ANNEX-XI

GUIDELINE FOR DESIGN OFLIGHT-LOAD BRIDGE

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GUIDELINE FOR DESIGN OF LIGHT-LOAD BRIDGE

Chapter XI-1 GENERAL

XI-1.1 Scope of Application

This Guideline shall be applied to the following suspension bridge.

(1) Light-load bridge (Suspension Br., Suspended Br.) within the Kingdom of Bhutan.

(2) This suspension bridge shall be mainly serviced for pedestrian, bicycle, pedestrian with pack, and power-tiller with cart.

There is a Guideline (SBP) for two types of suspension bridge in Bhutan. One is suspension bridge and the other is suspended bridge. The suspension bridge has main towers and cables that suspend the floor deck, while the suspended bridge has no tower but main cables under the floor deck.

This Guideline shall be adapted to the design of light-load bridge to enable traffic of light vehicle on the basis of the SBP Guideline.

The "light vehicle" represents power-tiller with cart described in "Chapter XI-2 Design Condition".

XI-1.2 Principals of Design and Construction

(1) The structure of the each part in the bridge shall be simple and designed taking fabrication and assembly, transport, erection, and management into account.

(2) Appropriate construction method shall be selected considering topographical condition of the proposed construction site.

As for this light-load bridge, the width is wider and assembly structure of floor is stronger than pedestrian bridge. Therefore, (1) and (2) are described here aiming to rouse attention.

Chapter XI-2 DESIGN CONDITION

XI-2.1 Width

(1) The bridge width shall depend on the specification of the power-tiller for which traffic is allowed.

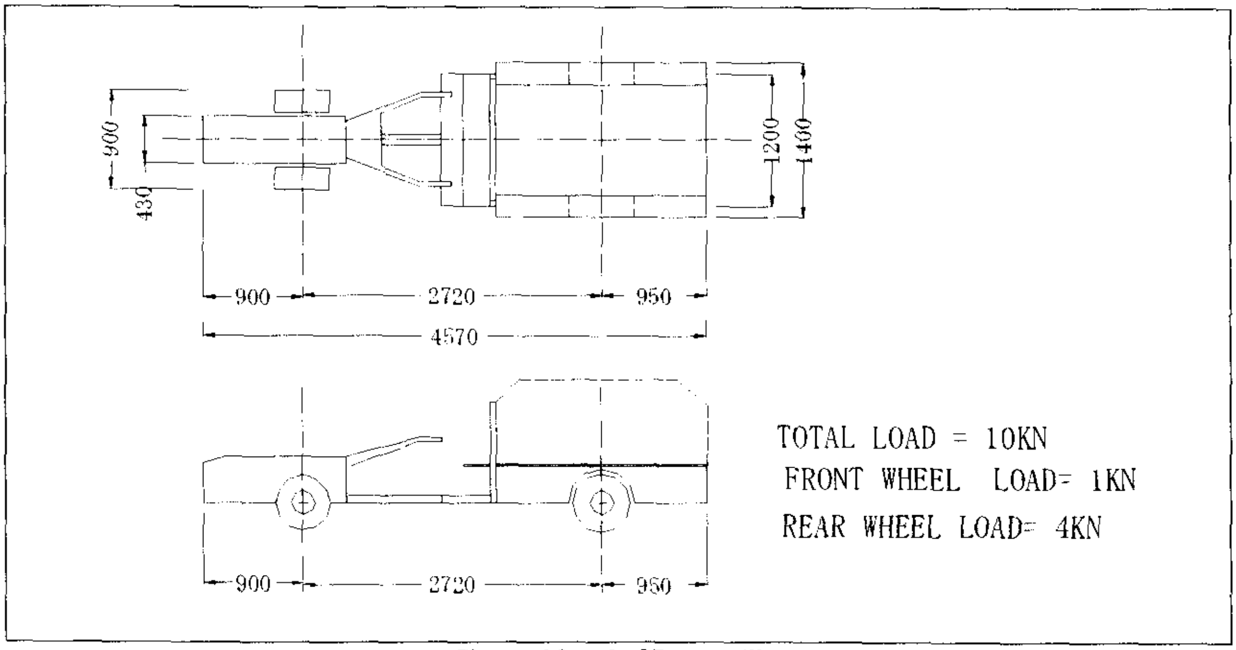
(2) Effective width shall be assumed to be 1.7 m.

(3) Change of width shall be permitted, in case that there is a special reason for traffic condition of the planning area and so on.

For the adoption of basic width, the condition concerning light vehicle traffic was as follows, from the consultation with MOA, DOR, and the road administrator of Dzongkhag. The type of power-tiller used widely for agriculture shall be considered. Since frequency of traffic on the bridge is not much, power-tiller is not assumed to either encounter or outstrip other pedestrian and light vehicle on the bridge.

Therefore, the width of carriage way is assumed to be 1.7 m. However, it is necessary to revise related items in this Guideline if the carriage width is modified according to special consideration or reasons such as local traffic condition and others.

Standard width of the pedestrian suspension bridge in the SBP Guideline is 1.2 m for suspension bridge and 1.0 m for suspended bridge.



Size and Load of Power-tiller

XI-2.2 Live Load

Live load used for design of the light-load bridge shall be standardized as follows. However, it is not necessary to follow this standard in case of exceptional traffic situation in a region. As for the load, the following value shall be applied.

(1) As for uniform load used for the design of the main cable, tower and substructure, the following value shall be adopted.

Uniform live load: 2.5 kN/m (one porter 1.5 kN/ 60 cm equal to the walking interval)

(2) As for concentrated load used for the design of the deck slab, floor assembly and hanger, the following value shall be adopted.

- Porter Load: 2 x 1.5 kN/person (corresponding to parallel walking of two porters)
- Light vehicle (power-tiller) Load):
  Total load: 1.0 kN
  Rear wheel: 4.0 kN/wheel, Front wheel 1.0 kN/wheel)

(a) Uniform Load Intensity (kg/m)

Uniform load intensity mentioned in the SBP Guideline is as follows:

- Suspension Bridge 2.5 kN/m^2 x 1.0 m =2.5 kN/m
- Suspended Bridge 2.5 kN/m^2 x 1.2 m =3.0 kN/m

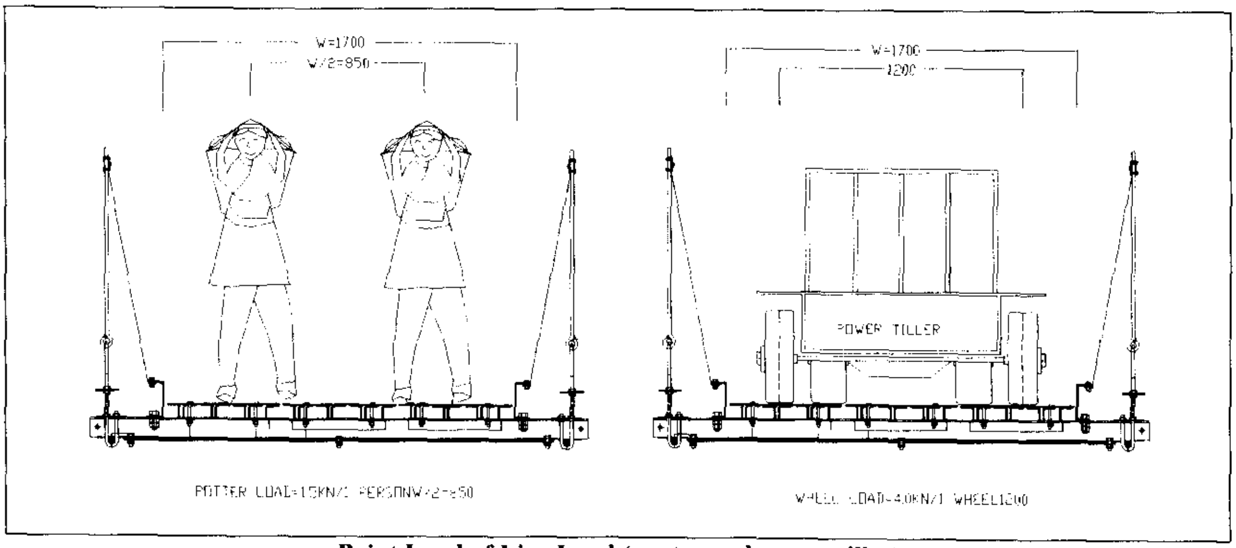
In this Guideline, uniform load intensity for the light-load bridge is set at 2.5 kN/m taking due consideration on traffic condition of users at site and the Japan's design standard of suspension bridge for pedestrian. In the course of the examination of the uniform load intensity, it was judged that the uniform load intensity for SBP adopted in Bhutan (2.5 kN/m^2 or 4.25 kN/m) is too big for the wider carriage way of 1.7 m of the light-load bridge for light vehicles.

This uniform load intensity (2.5 kN/m) is equal to that of SBP of 1.0 m width as mentioned in the SBP Guideline, which was calculated assuming a line of porters with pack (1.5 kN/porter) keeping an interval of 60 cm on the bridge or two lines of pedestrian without pack keeping the same interval on the bridge. It was judged that this uniform load intensity is also applicable as the uniform live load for the design of the light-load bridge that would be constructed as a part of the farm mule track. Moreover, the uniform live load, which is derived from the total weight of the assumed power-tiller with cart, is less than that equivalent to the above mentioned uniform load intensity.

