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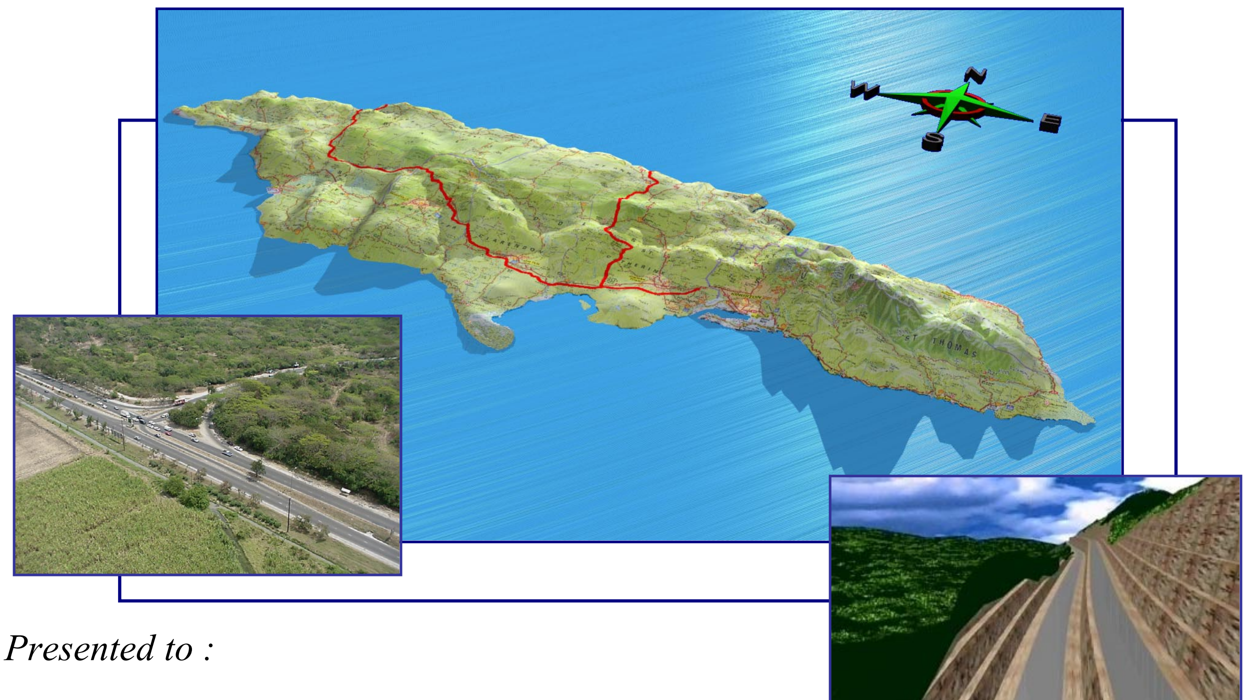
HIGHWAY 2000 PROJECT
Preliminary Design Phase

Structural Design Criteria and Standards Report



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By :

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Development Bank of Jamaica Ltd

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Preliminary Design Phase

Structural Design Criteria and Standards

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1 GENERAL DESIGN CRITERIA AND PROCEDURES

1.1 GENERAL DESIGN REQUIREMENTS

Safety and reliability shall be of prime importance for the design of all structures involved in the project. Structures must be designed to be structurally and operationally safe in terms of accommodating highway traffic, operations and maintenance activities, and all marine traffic in the case of river crossings, for the duration of the 75 year design life.

Structural designs shall also incorporate quality standards for the appropriate selection of design concepts, design details, materials used, and construction methods and techniques. The designs must recognize the need for the ease of replacement of critical components, bearings and expansion joints, the need for future widening, where required, and the provision of access for maintenance.

Progressive collapse shall not extend beyond the deck movement joints on either side of the major element that is removed. A loading of 10% of design live load shall be assumed to be remaining on the structure in this case.

Structural designs shall provide sufficient redundancy of load-paths to supports in order to avoid progressive or total collapse of bridge or portion of bridge should a major element fail. Consequently, through girder type structures or structures with deck supported by only two or three main girders shall not be used for any overpass, underpass or river crossing.

1.2 AESTHETIC CONSIDERATIONS

Aesthetics must be considered in the design of all structures, and especially the structures across rivers or close to developed areas. Aesthetic treatments to be incorporated in the structural designs should complement the surrounding environment and generally be compatible with similar structures located in the general vicinity. This compatibility is of major importance for the structures to be built alongside existing ones in the "Old Harbour By-pass" portion of the highway.

Guidelines in ACI publication MP-1 shall be used as a general guide for incorporating aesthetic treatments in the structural designs. Proposed aesthetic treatments for structures must be addressed in the Proposal Submission documentation.

1.3 GEOMETRY

1.3.1 General

Width of highway bridges shall comply with Highway 2000 cross sectional requirements for each Section of the highway. In all cases, lane alignment shall be maintained.

Bridge design and geometry shall allow for the future widening of Highway 2000 to 8 lanes between Kingston and the Bushy Park Junction and to 6 lanes between Bushy Park Junction and Four Paths. Bridges need not be initially constructed for the additional lanes but provisions shall be made to allow for the addition of lanes in the highway median.

