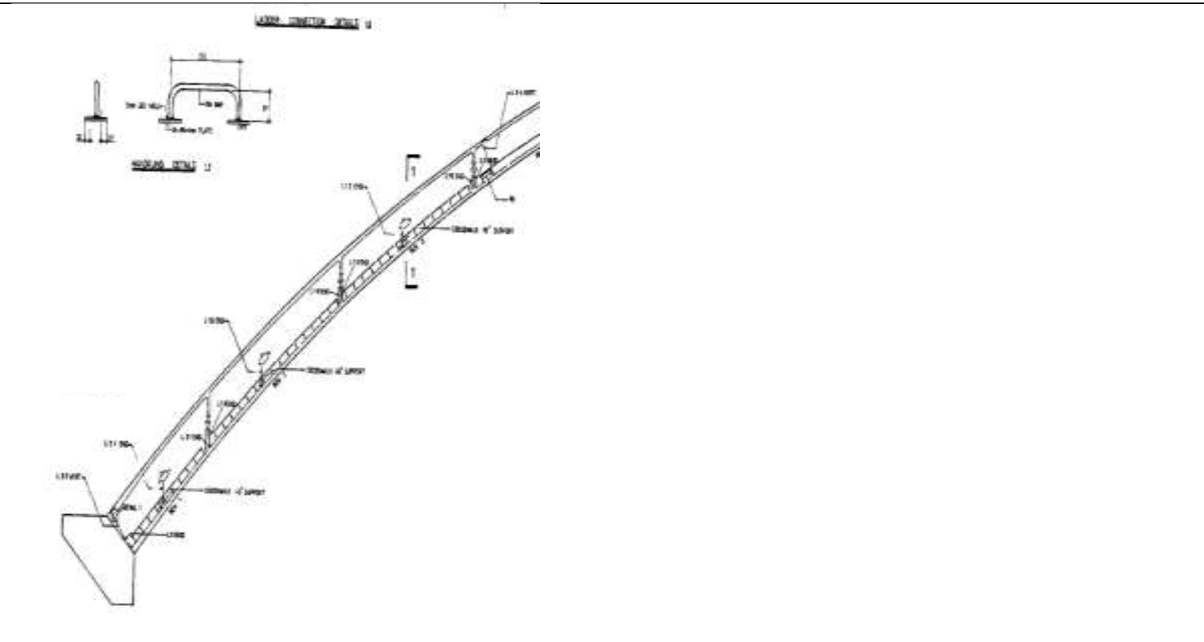
Portugal

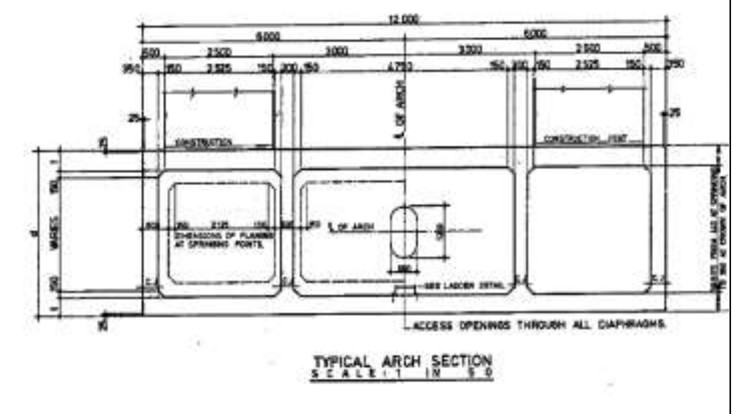
	
Description for platforms, landings, walkways, catwalks, etc.: walkway along retaining wall between abutments.	Description for ladders, stairs, hoists, lifts, step irons, etc.: ladder.