Even for this load intensity (2.5 kN/m), it might be considered too big taking into account of Japan's design standard or low population density of rural ares of Bhutan. However, it was finally adopted considering present traffic situation observed at the existing SBPs that a herd of cattle or horses with pack load often pass the bridges. In Japan's design standard, the design live load intensity of 2.0 kN/m^2 is adopted for the main cable of the SBP. The width of the carriage way is generally determined taking into account of results of traffic survey and plan of utilization of the bridge in the future.

(b) Porter's Concentrated Load

Porter's concentrated load was determined to conform with the SBP Guideline. Loading condition is shown in the following figure. The porter's load (P = 1.5 kN/person) consists of the porter himself and pack that he carries. On the other hand, concentrated load of light vehicle was determined as mentioned above assuming weight and size of a power- tiller with cart, which is widely used for agriculture in the rural areas. The load condition of the light vehicle is shown in the following figure. The concentrated load of the light vehicle can be used for the design of floor assembly and hunger as far as the carriage way width is kept at 1.7 m.



Point Load of Live Load (porter and power-tiller)

XI-2.3 Impact Coefficient

(1) For the design of the light-load bridge, impact coefficient for the live load is not adopted considering low speed of the light vehicle. However, in case that the width and the deck slab structure indicated in this Guideline are modified, the impact coefficient shall be duly examined.

Impact coefficient is largely affected by driving speed and flatness of road surface. The impact coefficient by the power-tiller (light vehicle) was examined together with standard width of the carriage way. Prior to the examination, vibration by traffic such as perpendicular vibration, rolling and torsion was checked and confirmed at existing SBPs. As a result, the vibration confirmed was not small or negligible one. Taking into account such results of site investigation and expected improvement of stiffness of the bridge structure as a whole, it is recommended to control the maximum speed of the assumed light vehicles with full load by setting the structural and traffic management conditions as follows:

- Width of the carriage way shall be limited to 1.7 m against the wheel width of cart (1.4 m) so that the speed should be controlled by the driver,
- Flat floor deck structure with steel angle shall be adopted so that impact by the passing light vehicle should be reduced,
- Passing light vehicle will not encounter any pedestrian, animals or light vehicles on the bridge from the opposite direction, and
- Passing light vehicle will be outstrip neither pedestrian, animals nor light vehicles on the bridge
- Consequently, the impact coefficient (i) of "0.0" was adopted.

Chapter XI-3 SUSPENDED STRUCTURE (FLOOR ASSEMBLY)

XI-3.1 General

(1) Unstiffening girder shall be adopted as a standard.

(2) Cross bracing shall be installed as a standard.

(3) Wind-guy cable shall be installed regardless of the span length.

Traffic of pedestrian and light vehicle, and traffic vibration of perpendicular, rolling and torsion shall be necessary to consider for the planning of light-load bridge as compared with pedestrian suspension bridge.

Though the weight of the adopted light vehicle becomes big as the concentrated load in comparison with the design load of pedestrian suspension bridge, its value would be small, if the weight of light vehicle was replaced in area and direction occupying bridge surface. This is a load indicated in kN/m^2 or kN/m for each area or for longitudinal direction on the suspension bridge as described in Chapter XI-2.2.

However, since the load of 10.0 kN corresponds to that of walking in group of about 13 peoples being within 5 m of traveling direction on the suspension bridge, it is clear that this load becomes bigger compared with the traffic vibration under an usual condition of utilization. Thus the Guideline of the light-load bridge shall consider the following expectations of effectiveness.

- Inhibitory effect of the traffic vibration by pedestrian would be expected in widened width and an increase of bridge member's weight, though the uniform load intensity is same as the suspension bridge for pedestrian. (Increment of rigidity on overall suspension bridge, Increment of difference in mass between pedestrian and suspension bridge itself)
- Inhibitory effect of the traffic vibration would be expected adopting steel deck slab and curb.
- Inhibitory effect of the traffic vibration would be expected adopting cross bracing and slanting wind-guy cable.

Moreover, in the design of the floor assembly for light-load bridge, principal design conditions shall not be changed that of the pedestrian suspension bridge. The adoption of the each structure and the material shown in Chapter XI-3 and XI-4 shall be fully considered in the planning and design for the suspended structure.

XI-3.2 Deck Slab

(1) There are wooden deck slab and steel deck slab. For the light-load bridge, it is assumed to use the steel deck slab as a standard.

(2) Deck slab shall have durability more than that of pedestrian suspension bridge.

(3) Deck slab shall use the material with high reliability, as deck slab has the function of not only floor assembly but also a part of main girder and cross bracing.

(4) Minimum thickness of the steel deck slab is assumed to be 6 mm, however, it can be assumed 3 mm in case that the special corrosion measures are done.

In Bhutan, wooden deck slab is common as the deck slab structure of pedestrian suspension bridge. Wooden deck slab is changed once a year in the current condition of the maintenance and management. From the investigation of a few existing bridges, serious damaged parts in the several places of the deck, which is occurred in six months after changing of wooden deck slab, is verified. It is thought that the cause of these damages is derived from the insufficient material to durability and quality, and foot load of livestock.

For the deck slab of the light-load bridge, the steel deck slab shall be adopted as a standard, because the deck slab of light-load bridge under the load of front driving wheel and the rear wheel loaded the concentrated load 4.0 kN will be under the harsh conditions in comparison with that of pedestrian suspension bridge when the driving wheel pulls total load 10.0 kN. *(This is described in Chapter XI-2.3 in detail)*

Moreover, traffic vibration of the light vehicle crossing the light-load bridge becomes larger than that of the pedestrian suspension bridge. Therefore, for the steel deck slab, it is necessary to use reliable section's size and material for the deck slab that they enable to expect the action of the stringer and the cross bracing indirectly more than that of wooden deck slab.

XI-3.3 Curb

(1) Curb shall be installed at the both sides of the longitudinal direction of the deck slab.

(2) Curb height shall be assumed to be about 10 cm from the road surface.

(3) Hinged connection shall be installed at appropriate part in the curb.

At present, pedestrian suspension bridge in Bhutan has not installed a curb except a few wooden deck slab bridges. For the light-load bridge, curb shall be installed from the following reasons,

(a) Controlling wheel deviation of the light vehicle on the deck slab

(b) Consideration of width to enable to run at the minimum requirement to suppress the speed of the light vehicle

(c) Expectation of suppression effect of the traffic vibration that expects to occur at the longitudinal action of the curb

Consequently, Hinged connection to avoid serious damage of curb member shall be installed at appropriate location of the curb in consideration of the interval of deck slab and transportation weight for the installation of curb.

XI-3.4 Cross Beam

(1) Cross beam shall be a structure that can surely be transmitted the reaction from the deck slab to hanger or main cable and also lateral load to wind-guy cable.

Cross beam of the light-load bridge shall be assumed to be a structure that a lot of reaction and action acting onto the bridge can certainly be transmitted. Especially, for the connection between member and cross beam, and also for the installation of bolt hole of cross beam, it is necessary to study in detail considering the direction of stress and the deficit of sectional area.

Chapter XI-4 OTHER STRUCTURE

XI-4.1 Hanger

(1) Hanger shall be assumed to be a structure that the reaction of the cross beam and wind-guy cable can surely be transmitted to the main cable.

(2) Safety factor of the hanger and member related with the hanger shall be assumed to be 3.0.

Design tensile strength of the hanger for the light-load bridge will be bigger than that of the pedestrian suspension bridge according to the increase of reaction by live load of the rear wheel and the increase of dead load deriving from widen width and improvement of the floor assembly. Therefore, it is necessary to change the hanger's structure design in consideration of the increase of the above reaction and load.

Introduced balance of the initial tension at the erection shall be assumed to be a structure that sufficient adjustment of the tension is possible, because introduced balance of initial tension relates directly to stiffness of the entire bridge and damage of the floor assembly. Moreover safety factor, 3.0 applied to the SBP Guideline.

XI-4.2 Cable Band

(1) Cable band shall be assumed to be a structure that the hanger tension can surely be transmitted to the main cable.

(2) Sliding safety factor of the cable band shall be assumed to be 3.0.

(3) Design of cable band in the vicinity of the main tower shall be carefully considered, because the slippage of cable band will be occurred easily nearby the main tower.

Cable band shall tighten the cable uniformly and be a structure so as to suppress the decrease of tightening power of cable.

In the existing pedestrian suspension bridge, the damages such as slippage of the cable band and deformation of the floor assembly causing the looseness of cable band in the vicinity of the main tower are observed. Moreover, from the survey result of the existing bridge, though the same type (size and shape) of the cable band is used through the entire span, damage such as slippage of the band occurs mainly in the vicinity of the main tower.

Therefore, the cable band structure in the vicinity of the main tower (about one eighth of span) is preferable to be able to tighten the cable band more effective than the present standard design except the case that tightening cable band to increase its effect is regularly performed. The measures of the above case is as follows:

(a) Improvement of safety factor by number's increase of the tightening bolt, and

(b) Filler having durability like steel wire shall be used in crevice between the band and the wire.

XI-4.3 Wind-guy Cable

(1) Wind-guy cable shall be installed to maintain the light-load bridge's stability against wind.