1.3.2 Road Grade Separations

1.3.2.1 Overpasses

An overpass is defined as road grade separation for which the highway passes over the intersecting road. Required vertical clearance under the structure (or structures in the case of twin bridges) is 5.0 meters. Required lateral clearance from the edge of the local road to the face of abutments or support elements is 10.7 meters, as shown on Typical Drawings PO-0001 to PO-0003.

Cross section of the structures depends on the geometry of the highway (number of lanes, width of median, etc.) which varies along its length.

1.3.2.2 Underpasses

An underpass is defined as road grade separation for which the highway passes under the intersecting road. Required vertical clearance under the structure is 5.0 meters. Required lateral clearance from the edge of highway outside shoulders to the face of abutments or support elements is 10.7 meters. Required lateral clearance from the edge of highway inside shoulders to the face of pier or support elements is as follows:

- Six lane underpasses with allowance for 8 lanes: 4.0 m ;
- Four lane underpasses with allowance for 6 lanes: 5.5 m ;

- Four lane underpasses with 6 m median: 1.5 m.

These clearances are shown on Typical Drawings PO-0005 to PO-0007, together with the required transverse section of the structure. Total length of the structure depends on the width of Highway 2000 at each particular location.

1.3.2.3 Railway Crossings

Clearances for railway in highway over railway crossings shall be as follows :

Vertical clearance between top of rail and underneath of structure :	7.0 metres
Lateral clearance between center-line of track and face of wall, support element or other structural element :	4.0 meters

Geometry and required clearances are illustrated on typical drawing PO-0004.

If railway crossings with railway over highway arrangement are used, required design criteria and loading for the railway bridge shall be obtained from the railway owner or operator and from governing Authorities. Vertical clearance under such structures shall be 5.0 meters.

1.3.2.4 Field Connectors

Field Connectors are box or rigid frame structures crossing under the highway in order to allow passage of pedestrians and farm animals and equipment. These structures shall have a minimum opening of 5.0 meters high by 4.0 meters wide. Total length of the structure depends on the width of Highway 2000 at each particular location. Minimum dimensions are shown on Typical Drawing PO-0008.

Design loads for these structures shall be the same as for bridges, taking into account the presence and effects of the fill on top of the structure. Minimum transverse and longitudinal grades shall be provided on the inside carriageway to insure proper drainage of the surface.

1.3.3 River and Gully Crossings

1.3.3.1 Box Structures

Box type structures can be used for highway crossing over small gullies. These structures shall be sized (width and height of opening) and positioned (elevation of invert, grade, etc.) according to hydraulic criteria and design data. Total length of the structure depends on the width of Highway 2000 at each particular location. Adequate scour and erosion protection, such as wing walls, rip-rap, aprons and cut-off walls, shall be provided.

Design loads for these structures shall be the same as for bridges, taking into account the presence and effects of the fill on top of the structure.

1.3.3.2 Main River Crossings

Main river crossings shall be designed and positioned in order to comply with the hydraulic requirements stated in sub-section 1.5 hereafter. Both longitudinal and lateral stream current forces shall be taken into account in the design of piers and other elements located in the flow or possible flow of water.

1.3.4 Designs with closed abutments

For overpasses or underpasses, closed abutments structural designs are not acceptable with the exception of railway overpasses (highway over railroad) and field connectors. Closed abutment designs could be used for small gully or river crossings provided that hydraulic and scour protection requirements are met.

1.4 HYDRAULIC CONSIDERATIONS

1.4.1 Minimum hydraulic opening

Adequate hydraulic opening shall be provided for all bridges over rivers or gullies, based on a 100 years return period maximum flow. Effective hydraulic opening shall be used for establishing maximum high and low water levels. For all bridges, required minimum freeboard relative to high water is 1 meter.

Additional information regarding catch basins, flows and other hydraulic data can be found in the “Drainage and Hydrology Report”.

1.4.2 Pier locations

As much as possible, construction of piers in the main river bed should be avoided. Piers should preferably be located outside of the main channel of rivers or gullies.

Where piers lie in the possible flow of water, they shall be on an alignment that causes the minimal change to the hydraulic regime of the watercourse and their interference should be taken into account when establishing the required hydraulic opening. Also, adequate protection against scour and erosion, as described in following sub-section, shall be provided.

Temporary dykes, caissons or other water control means shall be used for the construction of support elements in locations covered or potentially to be covered by water. The possibility of flash flood or sudden raise in water level shall be taken into account in the sizing and design of such temporary elements.

Design and construction methods for temporary dikes, caissons and other water control means shall conform to all applicable environmental and river protection requirements.

1.4.3 Scour and Erosion Protection

For all piers and abutments located in or adjacent to the river bed, or lying in locations that could be subjected to flooding, adequate scour and erosion protection shall be provided.

Scour protection shall be provided to maintain stable structures and channels at culverts and bridges. Type of protection and size of elements (class of rip-rap, etc.) shall be chosen according to expected flows and velocities. Protection shall be extended to all parts of substructure, which could be affected by scour in the worst case scenario.