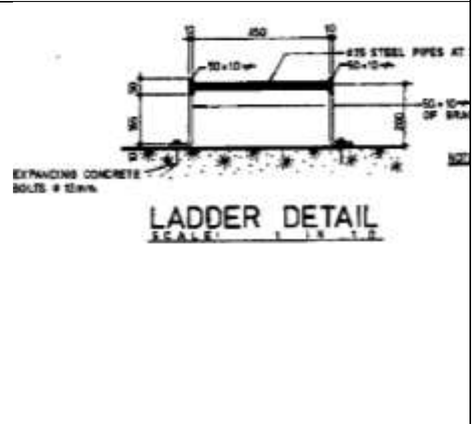
	
Description for Fall arrest systems, handrails, etc.: handrails.	Description for lighting in closed spaces.

South Africa

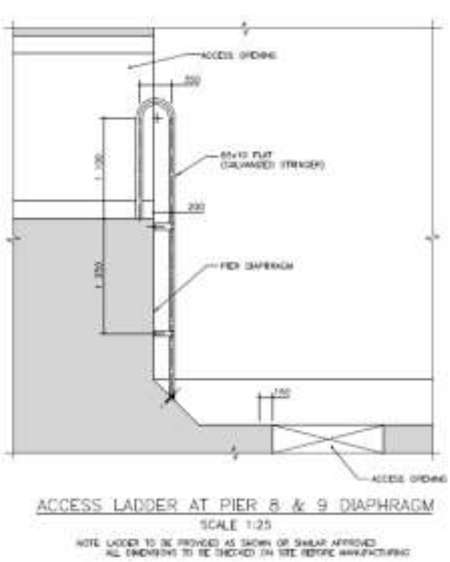
	
Access chamber on pier head to inspect and maintain bearings. Entry into chamber from within the deck through manholes in soffit above piers.	
	

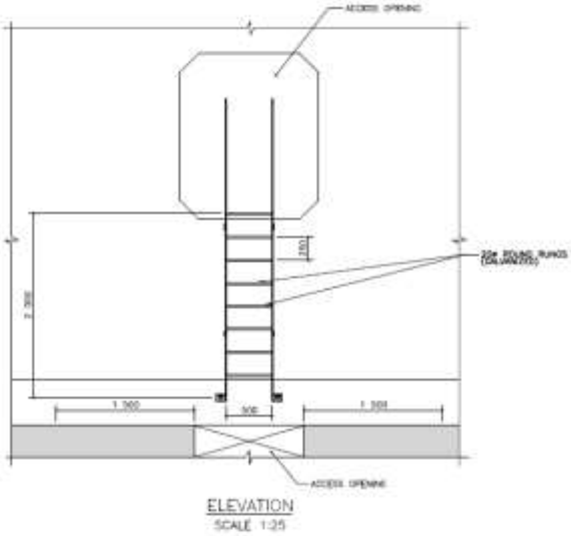




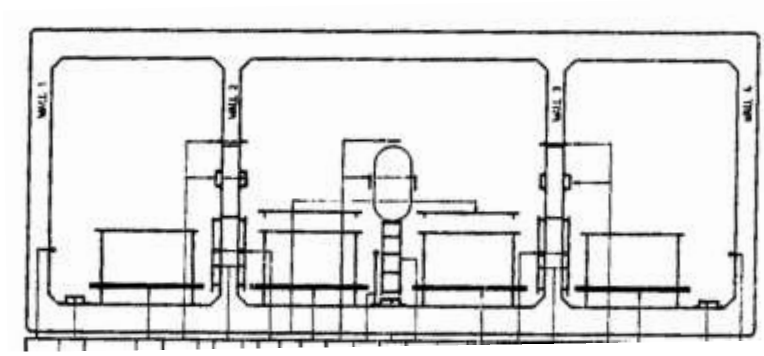


Ladder on centreline of arch.