(2) It is preferable to plan that the wind-guy cable is also effective for traffic vibration.

For the planning of the light-load bridge, as described in Chapter XI-3.1, the wind-guy cable shall be introduced regardless of bridge type or span length. This is considered that not only general coping effect to lateral load but also restraining effect to vertical vibration are expected as installation effectiveness of wind-guy cable.

Therefore, planning, design, construction, maintenance and management for wind-guy cable shall be fully considered them. Especially, it is preferable that the wind-guy cable is arranged diagonally in direction of height.

Simplified wind-guy cable tightened by only 4 Nos. of wires used for the existing pedestrian suspension bridge (for only small span) shall not be introduced for the light-load bridge, and it is preferable that usual wind-guy cable (not simplified one) shall be used for the light-load bridge.

Chapter XI-5 RUST-PROOF

(1) For the rust prevention measures of the steel material, galvanized materials shall be used as a standard

For the rust-proof measures of the steel part of the light-load bridge, galvanized materials to be able to reduce the maintenance and management work shall be assumed to use as a standard. Moreover, for the rust-proof plan of steel material, as the cable band, clip, turnbuckle, rod and bolt tend to rust easily in comparison with the other part of steel material, the maintenance and management plan which enable to treat the rust-proof shall be conducted referring to the results of the maintenance and management survey of the existing pedestrian suspension bridge.

Chapter XI-6 MAINTENANCE AND MANAGEMENT

There are the following two points regarding the management for the light-load bridge.

(1) Traffic management to ensure the safety of pedestrian and light vehicle.

(2) Maintenance and management for durability of the entire bridge.

To ensure the safety of pedestrian by appropriate traffic management, it is necessary to try to execute inspection, maintenance and management and rehabilitation of the light-load bridge.

(a) Traffic Management

The damages in the several parts of the bridge will be occurred and more than this thing, the users of the bridge would be encountered the damages, if a bigger vehicle more than the light vehicle load, which is considered at the design stage was passed on the light-load bridge.

Accordingly, it is important to have notice to pay the attention and enlightenment to the users of the light-load bridge. Its notice items are considered as the following and shall be indicated on the attention board near the bridge.

1) Weight and size of the light vehicle to enable to cross a bridge (Example)

Width x Length x Total weight (1.4 m x 5.0 m x 1.0 kN)

2) Notes of Light vehicle to pass a bridge (Example)

- Light vehicle shall cross after confirmation not to exist oncoming pedestrian on the bridge,
- Common pedestrian shall not cross the bridge in case that the oncoming light vehicle on the bridge exists,
- For traffic safety, operation speed of light vehicle shall be equivalent to that of common pedestrian, and the light vehicle shall not overtake pedestrian walking ahead on the bridge,
- In case of crossing bridge in condition of strong wind, it is necessary to pay attention in particular, and
- Playing on the bridge shall not be allowed.

To the user's attention for the above notices, it shall be considered to distribute a hand bill or get into a newspaper at the formal opening and installation of attention board for the bridge.

ATTENTION!!

SIZE AND TOTAL LOAD SHOULD NOT EXCEED(4570 x 1400mm) 1000 Kg

STOP! MAKE SURE NO ONE PASSSING IN OPPOSITE DIRECTION.

DO NOT OVER TAKE WALKING MAN, MOVE WITH SAME SPEED.

NO PASSING WHILE WIND VELOCITY IS HIGH.

NO PLAY ON THE BRIDGE.

Example of Attention Board

(b) Maintenance and Management

For the existing bridge, the appropriate inspection, maintenance and management will be required for ensuring safety and smooth traffic. For the inspection, maintenance and rehabilitation, it shall conduct after setting up the effective plan based on the experience and achievement for that of existing pedestrian bridge.

Moreover, the results of the inspection, maintenance and rehabilitation shall be managed using bridge inventory sheets or rehabilitation inventory sheets. Ordinary inspection and periodic inspection are generally described as follows:

- Ordinary inspection: Ordinary inspection is conducted in visual inspection regarding the floor deck surface, curb, wire mesh, anchor, hanger, main cable and wind-proof cable. It shall be conducted according to the schedule of inspection of the usual road
- Periodic inspection: Periodic inspection shall be conducted once / 1 - 3 years periodically and it shall be basically inspected the structure details of the bridge in visual inspection. If deformation or damage of the bridge is found out in the inspection, the works such as detailed inspection, traffic control, and maintenance / rehabilitation shall be conducted based on the consultation with the person in charge of the maintenance / management and the experts.
- For the inspection, the following method based on the visual inspection is recommendable.
    - For material investigation in distance, using a telescope in visual inspection shall be assumed to be basic.
    - Level of tension for the hanger and wire net shall be confirmed by touching them directly.
    - Looseness of bolts shall be confirmed by touching them directly or knocking them by hammer.
    - Location of the cable band, clip and important bolt shall be put a mark at construction stage.

Moreover, it is important for maintenance and rehabilitation to examine the cause of damage. From the result of investigation for the existing bridge and consultation with the personnel who were engaged in preparing this Guideline, the main check points and items in the periodic inspection are indicated as below:

Place and Item for Periodic Inspection

No	Name of Place	Item for Periodic Maintenance
1	Entire bridge	● Inclination of bridge surface, Skeleton form of entire bridge, Abnormal vibration at crossing bridge.
2	Main tower	● Inclination of entire tower, Partial corrosion/deformation of tower member. ● Corrosion of anchor bolt at saddle of tower top ● Corrosion of anchor bolt at lower part of tower
3	Main cable, Anchor	● Parallel level of right and left cable at each hanger location ● Parallel level of anchor stay portion if plural cables are used ● Condition of maintenance and management at fixing point of anchor (corrosion, adhesion of mud, grass cutting) ● Interval and direction of anchorage of fixing point of anchor (clip etc.)
4	Hanger rod	● Condition of installation location (slippage of upper anchor) ● Balance of tension level of each hanger rod (tension condition requires) ● Verification of movable turnbuckle
5	Wind-guy cable	● Arrangement form of wind cable and wind tie ● Tensioning force of wind cable and wind tie

Place and Item for Periodic Inspection

No	Name of Place	Item for Periodic Maintenance
		● Unusual condition at each installation part and fixing point of each cable
		● Verification of working condition of turnbuckle
6	Desk slab surface	● Unusual condition of bolt installation to floor girder
		● Deformation and corrosion of floor member
7	Curb	● Looseness and coming-off of bolt installation to floor girder
		● Looseness and coming-off of bolt installation at hinge portion
8	Hand cable	● Parallel level of right and left cable at each hanger location
		● Condition of maintenance and management at fixing point of anchor (corrosion, adhesion of mud, grass cutting)
		● Interval and direction of anchorage of the fixing point of anchor (clip etc.)
9	Wire net	● Verification of breakage
		● Treatment condition of net in the vicinity of handrail (so as not to cause obstacle to traffic of pedestrian on bridge)
		● Verification of tensioning force (there is other defect if unusual tensioning condition is occurred)
10	Cross beam	● Deformation of center span of cross beam
		● Verification of soundness for installation part of various member
11	Cross bracing	● Looseness and coming-off of bolt installation
		● Unusual deformation of member
12	Substructure	● Concrete crack in the vicinity of cable anchor part
		● Concrete crack and sinking in the vicinity of lower part of tower

Chapter XI-7 REFERENCE

XI-7.1 Proposal Matter to General Plan of Suspension Bridge (based on the result of the existing suspension bridge investigation)

On the occasion of the Guideline preparation for the light-load bridge, six existing suspension bridges were investigated. From the result of two bridges below, proposal matters noted for the future planning of the light-load bridge are enumerated as follows. Moreover, Bridge No.1 was planned and constructed as a light-load bridge for transporting power-tiller.

(1) Bridge No.1: Bondey Zam constructed in 1992 year (Paro, Suspension Bridge, Wooden Deck, L = 81.4 m, W = 1.5 m)

(a) Verification of damage parts of the wooden deck slab

- Maintenance and management to repair or change a wooden deck slab is usually executed once a year and is becoming financially severe for GORB.
- The direct danger to pedestrian and light vehicle is forecasted, because of a length shortage of template at the edge of deck slab, in addition to the above, the wooden deck slab structure is one layer in longitudinal direction.
- Secondary damage to the structural main body by deviation of light vehicle's wheel is also predicted.
- For the future plan of pedestrian suspension bridge and light-load bridge, steel deck slab having higher durability shall be required to use.

(b) Verification of sag difference on the anchor (back stay) portion of the main cable using plural cable.

In Bhutan, usable cable size is regulated taking account of the trafficability and workability in site, and in general, plural cable for main cable is mainly adopted. If the difference of sag in quantity on the anchor shall be indicated, there would be high problem in terms of safety, because the main cable with the difference of tension seems to be one cable even using plural cable.

Accordingly, in case of the adoption of plural cable in tension management at the construction stage, the management of the shape and tension for main cable shall fully pay attention to plural cable more than that of single cable.

(c) Verification of tension condition of the wind-guy cable and the low level maintenance management

Wind-guy cable is an effective member to control not only lateral load by wind load but also traffic vibration by users and vehicles crossing a bridge. However, the wind-guy cable of this bridge is in the situation in which initial purpose is not accomplished, because of coming-off of the wind tie and damage at the edge of the fixing point of anchor.