Erosion control is to be provided to protect roadways embankments and structures against flowing water, waves or surface water.

1.5 FOUNDATIONS

Substructure elements (abutments and piers) of overpasses and underpasses may be founded on spread footings or piles according to the following considerations.

Substructure elements of river and gully crossings located in the river bed or in areas susceptible to be flooded or exposed to running water, shall be founded on piles.

Substructure elements of river crossings may be founded on spread footings only when these are constructed directly on the rock base or are located well away of flooding and are constructed on fill material.

1.6 SPECIAL CONSIDERATIONS FOR OLD HARBOUR BY-PASS STRUCTURES

Structural works for the “Old Harbour By-pass” portion of the highway (approximately from km 21 to km 34.2) consists essentially of twinning the existing structures built for the actual two lane By-pass. Existing structures will serve for the westbound direction of the highway while the new twinned structures will carry eastbound traffic. The new structures shall, as much as possible, reproduce the general dimensions, span arrangement and aesthetics elements of the existing structures. The concessionaire will however remain fully responsible of providing adequately designed structures as per the design criteria and requirements contained herein and in other parts of the tender documents. The new structures shall provide the possibility of widening the bridge deck to accommodate a future additional eastbound lane in the median of the highway.

Also, future modification of the actual structures in place in the “Old Harbour By-pass” will be required for the accommodation of an additional west-bound lane in the median of the highway.

Existing box culverts in the “Old Harbour By-pass” portion of the highway will have to be extended across the new east-bound lanes of Highway 2000.

One existing bridge, Colleburns Gully Bridge (km 21.3) on this portion of the highway will have to be reconstructed due to a local change in the highway profile. Hence, two new structures will have to be constructed at that particular location.

2 DESIGN STANDARDS

2.1 DESIGN LIFE

The design service life of all bridges and structures in the project shall be 75 years.

2.2 DESIGN CODES

British Standards Institute (BSI) B.S. 5400, Part 2 shall be used for highway loading. For all other type of loading, except earthquake loading, Canadian Standards Association CAN/CSA-S6-88, ‘‘Design of Highway Bridges’’ shall be used.

Earthquake loading for use on restraining features and substructures, shall be as per the requirements of American Association of State Highway and Transportation Officials (AASHTO), Section 3.21 : Earthquakes, Standard Specification for Highway Bridges.

Reinforced concrete and structural steel shall be designed to the requirements of Canadian Standards Association CAN/CSA-S6-88, “Design of Highway Bridges”.

2.3 DESIGN LOADING

2.3.1 Highway Live Load

Highway loading shall be to the requirements of British Standards Institute(BSI) B.S. 5400: Part 2; Steel, Concrete and Composite Bridges; Specification for Loads.

Traffic loading shall comprise HA type loading and 30 units of HB loading applied according to the requirements of BS-5400.

Longitudinal loading due to breaking and accidental skidding shall be as per BS-5400.

2.3.2 Dead Loads

Dead load calculations shall be based on the following material unit weights :

Concrete : 24.0 kN/m^3

Structural Steel : 77.0 kN/m^3

Asphalt : 23,5 kN/m³

2.3.3 Earth Pressure

Loading due to earth pressure shall be according to the requirements of Canadian Standards Association CAN/CSA-S6-88, Design of Highway Bridges. Earth pressure parameters shall be established for each type of backfill material and compacting equipment used.

2.3.4 Wind Loading

Wind loading shall be to the requirements of Canadian Standards Association CAN/CSA-S6-88, Design of Highway Bridges, assuming a basic wind speed of fifty six meters per second (56 m/s).

2.3.5 Water Flow Loading and Hydrostatic Pressure

Stream current loading, acting on piers and other elements located in the possible flow of rivers, and hydrostatic forces acting on submerged portions of structures shall be to the requirements of Canadian Standards Association CAN/CSA-S6-88, ‘‘Design of Highway Bridges’’.

2.3.6 Seismic (earthquake) Loading

The inertia forces (vertical and horizontal) arising from earthquake loading which are to be resisted by bridge restraining features and substructures shall be determined by the use of ground acceleration factors and design approach according to AASHTO specifications for zone 3 (California) or applying the following:

Horizontal force: 25-30% superstructure weight
Vertical force: 10% superstructure weight

2.3.7 Ship impact

For bridges crossing over navigable waters, impact of ships shall be taken into account in the design of piers and pier foundations, or adequate remote protection devices shall be provided.

The number of piers to be designed against impact or requiring protection as well as the size of vessels to be considered in the calculation of collision forces shall be determined by the Concessionaire in consultation with the navigational authorities.

Piers and pier foundations shall be designed to resist direct impact, head-on, oblique and sideways impacts by fully-laden vessels and unloaded vessels.

The bridge superstructure shall be designed to resist a local ultimate horizontal design force of 50 kN representing a collision between a ship's antennae structure and the bridge superstructure unless a survey of vessels effectuated by the successful Proponent or the local Authorities indicate otherwise.

2.3.8 Creep and shrinkage

Creep and shrinkage shall be as per CEB-FIP, March 1990, Model code.