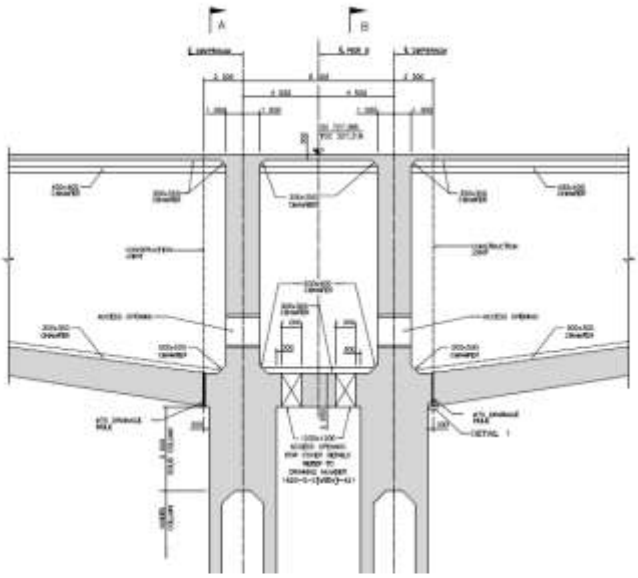


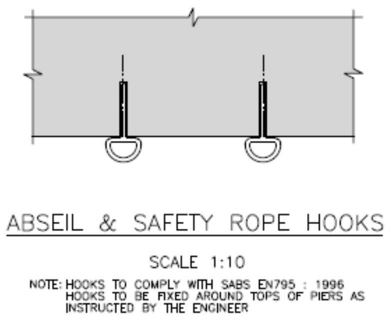


Ladders in deck void.