From this situation, secondary damage occurs at the bolt installation of the cross bracing and floor deck of the part of the floor assembly. Therefore, it is necessary to enhance maintenance and management for the wind-guy cable more than ever.

(d) Others

As aforementioned, consideration and installation regarding durability of deck slab and curb for wheel inducement are required for this bridge for transporting light-load vehicle.

(2) Bridge No.2: Mitshi Zam constructed in 2000 year (Paro, Suspended Bridge, Steel Deck, L = 61.0 m, W = 1.0 m)

(a) Verification of insufficient quality control of steel deck slab made at workshop

The steel deck slab of the bridge is the integrated factory product processed at a workshop using angle member and flat bar. However, it is obviously verified that the accuracy condition on the length, installation location and weld finishing of the each member is unequal. Superstructure of a bridge is primarily planned and designed on the assumption that is "prefabricated structure" with the factory product material to be able to expect a high quality.

As the low quality of even the simplified structure such as a steel desk slab is verified, it is necessary to be strengthened inspection and instruction more than ever.

(b) Verification of unequal sag quantity of the main cable

Difference of the height of the right-left main cable is seen in the vicinity of the center span of deck slab. This is thought to be adjustment shortage of main cable at the construction stage and it causes to be loosing main cable buried in anchor of the concrete after the construction.

Therefore, when the anchor type that cannot adjust the main cable after the construction is adopted, it is necessary to enhance construction accuracy of the main cable more than before.

(c) Verification of poor tension and arrangement of the hanger rod.

In Bhutan, for the design of a suspended bridge, the dead load for the floor assembly and live load are shared with main cable and handrail cable. Therefore, the hanger rod is arranged for even the suspended bridge. However almost all of the hanger rods in this bridge are situated in the state of no tension, and also the location of the fixing points are not in constancy.

On the contrary, there is enough tension in the wire mesh net installed at the lateral girder and handrail cable. From the above fact, it is clear that the result of construction based on the primarily design concept is not reflected and there is a problem for the structure plan.

Therefore, the study of a structural change to be tension adjustment system (turnbuckle method etc.) at the hanger rod is required to insure construction accuracy of each cable

(d) Verification of vibration properties in condition of no wind-guy cable

This bridge is not installed wind-guy cable, because it is not required to install a wind-guy cable in case of the suspension bridge with span length 60 - 70 m or less as stipulated in the SBP Guideline. In the site investigation, when vibration (vertical, horizontal and torsion) occurred intentionally, the vibration became big amplitude, and this amplitude was seemed not to be absolutely safety situation for pedestrian with pack and light vehicle.

(e) Others

Edge of the hanger rod is ring weld finishing, however it couldn't be observed that the welding situation at this part was enough. Same structure of ring weld finishing is also adopted for the hangar rod of the suspension bridge. Then as the hanger member is the main member of the pedestrian suspension bridge and light-load bridge, it is necessary to do careful design and proper fabrication planning. Therefore, product inspection at the workshop described in (a) shall be considered more than ever.

XI-7.2 Design Standard Comparison between Bhutan and Japan

The design standard comparison between the kingdom of Bhutan and Japan regarding pedestrian suspension bridge is compared by the following main item as shown in the following table.

Design Standard Comparison for Pedestrian Suspension Bridge

1	Applied span length (Achievement)	Japan: 200 m (achievement is not confirmed) Bhutan: 250 m (with tower), 300 m (without tower) (160 m) (230 m)
2	Width	Japan: 1.0 m - 2.5 m Bhutan: 1.2 m (with tower), 1.0 m (without tower)
3	Number of achievement	Japan: about 1,400 bridges (including out of standard) Bhutan: 227 (with tower), 122 (without tower)
4	Live load	Japan: Main cable, Tower, Substructure → 200 kg/m^2 Floor assembly, Hanger → 300 kg/m^2 Bhutan: Main cable, Tower, Substructure → 250 kg/m^2 Floor assembly, Hanger → 2 * 150 kg/0.6 m pich
5	Impact coefficient	Japan: i = 0.0 Bhutan: i = 0.0
6	Safety factor	Japan: Main cable 3.0, Hanger 3.5, Wind-proof cable 1.5 Bhutan: Main cable 3.0, Hanger 3.0, Wind-proof cable 3.0
7	Hanger	Japan: Cable, Rod (forged) Bhutan: Steel bar (for reinforcement concrete)
8	Wind-proof cable	Japan: Cable Bhutan: Cable (cable is not installed in span 60 - 70 m or less)
9	Lateral bracing	Japan: Single or double Bhutan: Single
10	Fixing of cable	Japan: Main cable → Socket, Tightening stop, Wedge stop Others → Socket, Tightening stop, Wedge stop, Clip stop Bhutan: Main cable → Socket, Clip stop (bulldog) Others → Clip stop (bulldog)
11	Main tower	Japan: Material → Steel, Concrete Bottom condition → Fix, Hinge Bhutan: Material → Steel Bottom condition → Hinge
12	Anchor part	Japan: Gravity type anchor block Bhutan: Gravity type anchor block
13	Deck slab	Japan: Wood, Reinforcement concrete, Steel Bhutan: Wood, Steel
14	Curb	Japan: Provided Bhutan: Not provided
15	Handrail	Japan: Provided Bhutan: Not provided (wire net is provided)
16	Lateral member	Japan: Provided Bhutan: Provided
17	Stringer	Japan: Provided Bhutan: Not provided (deck slab is used in place of stringer)

XI-7.3 General View Drawing of Pedestrian Suspension Bridge

The general view drawings (reference) of pedestrian suspension bridge in Bhutan and Japan are shown as follows:

- Standard Suspension Bridge with Gravity Foundation (Bhutan): Fig XI-1,
- Standard Suspended Bridge Inclined with Gravity Foundation (Bhutan): Fig XI-2,
- Standard Suspension Bridge with Span 50 m (Japan): Fig XI-3,
- Standard Suspension Bridge with Span 150 m (Japan): Fig XI-4.

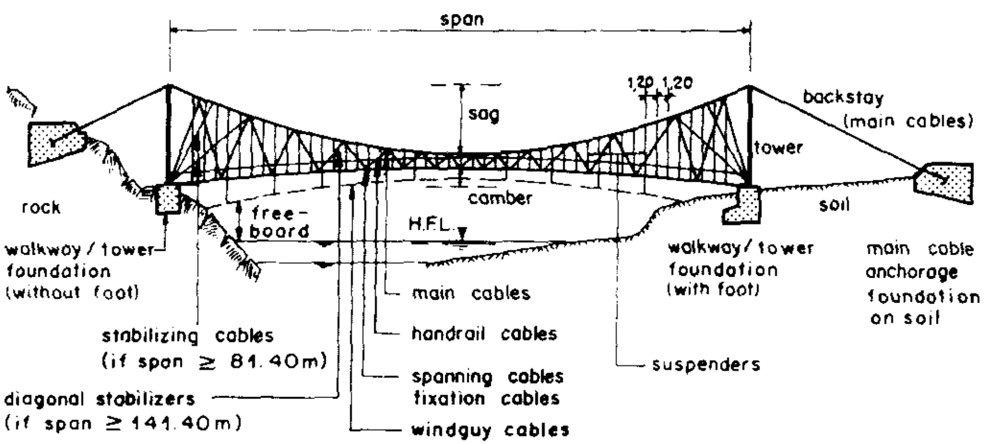
XI-7.4 Drawings for Proposed Light-load Bridge

The following drawings for proposed light-load bridge at Khoma and Autsho in Lhuntse and at Gorthongla in Mongar are initially prepared as follows:

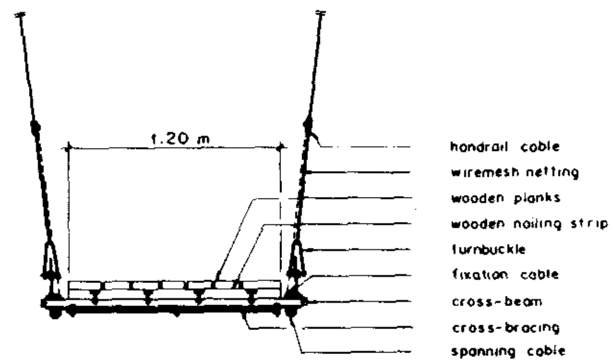
- Khoma Zam Planning (Suspended Bridge): Fig XI-5,
- Autsho Zam Planning (Suspension Bridge): Fig XI-6,
- Gorthongla Zam Planning (Suspended Bridge): Fig XI-7,
- Detail of Suspension Bridge Cross Beam and Steel Deck: Fig XI-8,
- Suspended Bridge Cross Beam and Steel Deck: Fig XI-9,
- Cross Beam Side View: Fig XI-10,
- Detail of Steel Deck and Steel Deck Bottom View: Fig XI-11.