2.3.9 Construction loads

Construction loads shall be as per AASHTO LRFD Bridge Design Specifications, 1 st ed, 1996.

2.3.10 Combinations

Loading combinations shall be as per BS-5400: Part 2.

2.4 DESIGN REVIEW

The concessionaire shall submit, to the Project Management Unit, the final design of bridges and structures for review. Documents presented shall include plans and description of proposed construction materials and methods, as well as a complete design brief for each structure to be built. No construction work on bridges or structures shall begin until the Project Management Unit has accepted the designs as compliant.

3 MATERIALS

3.1 GENERAL

All materials used in this Project shall be new.

The following products and systems are not approved for use on this Project:
- stay-in-place steel decking formwork;
- timber components;
- proprietary composite steel/concrete girders;
- steel bridge deck systems;

3.2 STRUCTURAL STEEL

All structural steel used for bridges shall be weathering steel to Canadian Standards CAN/CSA-G40.20/G40.21-92, General Requirements for Rolled or Welded / Structural Quality Steel, Grade 350A, with a Yield Strength of : F_y=350 MPa.

3.3 STRUCTURAL CONCRETE

Concrete shall comply with the requirements of Canadian Standards Association CSA-A23.1-94: "Concrete, Materials and Methods of Concrete Construction"

Except for segmental concrete bridges, all concrete incorporated in the works shall attain a minimum compressive strength (from a cylinder test) of 26 MPa at 28 days.

For segmental concrete bridges, minimum compressive strength shall be 45 Mpa at 28 days. Also, adequacy of aggregates to limit adverse time dependent effects shall be assured.

Maximum aggregate size shall be of 20 mm.

3.4 REINFORCING STEEL

All reinforcing steel shall be deformed steel billet bars to the requirements of Canadian Standards Association CAN/CSA G30.18-M92, Grade 400, with a Yield Strength of F_y = 400 Mpa.

All bars to be welded or hot dip galvanized shall be of Grade 400 **W**. Bars must be bent prior to galvanizing.

Mechanical connections for reinforcing bars shall develop, in tension or compression as required, at least 120% of the specified yield strength of the bars, but not less than 110% of the mean yield strength, representative of the bars to be used, in the test of the mechanical connection. The total slip of the reinforcing bars within the splice sleeve of the connector after loading in tension to 0.5fy and relaxing to 0.05fy will not exceed the following measured displacements between gauge points straddling the splice sleeve:

-	For bars sizes up to and including No. 45	0.25 mm
-	For No. 55 bars	0.75 mm

3.5 PRESTRESSING STEEL

All prestressing steel shall be low relaxation conforming to Canadian Standards Association CSA A23.3-94 “Design of Concrete Structures, with an Ultimate Tensile Strength of 1860 Mpa.

4 SPECIAL REQUIREMENTS FOR STEEL SRUCTURES

4.1 STRUCTURAL DETAILS

4.1.1 End Beams and Floor Beams

End floor beams and end diaphragms under expansion joints shall be so arranged as to permit coating and future maintenance of surfaces that are exposed to surface run-off.

End diaphragms of box girders shall be detailed to prevent ingress of water into the boxes. The ends of box members are to be sealed where possible. Weep holes shall be provided to allow for proper drainage and circulation of air.

Floor beams and diaphragms at piers and abutments shall be designed to permit jacking of the superstructure, unless the main longitudinal members are so designed.

4.1.2 Intermediate Diaphragms and Cross Frames

Intermediate diaphragms shall be designed as single rolled or built-up sections or alternatively, as cross frames comprised of single structural shapes such as single angles or WT shapes. The details of all cross frames shall allow full access for field coating to all surfaces of individual members, exclusive of the faying surface of connections.

4.1.3 Vertical and Longitudinal Stiffeners

On edge beams, vertical and longitudinal stiffeners shall be located on the inside faces of the webs.

4.2 FATIGUE

Design against fatigue shall be according to the requirements of Canadian Standards Association CAN/CSA-S6-88, Design of Highway Bridges. Fatigue design shall be based on more than 2 million design stress cycles.

4.3 BOLTING AND WELDING

All bolts shall be to the requirements of American Society of Testing Materials ASTM A 325M (High Strength steel bolts, nuts and washers that have atmospheric corrosion resistance similar to that of weathering steel). High strength bolted connections shall be friction type, and bolts shall be installed by the use of the “Turn-of-nut” tightening method in accordance with Canadian Standards Association CAN/CSA-S6-88, Design of Highway Bridges and CAN/CSA-S16.1-94, Limit States Design of Steel Structures.

All welding incorporated into the works shall be to the requirements of Canadian Standards Association CSA W59-M1989, Welded Steel Construction, (Metal Arc Welding).

5 SPECIAL REQUIREMENTS FOR STRUCTURAL CONCRETE

5.1 CONCRETE CONSTITUENTS AND MIX FORMULAE

Mix formulae for all various concrete types to be used on the project shall be presented for review and assessment for compliance to the Project Manager Unit. Submitted documents shall include the origin and characteristics of all constituents (cement, aggregates, water, admixtures, etc.), dosage and results of laboratory tests on samples.