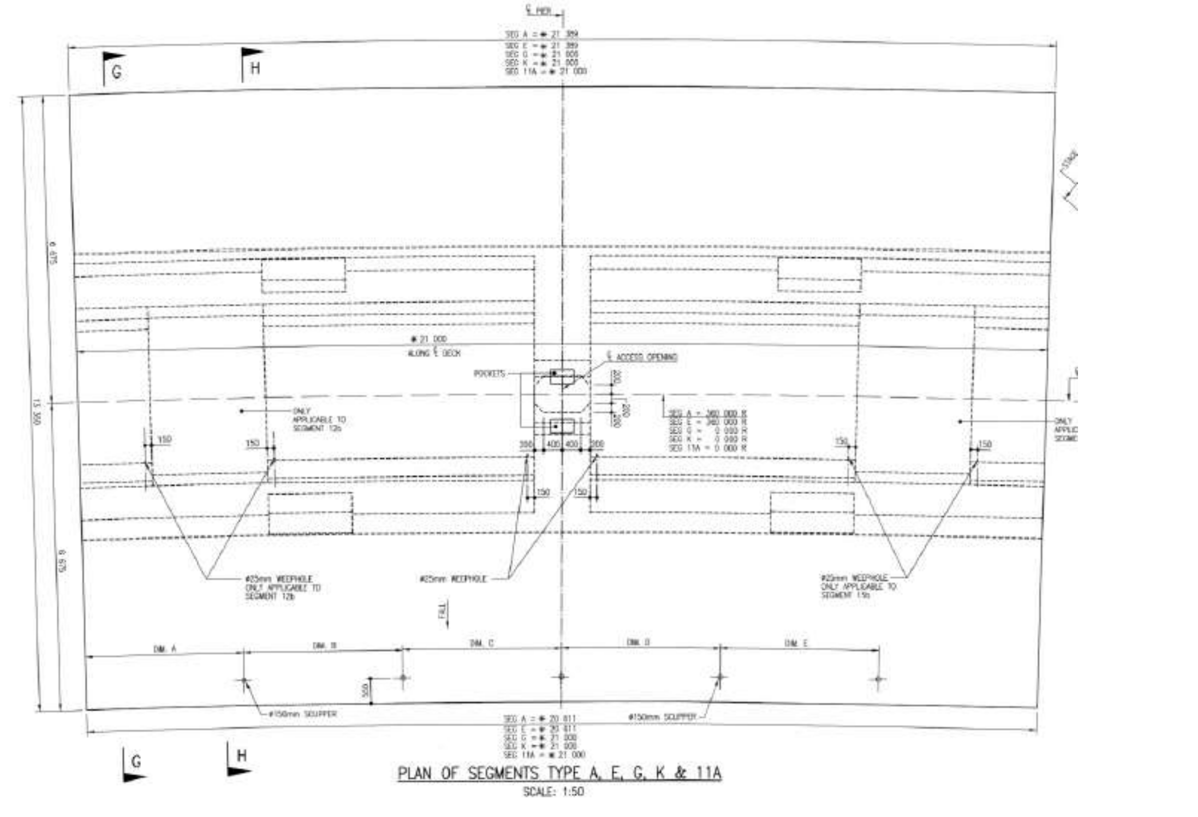


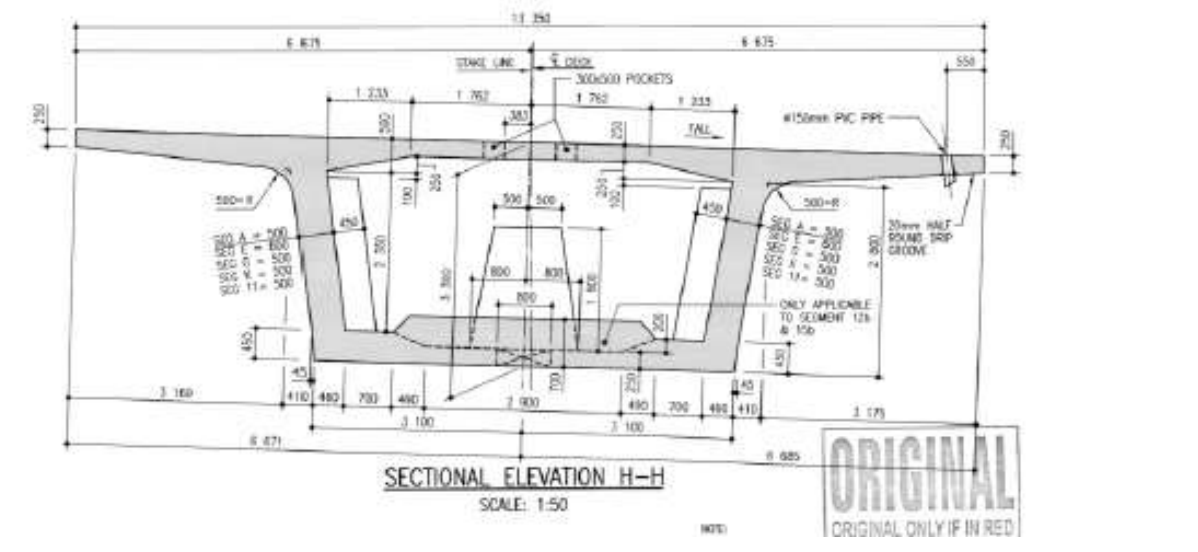
Handrails and platform on cross-walk between boxes of arch.





