3-2-2-3 Outline of Design Specifications

(1) Road Design Specifications (Arterial National Highway)

The road specifications are as follows:

Table 3-2 Road Design Specifications (Arterial National Highway)

Item			Remarks
Design speed	Access road	20km/hr	
	Main road	60km/hr	
Minimum curve radius	Access road	15m	
	Main road	120m	
Vehicle road width		7m	Conforms to the Primary National Highway (PNH)
Standard cross-fall		2%	
Maximum vertical gradient	20km/hr	8%	
	60km/hr	7%	

(2) Bridge Design Specifications

(2)-1 Arterial National Highway

The bridge design specifications for the arterial national highway should be as follows:

Table 3-3 Bridge Design Specifications (Arterial National Highway)

Item			Remarks
Design standard		Standard Specification and Code of Practice for Road Bridges, The Indian Road Congress (IRC), Specifications for Highway Bridges	
Road classification		National Highway	
Design live load		Critical load according to the Single lane IRC 70R (wheeled) and Double lane IRC Class A	
Design horizontal seismic coefficient		Kh = 0.22 Kv = 0.0	Zone V (conforms to zoning of the State of Assam, India)
Concrete strength	Substructure	21N/mm^2	
	Superstructure	30N/mm^2	Post-tension PC girder
	Slab	30N/mm^2	Filling concrete between each flange of T-girders
Pavement	Asphalt pavement	t = 60mm	

(2)-2 Farm Road

The bridge design specifications for the farm roads should be as follows:

Table 3-4 Bridge Design Specifications (Farm Road)

Item			Remarks
Design standard	Substructure	Standard Specification of Bhutan Specifications for Highway Bridges	
	Superstructure	Standard Specification of Bailey Bridge	
Road classification		Farm road	
Road width		3.277m	
Design live load		IRC 24R	24t (18t; If the existing Bailey bridge is reused, the live load is limited to 18t.)
Design horizontal seismic coefficient		Kh=0.22 Kv=0.0	Zone V (conforms to zoning of the State of Assam, India)
Concrete strength	Substructure	RC Structure: 21N/mm^2 Without reinforcement: 18N/mm^2	

Note: The construction of the farm road should be implemented by the Bhutanese side

3-2-2-4 Road Design

(1) Road Specifications

(1)-1 Arterial National Highway

The DoR is promoting the reconstruction of arterial national highways into double-lane highways. The bridges covered by the third bridge reconstruction project under the grant aid program of Japan as well as the remaining five bridges that will be reconstructed by Bhutan are all designed to be double-lane. Therefore, in principle, the national highway bridges covered by this survey should also be designed as double-lane.

- Bridge standard: Class A or 70R (Single lane)
- Road specification: National Highway (Double Lane)
- Design speed: 60km/hr

(1)-2 Farm Road

The bridges on the farm roads in Bhutan are generally designed as single-lane. Therefore, in principle, the bridges on the farm roads covered by this survey should also be designed as single-lane.

- Road standard: 24R (Single lane)
  Note: If conversion of the existing bridge is considered, the live load is limited to 18R.
- Road specification: Farm road (Single Lane)

(2) Lowering of the Design Speed

As mentioned in the previous section, the design speed of National Highway No.5 is 60km/hr. However, the design speed of the access road should be 20km/hr in areas where the bridge is backed by a steep cliff that makes it difficult to ensure that the alignment of the road is in keeping with the prescribed design speed, as the lowering of the design speed will not cause significant deterioration in traffic function.

(3) Road Width

Bhutan has established a standard road width in accordance with the road specifications. Since National Highway No.4 and No.5 correspond to SLNo.2 Primary National Highway (PNH), the road width should be 7m.

Table 3-5 Road Specifications and Width

Standard Specification for permanent bridges on various roads					
SL No.	Road Classification	Carriage width (m)	Loading capacity	Footpath	Remarks
1	Asian Highway (AH-48)	7.50	Single lane IRC 70R (Wheeled) OR Double lane IRC class A (whichever is critical)	Optional	
2	Primary National Highway (PNH)	7.00	Single lane IRC 70R (Wheeled) OR Double lane IRC class A (whichever is critical)	Optional	
3	Secondary National Highway (SNH)	5.50	IRC Class A (double lane)	Optional	
4	Dzongkhag Road	3.50	IRC class A (Single lane)	Optional	
5	Farm road	3.50	IRC class A (Single lane)		
6	Thromde road	Varies from 7.50 to 15.00	Single lane IRC 70R (Wheeled) OR Double lane IRC class A (whichever is critical)	Both side 1.50m wide	

Note : Bridges shall be designed for IRC class 70R (wheeled) loading and atleast 5.5m carriage width irrespective of the load classification, if the road has potential of catering traffic to planned or existing Hydro Power Plants or Projects.

However, the width of the temparary bridges (Bailey bridges) for single lane is 3.27m wide with 24R loading commonly used in farm roads and Double lane bailey bridge of 7.50m wide can be used in the PNH and SNH for temporary measures.

Source: "Guidelines on Use of Standard Work Items for Common Road Works", DoR, Aug. 2010

(4) Minimum Plane Curve Radius

If the location of the access road is restricted due to topographical conditions and the location of the bridge on the arterial national highway, the minimum plane curve radius of the access road should be the prescribed minimum plane curve radius (15m) adopted in the Project for Reconstruction of Bridges (Phase III).

If the location of the access road is not restricted, it should be 120m, which is the same as the standard for the main road.

3-2-2-5 Bridge Design

(1) Major Design Loads

(1)-1 Live Load

Bhutan has established specifications on the live load as shown in the table below. Since National Highway No.4 and No.5 correspond to Single Lane No.2 Primary National Highway (PNH), the design live load should be the critical live load from the values prescribed by Single Lane 70R and Double Lane Class A in the IRC standards.