5.2 SUPPLEMENTAL REQUIREMENTS FOR THE DESIGN AND DETAILING OF REINFORCED, PRESTRESSED AND POST TENSIONED CONCRETE

5.2.1 General

Design and detailing of reinforced, prestressed and post-tensioned concrete shall comply with the requirements of Canadian Standards Association CSA-A23.1-94: “Concrete, Materials and Methods of Concrete Construction” and CAN/CSA-S6-88: “Design of Highway Bridges”.

All concrete work and concrete reinforcement work shall be performed according to the above mentioned Standards. This includes concrete fabrication, delivery, placing, finishing and curing as well as forms for concrete and falsework.

5.2.2 Concrete Cover and Tolerances

Concrete cover and tolerances for the structures various components shall be in accordance with the indications of the following Table 5.1: “Table for Minimum Concrete Covers and Tolerances.

5.2.3 Drip Grooves

Continuous drip grooves shall be formed on the underside of the bridge deck. The grooves shall be located close to the facia, and shall have minimum dimensions for depth and width of 20 mm an 50 mm respectively.

Table 5.1 (a): “Minimum concrete covers and tolerances”

Environmental Exposure		Component	Reinforcement/Steel Ducts	Concrete Covers and Tolerances Cast-in place Concrete, mm	Concrete Covers and Tolerances Pre-cast Conncrete, mm
(a) no de-icing chemicals	1)	Top of bottom slab for rectangular voided deck	Reinforcing steel	40 ± 10	40 ± 10
			Pretensioning strands	-	55 ± 5
			Post-Tensioning ducts	60* ± 10	60* ± 10
no spray or surface run-off containing de-icing chemicals	2)	Top surface of: Buried structures with less than 600 mm fill*	Reinforcing steel	60 ± 20	40 ± 10
			Pretensioning strands	-	55 ± 5
no marine spray		Bottom slab of buried structures	Post-Tensioning ducts	80* ± 15	60* ± 10
	3)	Top surface of: Structural components except (1) and (2) above**	Reinforcing steel	60 ± 20	50 ± 10
			Pretensioning strands	-	70 ± 5
			Post-Tensioning ducts	80* ± 15	70 ± 10
	4)	Soffit of precast deck forms	Reinforcing steel	-	40 ± 10
			Pretensioning strands	-	38 ± 3
	5)	Soffits of: Slabs < 300 mm thick Top slab of voided decks	Reinforcing steel	40 ± 10	40 ± 10
			Pretensioning strands	-	55 ± 5
			Post-Tensioning ducts	60* ± 10	60* ± 10
	6)	Soffits of: Slabs 300 mm thick Structural components except (4) and (5) above	Reinforcing steel	50 ± 10	40 ± 10
			Pretensioning strands	-	55 ± 5
			Post-Tensioning ducts	70* ± 10	60* ± 10
	7)	Vertical surfaces of: Arches, solid and voided deck, pier caps, T-beams and interior diaphragms	Reinforcing steel	60 ± 10	50 ± 10
			Pretensioning strands	-	65 ± 5
			Post-Tensioning ducts	80* ± 100	70* ± 10
	8)	Inside certical surfaces of buried structures or inside surfaces of circular buried structures	Reinforcing steel	60 ± 20	40 ± 10
			Pretensioning strands	-	55 ± 5
			Post-Tensioning ducts	80* ± 15	60* ± 10
	9)	Vertical surfaces of: Structural components except (7) and (8) above	Reinforcing steel	60 ± 20	50 ± 10
			Pretensioning strands	-	70 ± 5
			Post-Tensioning ducts	80* ± 15	70* ± 10
	10)	Precast T, I and Box Girders	Reinforcing steel	-	28 + 5 or - 3
			Pretensioning strands	-	45 ± 5
			Post-Tensioning ducts	-	50 ± 10

Table 5.1 (b): "Minimum concrete covers and tolerances"

Environmental Exposure		Component	Reinforcement/Steel Ducts	Concrete Covers and Tolerances Cast-in place Concrete, mm	Concrete Covers and Tolerances Pre-cast Conncrete, mm
(b) Exposed to earth or fresh water	1)	Footing, piers, abutments, and retaining walls	Reinforcing steel	70 ± 20	55 ± 10
			Pretensioning strands	-	75 ± 5
			Post-Tensioning ducts	90* ± 15	80* ± 10
	2)	Concrete piles	Reinforcing steel	-	40 ± 10
			Pretensioning strands	-	55 ± 5
			Post-Tensioning ducts	-	60* ± 10
	3)	Caissons with liners	Reinforcing steel	60 ± 20	-
			Post-Tensioning ducts	80* ± 15	-
	4)	Buried structures with greater than 600 mm of fill	Reinforcing steel	60 ± 20	40 ± 10
			Pretensioning strands	-	55 ± 5
			Post-Tensioning ducts	80* ± 15	60* ± 10
(c) Exposed to swamps marsh, salt water, or aggressive back fill	1)	Footings, piers, abutments, and retaining walls	Reinforcing steel	80 ± 20	65 ± 10
			Pretensioning strands	-	85 ± 10
			Post-Tensioning ducts	100* ± 15	90* ± 10
	2)	Concrete piles	Reinforcing steel	-	50 ± 10
			Pretensioning strands	-	65 ± 5
			Post-Tensioning ducts	-	70* ± 10
	3)	Caissons with liners	Reinforcing steel	70 ± 20	-
			Pretensioning strands	-	-
			Post-Tensioning ducts	90* ± 15	-
	4)	Buried structures with greater than 600 mm of fill	Reinforcing steel	70 ± 20	50 ± 10
			Pretensioning strands	-	70 ± 5
			Post-Tensioning ducts	90* ± 15	80* ± 10
(d) Cast against and permanently exposed to earth	1)	Footing	Reinforcing steel	100 ± 25	-
	2)	Caissons	Reinforcing steel	100 ± 25	-
			Post-Tensioning ducts	120 ± 15	-
(e) Various		Componets other than those specifically covered in (a) to (d)	Reinforcing steel	70 ± 20 ***	55 ± 10 ***
			Pretensioning strands	-	70 ± 5 ***
			Post-Tensioning ducts	90* ± 15 ***	80* ± 10 ***