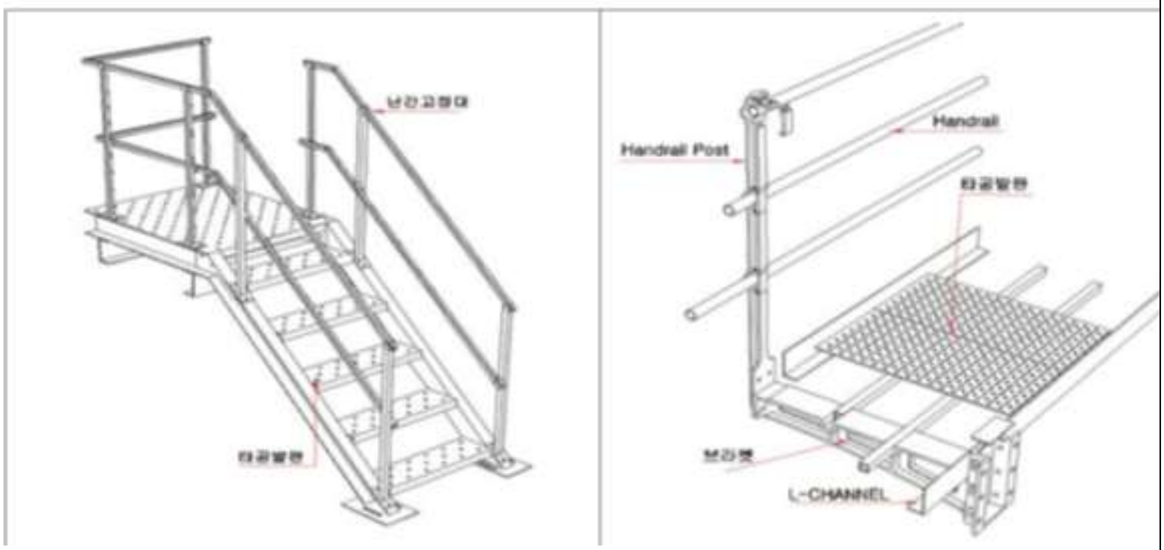
Abseil hooks for rope access in-between twin leaf pier columns of balanced cantilever.



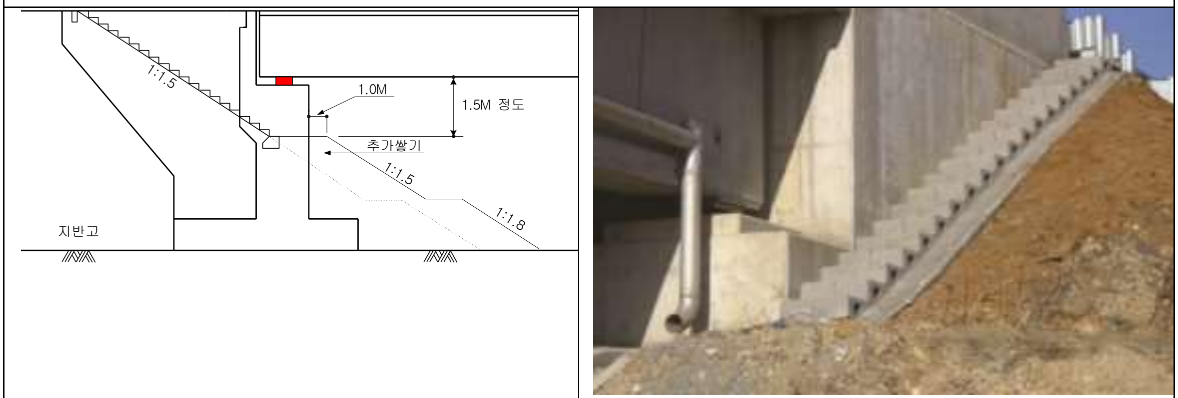


Manholes in deck soffit to access deck void and chamber in pier heads.

South Korea



Item b: Under Bridge Inspection Units (UBIU).



Steps are installed on embankments to assist inspectors.

Walkway platforms around pier heads.