Single Lane 24R in the IRC standards should be applied for the bridges on the farm roads because they are Bailey bridges.

Table 3-6 Live Load Standards in Bhutan

Standard Specification for permanent bridges on various roads					
SL No.	Road Classification	Carriage width (m)	Loading capacity	Footpath	Remarks
1	Asian Highway (AH-48)	7.50	Single lane IRC 70R (Wheeled) OR Double lane IRC class A (whichever is critical)	Optional	
2	Primary National Highway (PNH)	7.00	Single lane IRC 70R (Wheeled) OR Double lane IRC class A (whichever is critical)	Optional	
3	Secondary National Highway (SNH)	5.50	IRC Class A (double lane)	Optional	
4	Dzongkhag Road	3.50	IRC class A (Single lane)	Optional	
5	Farm road	3.50	IRC class A (Single lane)		
6	Thromde road	Varies from 7.50 to 15.00	Single lane IRC 70R (Wheeled) OR Double lane IRC class A (whichever is critical)	Both side 1.50m wide	

Note : Bridges shall be designed for IRC class 70R (wheeled) loading and atleast 5.5m carriage width irrespective of the load classification, if the road has potential of catering traffic to planned or existing Hydro Power Plants or Projects.

However, the width of the temparary bridges (Bailey bridges) for single lane is 3.27m wide with 24R loading commonly used in farm roads and Double lane bailey bridge of 7.50m wide can be used in the PNH and SNH for temporary measures.

Source: "Guidelines on Use of Standard Work Items for Common Road Works", DoR, Aug. 2010

(1)-2 Design Horizontal Seismic Coefficient

Bhutan is not included in the earthquake area classification map in the IRC standards, but the State of Assam in India, which is adjacent to the southern and eastern parts of Bhutan, belongs to "Zone V" (Very High Damage Risk Zone). Therefore, it is considered appropriate to apply "Zone V" to the whole area of Bhutan as well. Accordingly, based on the calculation formula in 222.5 of the IRC standards, the design horizontal seismic coefficient (Kh) should be 0.22.

The vertical seismic coefficient (Kv) is not taken into consideration.

$$Kh = (Z/2) \times (Sa/g) / (R/I) \times \alpha = 0.216$$

Where,

Z : Zone factor (V) = 0.36

Sa/g : 2.5 (T < 0.5sec : h=0.05)

R : Response reduction factor (=2.5)

I : Importance factor (=1.5 Importance Bridge)

A : Compensating rate due to the difference in the reduction factor (=0.8)

(1)-3 Other Loads

Other loads, such as dead load and earth pressure, should be calculated following the usual calculation formula.

(1)-4 Design Standard Strength of Concrete

1) Substructure

The design standard strength of the concrete used for the substructure should be the minimum design standard strength of the RC structure.

$\sigma ck=21N/mm^2$ (CYLINDER)

In the case of the structure without reinforcement, $\sigma ck=18N/mm^2$ (CYLINDER).

2) Superstructure

a) Prestressed Concrete Girder

In the project for the reconstruction of bridges phase 3 under the ODA scheme of Japan, which is currently under way, concrete of $30N/mm^2$ is used. According to the Japanese Specifications for Highway Bridges, the minimum design standard strength of post-tension concrete is $30N/mm^2$. Therefore, the design standard strength of the concrete should be $\sigma ck=30N/mm^2$ (CYLINDER).

b) Filling Concrete of Slab

The design standard strength of the filling concrete slab should be $\sigma ck=30N/mm^2$ (CYLINDER).

c) Bridge Pavement

A cement concrete pavement is often used in Bhutan. However, as this cannot provide a waterproof layer, if it is used on a bridge water may penetrate through the pavement, affecting the durability of the slabs. Therefore, asphalt pavement (60mm) should be used for this project.

d) Design Standards of the Road Accessory Structures

Taking into account the availability of local workforce and materials, the revetment, drainage gutter and other accessory structures of the bridges should wherever possible be of the same type as those commonly used in Bhutan, and designed in accordance with the IRC standards. For those items that are not covered by the IRC standards, the Road Civil Engineering Design Handbook published by the Japan Road Association should be referred to.

3-2-3 Outline Design Drawing

3-2-3-1 Design Outline

The table below shows the outlines of the replacement bridges.

Two bridges on National Highway No. 5

Table 3-7 Outlines of the Replacement Bridges-1

Bridge name	Dolkhola Bridge	Jigmiling Bridge
Bridge structure	2-span PC joining simple post-tensioned T-girder bridge	2-span PC joining simple post-tensioned T-girder bridge
Bridge length	70.0m	70.0m
Span length	35.0m	35.0m
Girder height	2.1m×4 main girders	2.1m×4 main girders
Width	7.0m (2 lanes)	7.0m (2 lanes)
Foundation structure	Spread foundation (Abutments A1 and A2 and Pier P1)	Spread foundation (Abutments A1 and A2 and Pier P1)
Main material	PC main girder concrete (σ_{ck}=30N/mm^2) RC concrete (σ_{ck}=21N/mm^2)	PC main girder concrete (σ_{ck}=30N/mm^2) RC concrete (σ_{ck}=21N/mm^2)
Method to erect superstructure	Erection girder method	Erection girder method
Notes	Responsibilities of the Bhutanese side: Removal • Bridge superstructure • Bridge abutment on both riverbanks • Existing revetment on the right bank • Embankment at the access road on the right bank	Responsibilities of the Bhutanese side: Removal • Bridge superstructure • Bridge abutment on the right bank • Removal of bridge pier