* Greater than 0.5d or indicated cover
** For concrete decks without waterproofing and paving, increase the concrete covers by 10 mm to allow for wearing of the surface concrete.
*** or as approved

At expansion joints, without joint armouring, the end of the concrete deck slab shall be provided with a drip groove. If joint armouring is provided, it shall cover the end of the deck slab and extend at least 50 mm below the concrete in order to form a drip protection.

5.3 MINIMUM NUMBER OF INTERMEDIATE DIAPHRAGMS FOR PRESTRESSED BEAM BRIDGES

The following are the minimum requirements for the use of permanent intermediate diaphragms in bridges constructed with AASHTO, PCI or other precast prestressed beams.

5.3.1 Simple Span Bridges

A minimum of one intermediate diaphragm shall be used in conjunction with the end diaphragms. All diaphragms will be placed prior to deck slab placement.

5.3.2 Two Span Continuous for Live Load Bridges

A minimum of one intermediate diaphragm shall be used in each span in conjunction with the end diaphragms. The discontinuous end diaphragms and intermediate diaphragms shall be placed prior to deck slab placement. The continuous pier diaphragm shall be poured with the last deck pour over the pier.

5.3.3 Three (or more) Span Continuous for Live Load Bridges

The two end spans shall have a minimum of one intermediate diaphragm. The fully continuous spans shall have two intermediate diaphragms since the end diaphragms for these spans cannot be cast prior to placing the deck slab. All intermediate disphragms and discontinuous end diaphragms shall be placed before commencing with the deck pour.

5.4 SUPPLEMENTAL REQUIREMENTS FOR SEGMENTAL CONSTRUCTION

5.4.1 General

The provisions of this clause apply to post-tensioned girders made of match-cast or cast-in-place concrete segments. The cross section may consist of single or multi-cell box segments that may be transversely prestressed.

Stresses due to the changes in the structural system, in particular the effects of the application of a load to one system and its removal from a different system, shall be accounted for. Redistribution of force effects due to creep shall be taken into account and allowance made for possible variations in the creep rate and magnitude. Design for these effects shall be as per section 5.14.2 of AASHTO LRFD Bridge design specifications.

5.4.2 Additional Ducts and Anchorages

Provision shall be made for the introduction of additional post-tensioning to compensate for excessive friction losses during construction and for future strengthening of the bridge.

Segmental box girder bridges with internal tendons shall be provided with additional anchorages and ducts capable of accommodating tendons with a capacity equal to at least 5 % of the positive and negative moment post-tensioning forces respectively. The ducts shall be located symmetrically about the bridge center-line and the anchorages shall be distributed uniformly at three segment intervals along the length of the bridge. At least one additional duct per web with adequate anchorage shall be provided.

For continuous bridges, the additional positive moment ducts and anchorages capacity need not be provided along 25 % of the span length on either side of an intermediate support. All additional ducts not utilized during construction shall be grouted at the same time as other ducts in the span.

Provision shall be made for access, anchorages, deviators and openings along the box girder cells to permit addition of external tendons located symmetrically about the bridge center-line for future strengthening. This provision shall be for at least 10 % of the positive and negative moment post-tensioning forces, respectively.

5.4.3 Diaphragms

Diaphragms shall be provided at abutments, piers and at locations of abrupt angular changes of the soffit of the girders. Provision shall be made in the diaphragms for opening for access, future strengthening and utilities.

5.4.4 Coupling of Post-tensioning Tendons

Not more than 50 % of the tendons in a member shall be coupled at the same section. The distance between couplers of adjacent tendons shall not be less than the segment length nor less than twice the segment depth.

5.4.5 Special provisions for Precast Segmental

5.4.5.1 General

Precast segmental bridges shall be designed to be erected by one of the following methods : Balanced cantilever ; Span-by-span ; and Progressive placement

The minimum age of the segments at the time of erection shall be 14 days.