Figures

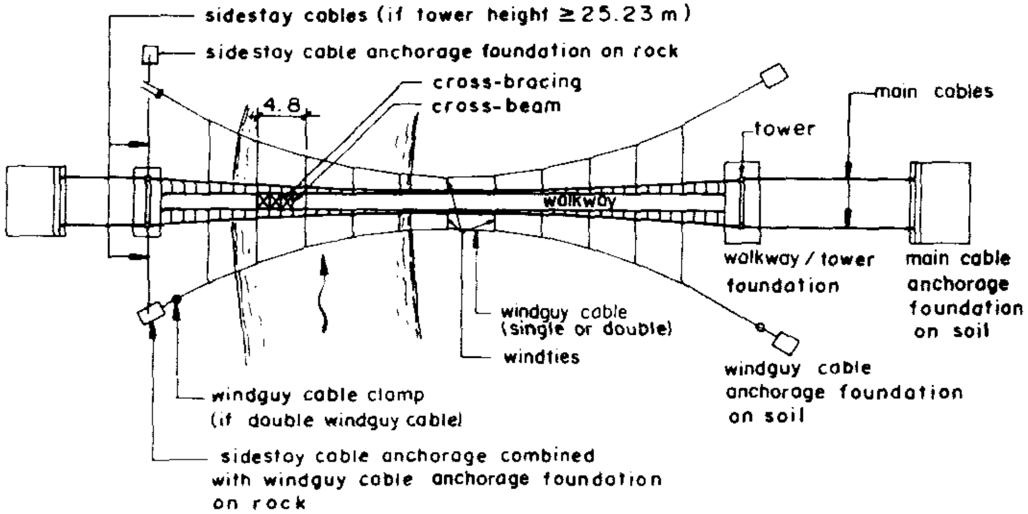
SIDE ELEVATION



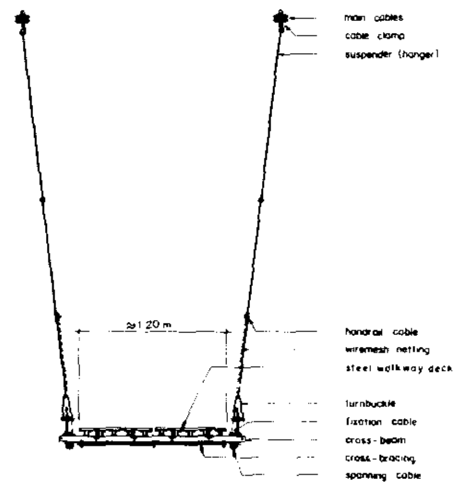
SECTION OF WALKWAY SUPPORT WITH STEEL WALKWAY DECK



PLAN



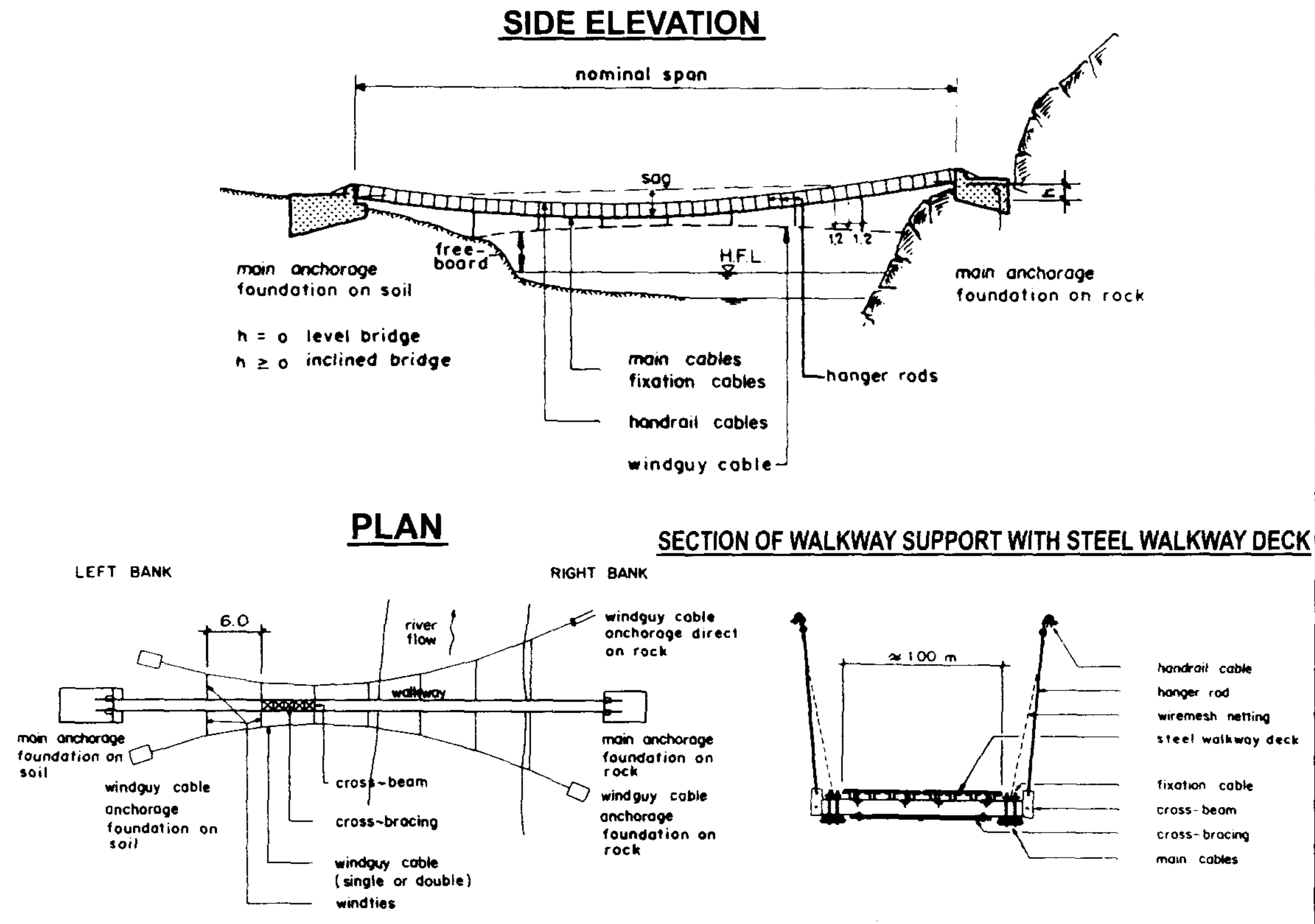
SECTION OF WALKWAY SUPPORT WITH WOODEN PLANKING



The Study on Agriculture and Farm Road Development in the Lhuntse and Mongar Districts in the Kingdom of Bhutan

Japan International Cooperation Agency (JICA)

Figure XI-1
Standard Suspension Bridge with Gravity Foundation (Bhutan)

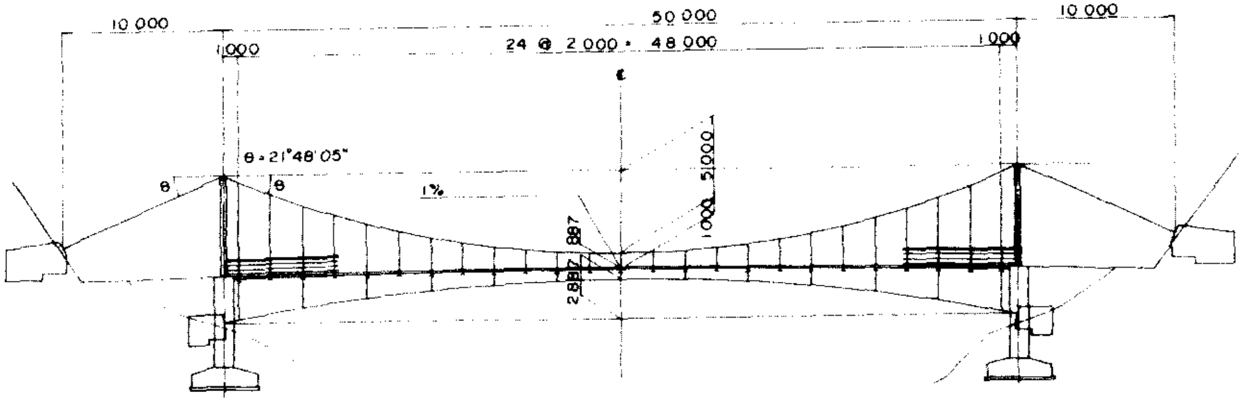


The Study on Agriculture and Farm Road Development in the Lhuntse and Mongar Districts in the Kingdom of Bhutan

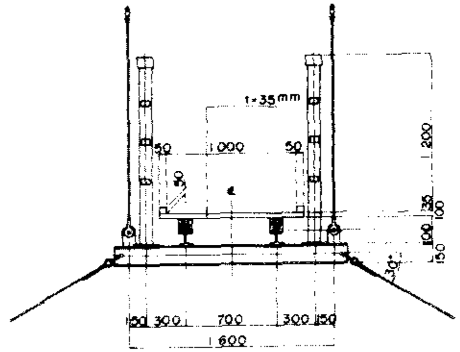
Japan International Cooperation Agency (JICA)

Figure XI-2
Standard Suspended Bridge Inclined with Gravity Foundation (Bhutan)