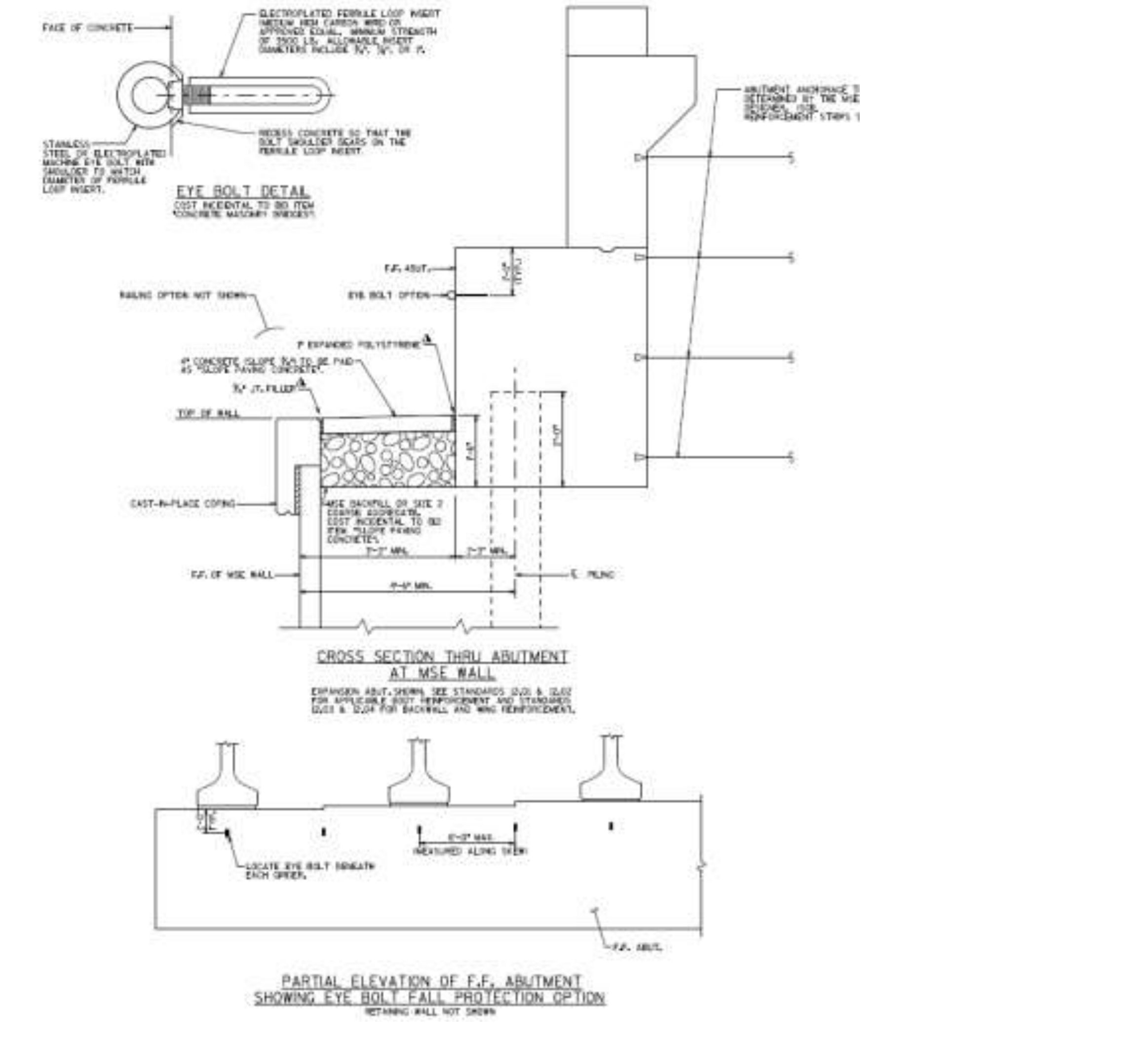
Spain

In some few cases, there are specific elements designed for the access to the bearings.

The platforms originally used during the construction of the cable-stayed spans of the bridge, for welding operations and others, were maintained as permanent moveable platforms.

	
Lift on the exterior side of a pier.	Ladder in the interior of the pier.
	
Description for lighting in closed spaces.	

USA-Wisconsin



Eye bolt installed in front face of abutment for tie off to perform inspections on top of MSE wall fill in front of abutments.

World Road Association (PIARC)

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