5.4.5.2 Joints

Precast segments shall be match-cast and erected with epoxied joints. The minimum thickness of epoxy shall be 2 mm on each surface if applied to both surfaces, or 3 mm if applied to one surface.

A minimum compressive strength of 350 kPa shall be provided over the entire cross-sectional area between precast segments by means of temporary post-tensioning until the permanent tendons are fully stressed.

5.4.5.3 Shear Keys

At the joints, shear keys incorporating corrugations shall be provided in the webs. The spacing of the corrugations shall be four times their depth. The corrugations shall be not less than 30 mm in depth and shall extend for as much of the web area width and depth as practicable.

Keys in the top and bottom flanges for alignment of segments during erection shall also be provided. Keys in the top and bottom flanges may be large single element keys.

5.4.6 Special provisions for Cast-in-place Segmental

5.4.6.1 General

Cast-in-place segmental bridges shall be designed to be constructed on falsework, by the balanced cantilever method, by span-by-span construction or by incremental launching.

5.4.6.2 Closure Segment

The length of a closure segment shall be such as to permit coupling of the duct sheaths and jacking of the tendons in the completed cantilevers.

5.4.6.3 Joints

The contact surfaces between cast-in-place segments shall be clean, free of laitance and shall be intentionally roughened. Longitudinal reinforcing bars in the segments shall extend across the joints.

5.4.7 Special provisions for Balanced Cantilever Construction

The provisions of this Clause shall apply to both precast and cast-in-place cantilever construction.

Longitudinal tendons may be anchored in the webs, in the slab, or in blisters built out from the web or slab. A minimum of two longitudinal tendons shall be anchored in each segment.

Continuity tendons shall be anchored at least one segment beyond the point where they are theoretically required for stresses.

The segment lengths, construction loads and sequence of construction assumed in the design shall be shown on the Final Design drawings.

5.4.8 Special provisions for Span-by-Span Construction

Provisions shall be made in design of span-by-span construction for accumulated construction force effects due to the change in the structural system as the construction progresses.

6 BRIDGE COMPONENTS

6.1 BRIDGE SLABS

6.1.1 Minimum Slab Thickness

The slab thickness shall be such as to provide the minimum covers specified in Table 5.1 of Clause 5.2.2 with the clear distance between the top and bottom reinforcement being at least 45 mm. In no case shall the slab thickness be less than 180 mm, except for cast-in-place deck slabs, which shall have a minimum thickness of 200 mm.

6.1.2 Allowance for wear

An additional thickness of 10 mm at the top surface of exposed concrete deck slabs shall be provided to allow for wear.

6.1.3 Surface Profile and Finish

Requirements and tolerances for surface profile and finish of slabs destined to be covered with bituminous concrete wearing surface shall be as per applicable design standards.

Requirements and tolerances for surface profile, finish, roughness and skid resistance of exposed slabs shall be as per applicable design standards or AASHTO "Guide for the Design of Pavement Structures for Rigid and Flexible Pavements" whichever are more stringent.

6.1.4 Cast-in-place Deck Slabs on Precast Panels

Precast panels for use with cast-in-place slabs on precast panels systems shall have a minimum thickness of 90 mm and contain pretensioned reinforcement.

When the precast panel acts compositely with the cast-in-place topping and the supporting beams, the panel thickness should not be more than 0,55 *h*, where *h* is the total thickness of the complete slab. Also, the pretensioning strands shall be located at mid-depth of the panel.

Deflection of the panels during construction shall not exceed 15 mm or 1/240 of the effective span of the panel.

6.1.5 Full-depth Precast Panels

The panels shall cover the full width of the bridge or transverse post-tensioning shall be used with a minimum effective prestress of 1.7 MPa.

At transverse or longitudinal joints, the panels shall be joined together by grouted shear keys. All panels shall be longitudinally post-tensioned, with minimum effective prestress of 1.7 Mpa.

Blockouts shall be provided in the panels at locations where the panels are to be connected to the beams for composite action.

Grout used in shear keys and blockouts shall have a minimum strength of 30 Mpa at 24 hours.

6.2 BEARINGS

All bearings used in the project shall be designed to allow for maintenance, inspection and replacement.

Elastomeric bearings should be used on shorter span bridges ; true "pot bearings" shall be used for longer span structures with high loads. Type of bearings (elastomeric, pot, mobile or fixed, etc.) shall be clearly indicated on the final design drawings.

6.3 JOINTS

The number of movement joints on the bridges shall be minimized as much as possible. The use of jointless integral abutment bridges for structures up to 90 meters in length is encouraged where the skew angle is less than 20 degrees and the foundation conditions are suitable for such construction.

6.4 BARRIERS AND RAILINGS

Concrete barriers shall be the New Jersey Parapet Type and shall conform to Performance Level 3 for overpasses, underpasses and river crossings as specified in the AASHTO Guide Specification for Bridge Railings.

Steel railings on overpasses, underpasses or river crossings shall conform to the requirements of Canadian Standards Association CAN/CSA-S6-88, Design of Highway Bridges or to Performance Level 3 of the above mentioned AASHTO Specification, whichever is the more stringent.