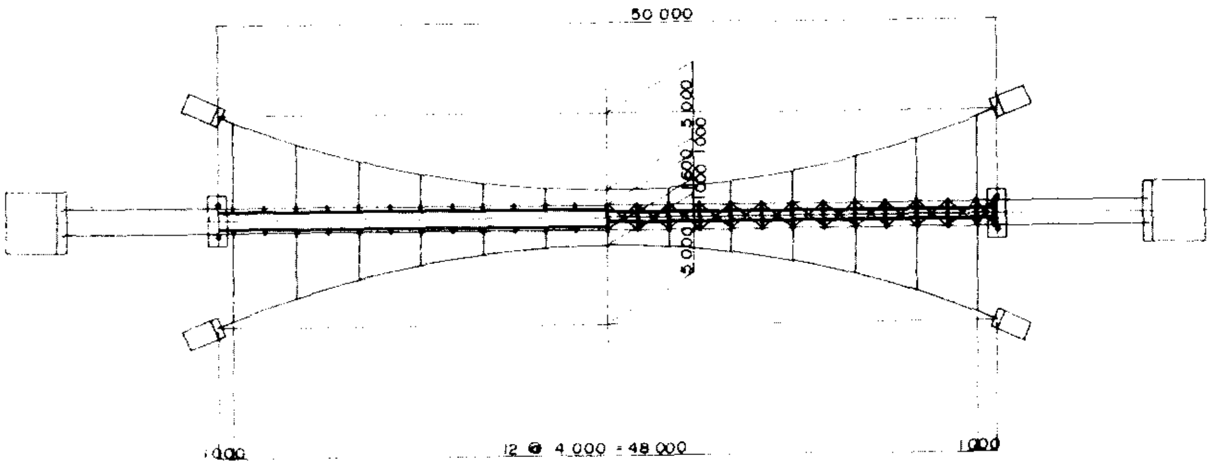
PLAN



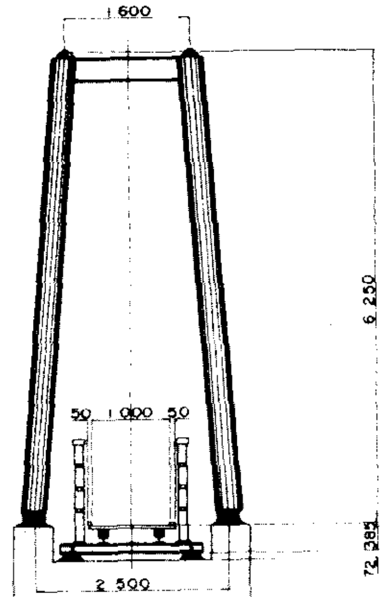
CROSS-SECTION



SIDE ELEVATION



CROSS-SECTION for TOWER SHAFT

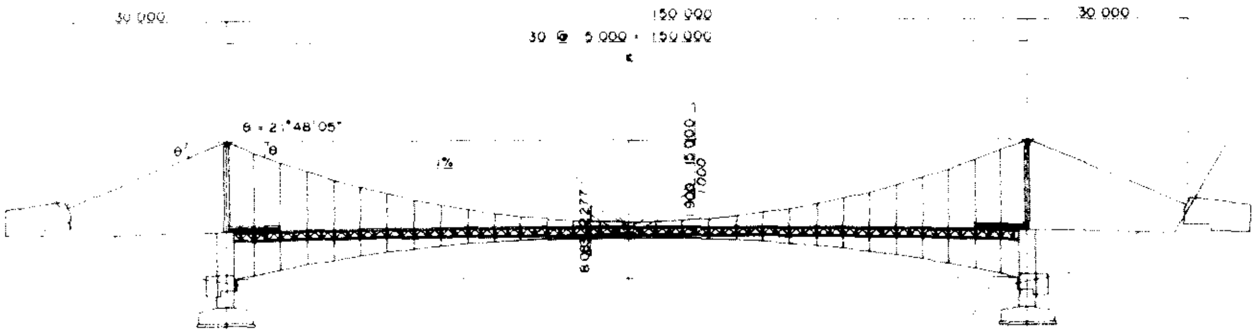


The Study on Agriculture and Farm Road Development in the Lhuntse and Mongar Districts in the Kingdom of Bhutan

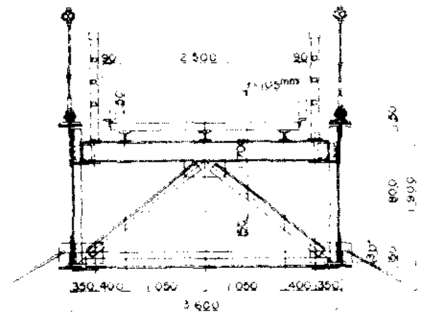
Japan International Cooperation Agency (JICA)

Figure XI-3
Standard Suspension Bridge with Span 50 m (Japan)

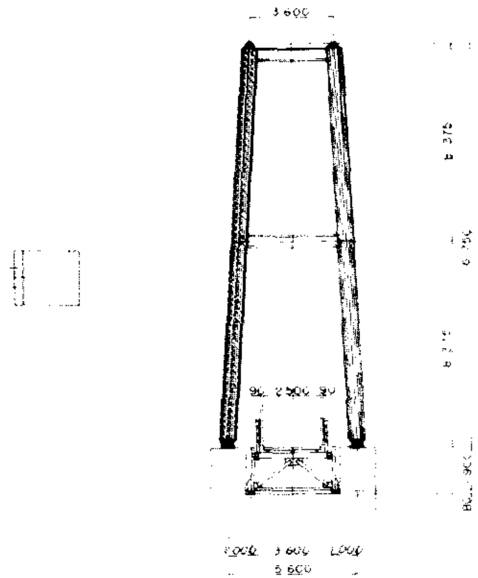
PLAN



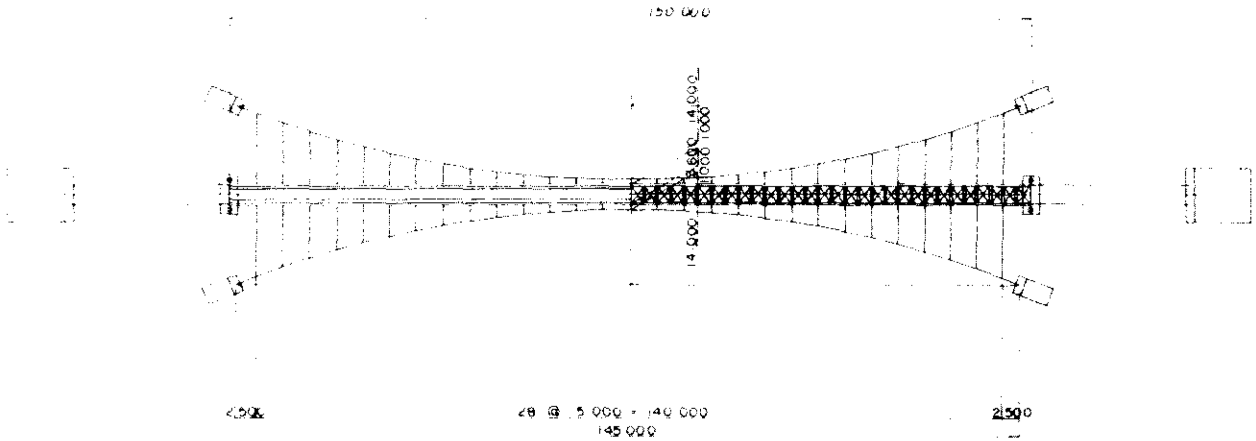
CROSS-SECTION



CROSS-SECTION for TOWER SHAFT



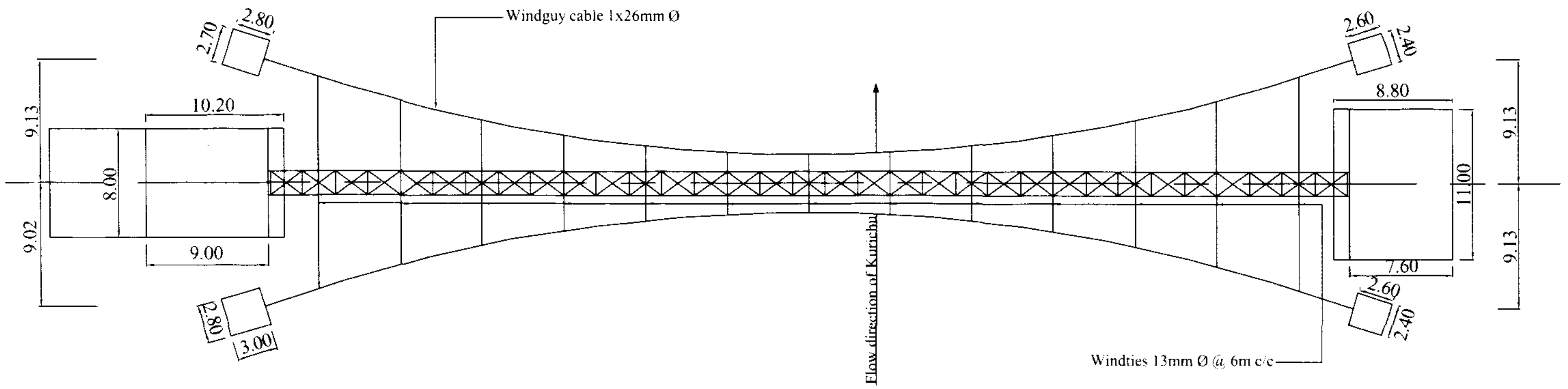
SIDE ELEVATION

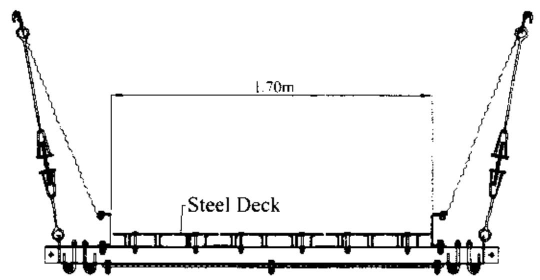


The Study on Agriculture and Farm Road Development in the Lhuntse and Mongar Districts in the Kingdom of Bhutan

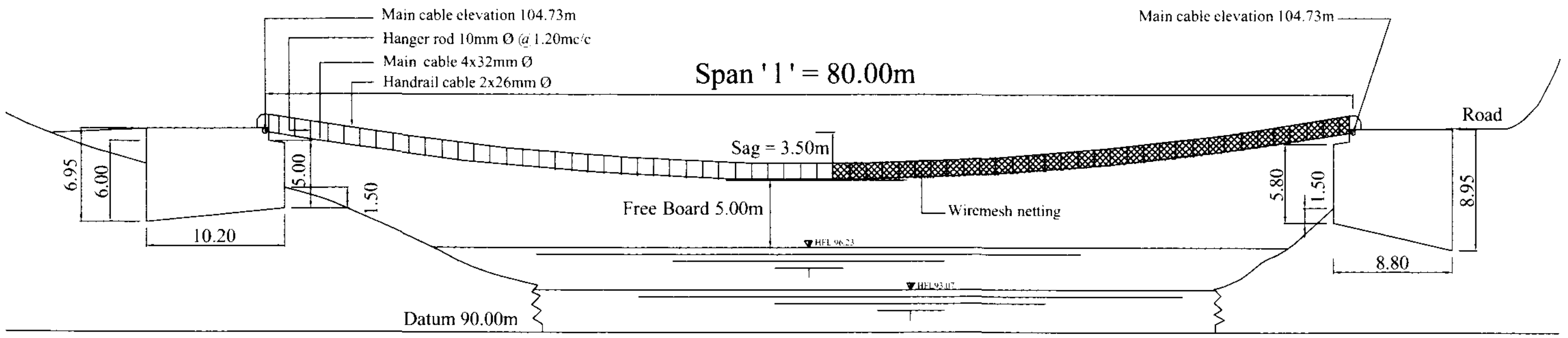
Japan International Cooperation Agency (JICA)

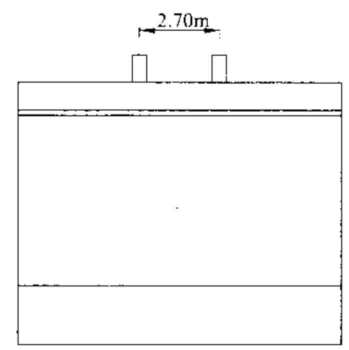
Figure XI-4
Standard Suspension Bridge with Span 150 m (Japan)





Suspended bridge cross beam and steel deck



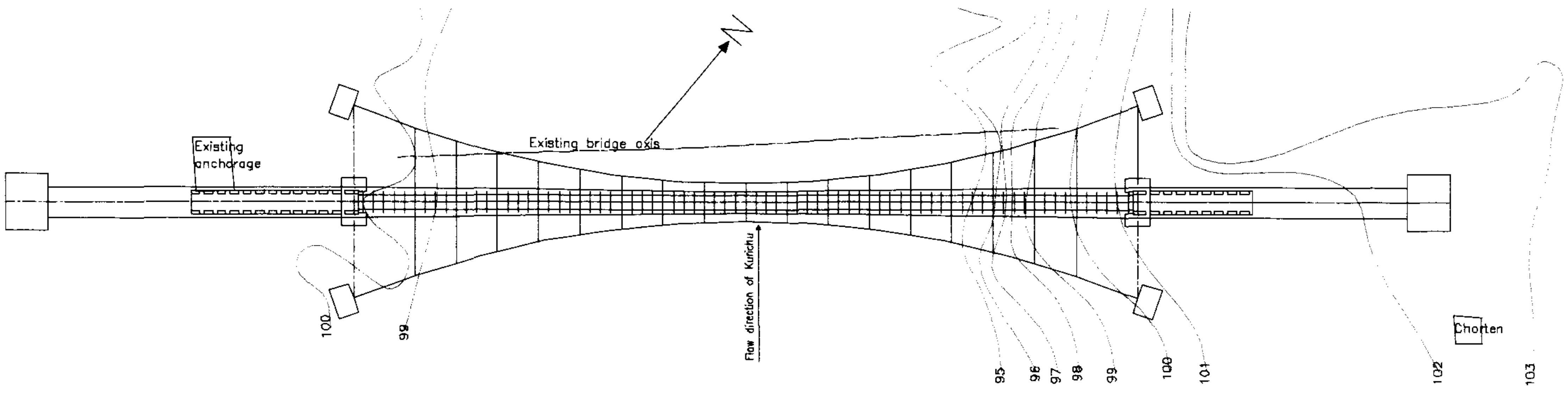


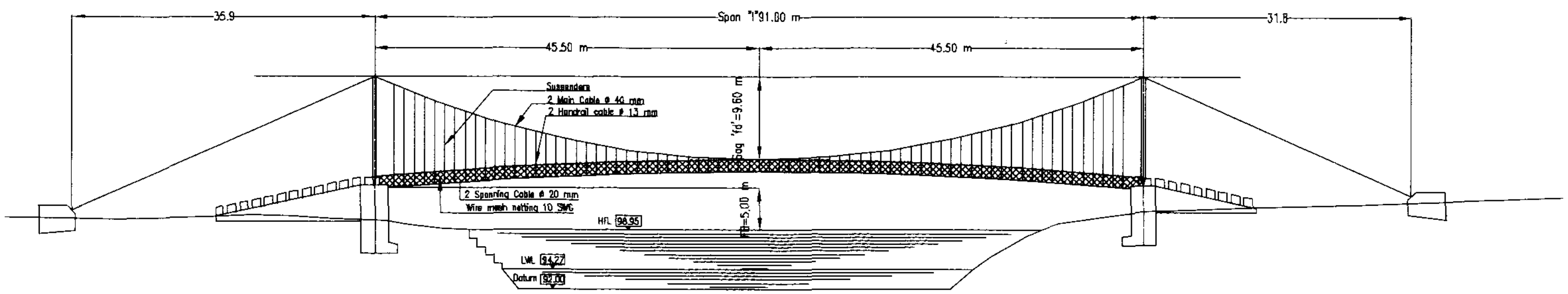
Front Elevation

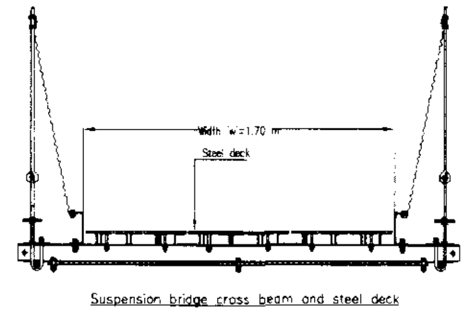
Bridge Name	Khoma Zam
Span	80.00m
River	Kurichu
Geog	Khoma
Dzongkhag	Lhuntse

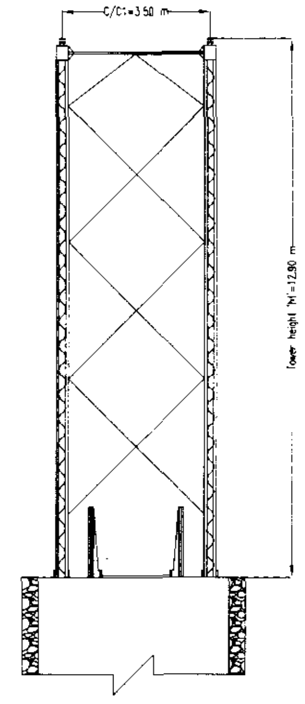
Load case	Load G (kN/m)	Tension T max (kN)	Sag, b (m)	Lowest Point Horz.dist. e (m)	Lowest Point Vert.dist. f (m)	Lowest Point Elevation (m)
Hoisting	0.202	56.16	2.91	40.00	2.91	101.23
dead Load	2.332	541.18	3.50	40.00	3.50	100.74
Full Load	4.832	988.23	3.99	40.00	3.99	101.82
Live Load	2.50	$E = 110 kN/mm^2$		Free Board = 5.00m		

The Study on Agriculture and Farm Road Development in the Lhuntse and Mongar Districts in the Kingdom of Bhutan	Figure XI-5 Khoma Zam Planning (Suspended Bridge)
Japan International Cooperation Agency (JICA)	









Bridge Name	Autsho zam
No.	
River	Kuri chhu
Geog	Autsho (L/B) and Jarray (R/B)
Span	91.00 m
Dzongkhag	Lhuntse