6.5 DECK DRAINAGE

Drainage shall be provided to remove water from the bridge deck at all locations and in a manner which is not detrimental to the fabric of the bridge structure.

Drainage gutters or other means of rainwater removal shall be provided on the bridge deck at sufficiently close intervals to ensure that, during a rainstorm of two (2) year return period, the edge of the bridge deck does not flood to a width greater than 500 mm in front of the curb.

Drainage gutters shall be extended below the deck slab to the level of the underneath of the superstructure at the drain location.

Materials used in drainage systems on the structures shall be capable of achieving a design life comparable to that of the structure. Components shall be replaceable.

6.6 APPROACH SLABS

Approach slabs are required for all bridge structures and shall be a minimum of 5,0 m long.

6.7 MAINTENANCE AND INSPECTION ACCESS

All parts of the structure shall be accessible for purposes of inspection, maintenance and repair.

Handrail bars shall be provided on deep steel plate girders. On edge or outside girders, this handrail should only be present on the interior side of the girder.

No access or maintenance points shall be placed in the traffic lanes or hard shoulders or in other locations that would obstruct or be hazardous to traffic.

Where hollow caissons, pylons, box girders or other such structures are present, they shall be accessible on the inside for inspection. Power points (for small electrical tools) shall be provided within these structures together with fixed lighting.

Bearings, cables and unbonded prestressing tendons shall be accessible for inspection and shall be replaceable without modification to adjacent structural elements and without disruption to traffic.

6.8 UTILITIES

The Concessionaire shall carry out the design and prepare all plans for utilities to be placed on the structures. Utilities to be accommodated on the structures have to be established with the Authorities having jurisdiction. Design and installation shall be in accordance with the requirements of those Authorities.

7 RETAINING WALLS

7.1 GENERAL

The top of the wall, whether level or sloping, will be finished in straight-line segments no shorter than 5 m in length.

Only concrete walls or walls with concrete facing (pre-cast or cast in place) will be used.

7.1.1 Design

Design of retaining walls and other retaining structures shall be based on Canadian Standards Association CSA/CAN3 S6-88, Design of Highway Bridges. Earth pressure parameters used for the design of the wall shall be established according to the type of fill material and compacting equipment used.

The service design life for all retaining walls and structures shall be 75 years.

7.1.2 Drainage

Drainage holes or weep holes through the wall, or drains in the back of the wall shall be provided in order to avoid the build-up of hydrostatic pressure behind the wall.

Drainage from behind the wall shall be discharged at locations that are aesthetically and environmentally acceptable.

7.1.3 Backfill

The first meter of backfill against the back of the wall shall be a compacted granular and permeable (draining) material. Backfill material for MSE walls shall meet the requirements stipulated in Section 7.2 hereafter.

7.2 MECHANICALLY STABILIZED EARTH (MSE) WALLS

MSE walls must not be used under the following conditions:

- When two intersecting walls form an enclosed angle of 70° or less.

- When utilities other than highway drainage must be constructed within the reinforced zone.
- With galvanized metallic reinforcements exposed to surface or ground water contaminated by acid mine drainage or other industrial pollutants as indicated by low pH and high chlorides and sulphates.
- When flood plain erosion may undermine the reinforced fill. Or where the depth of scour cannot be reliably determined.

Where steel reinforcement is used, the MSE backfill within the reinforced soil mass must meet the following electrochemical requirements:

- PH of 5 to 10
- Resistivity > 3000 ohm centimeters
- Chlorides < 100 ppm
- Sulphates < 200 ppm

The allowable tensile stress for steel reinforcements shall account for corrosion losses for the appropriate design life of the structure as follows:

- Galvanization Loss: 15 micrometers/year for first two years
  4 micrometers/year for subsequent years
- Carbon Steel Loss: 12 micrometers/year after zinc depletion

Maximum allowable stresses shall not exceed 0.55Fy for grid reinforcing members connected to rigid facing panels, where Fy is the yield stress of the steel used.

MSE walls with polymeric reinforcement shall not be used for walls over five meters high or for abutment walls. Geotextiles shall not be used for reinforcement.

The determination of the long-term design strength (LTDS) of geogrid reinforcing will follow the method outlined in Publication FHWA-SA-93-025 “Guidelines for Design, Specification, and Contracting of Geosynthetic Mechanically Stabilized Earth Slopes on Firm Foundations” January 1993. Partial factors of safety used in design will be as follows:

Geogrid Partial Factors of Safety								
Polymer Type	With Mill Test Certificates				Without Mill Test Certificates			
	FSCRP	FSID	FSD	FSUC	FSCRP	FSID	FSD	FSUC
HDPE	2.56	1.25	1.1	1.5	5.0	3.0	2.0	1.5
Polyester	1.54	1.25	1.1	1.5	2.5	3.0	2.0	1.5
Polypropylene	3.13	1.25	1.1	1.5	5.0	3.0	2.0	1.5

Where:
FSCRP = Partial factor of safety for Creep.
FSID = Partial factor of Safety for Installation Damage for –50 mm crush sand and gravel.
FSD = Partial Factor of Safety for Chemical and Biological Durability.
FSUC = Partial Factor of Safety for Uncertainties.