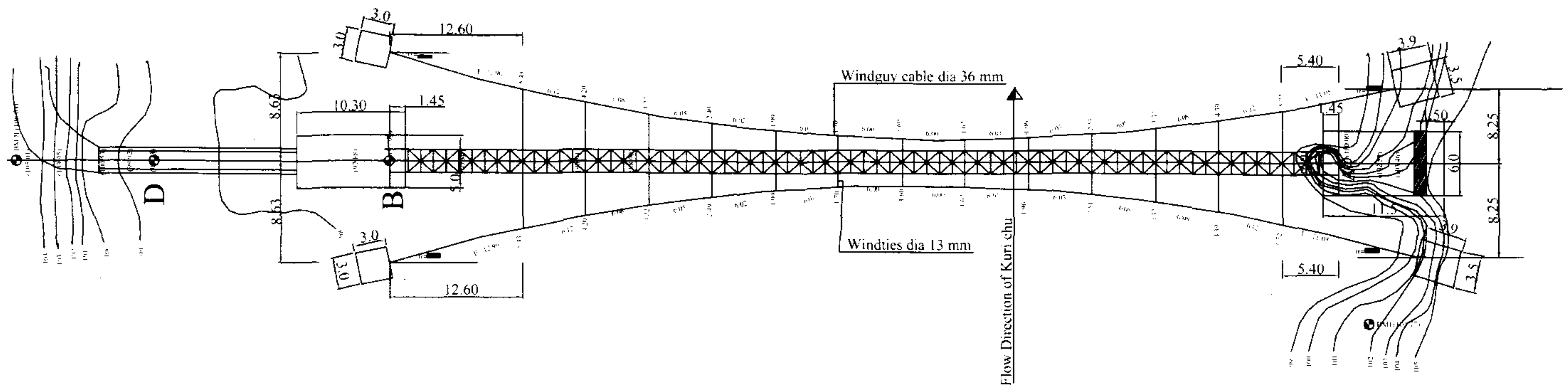
Cables	Load Case	Load G (kN/m)	Tension T (kN)	Sag f Camber c (m)	Elevation Of Vertex (m)	Displacement of Saddles ΔPL (m)	Displacement of Saddles ΔPR (m)
Main	Hoisting	0.098	10.16	10.857	108.113	-0.079	-0.071
	Dead load	2.950	289.11	11.90	107.07	0.000	0.000
	Full load	5.177	495.36	12.299	106.671	0.056	0.050
Spanning	Hoisting load	0.03	21.99	-1.82	102.15		
	Dead load	0.27	152.28	1.82	105.79		
	Full load	0.000	0.000	1.421	105.391		
	Live load	2.500					

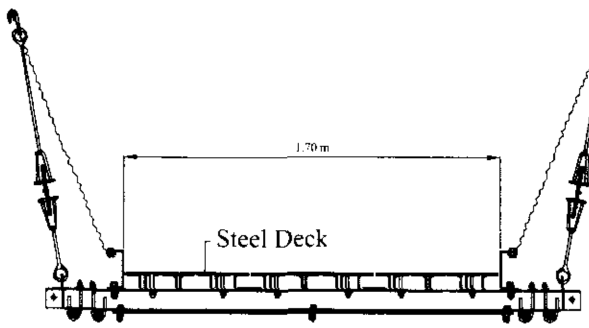
The Study on Agriculture and Farm Road Development in the Lhuntse and Mongar Districts in the Kingdom of Bhutan

Japan International Cooperation Agency (JICA)

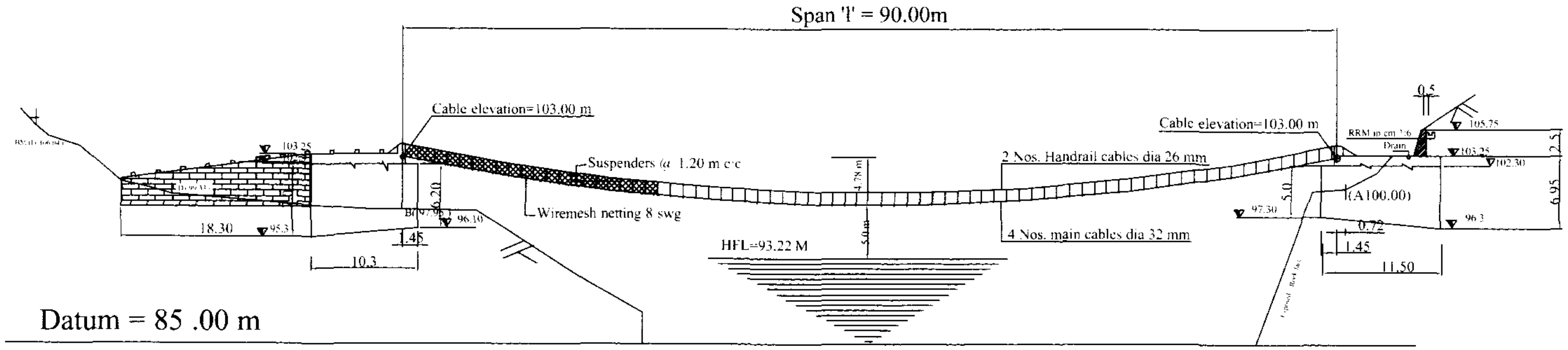
Figure XI-6

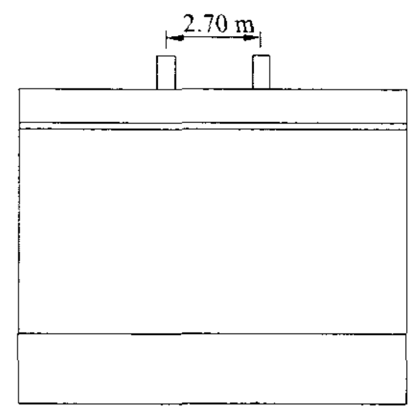
Autsho Zam Planning (Suspension Bridge)





Suspended bridge cross beam and steel deck



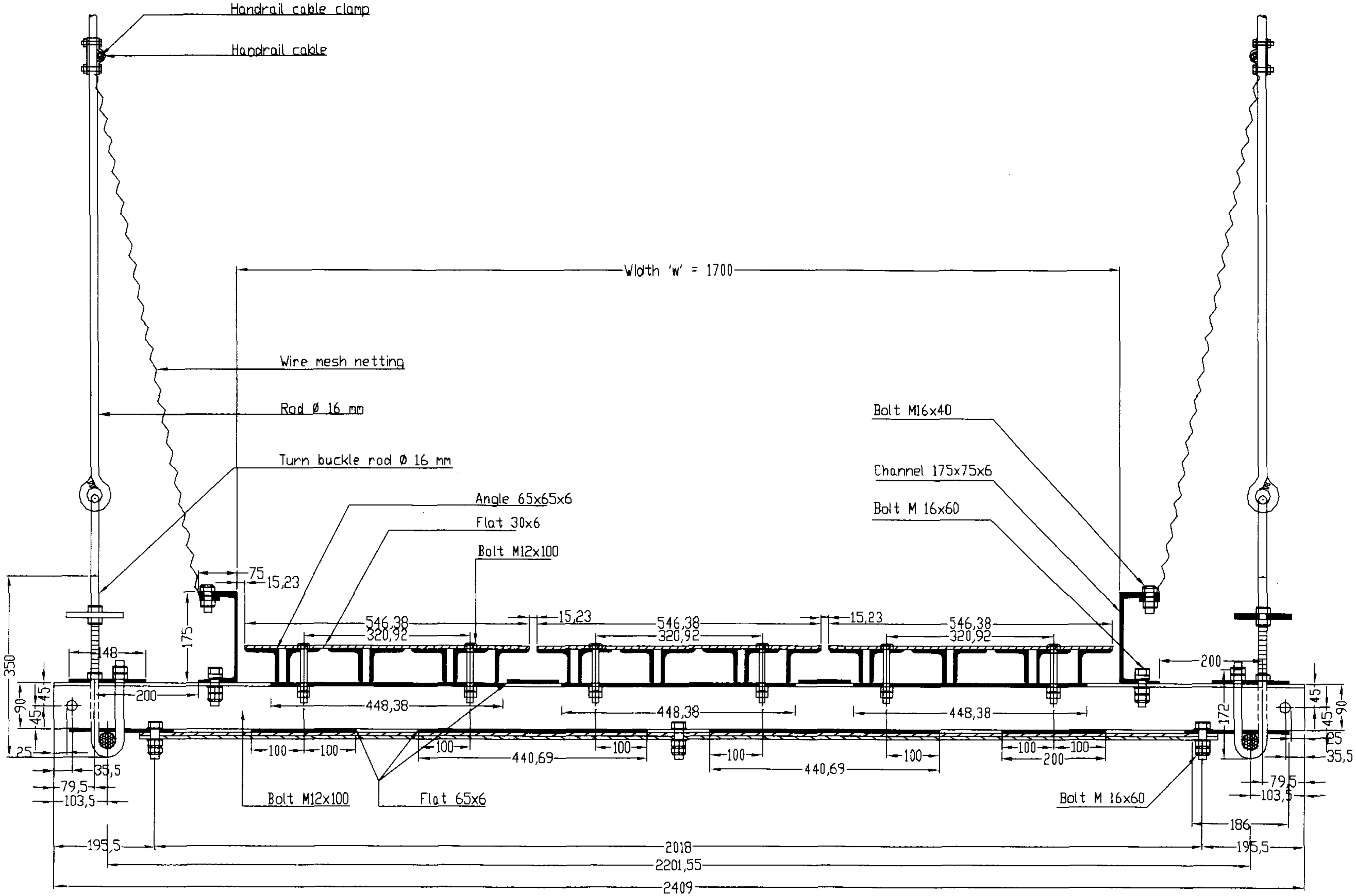


Front Elevation

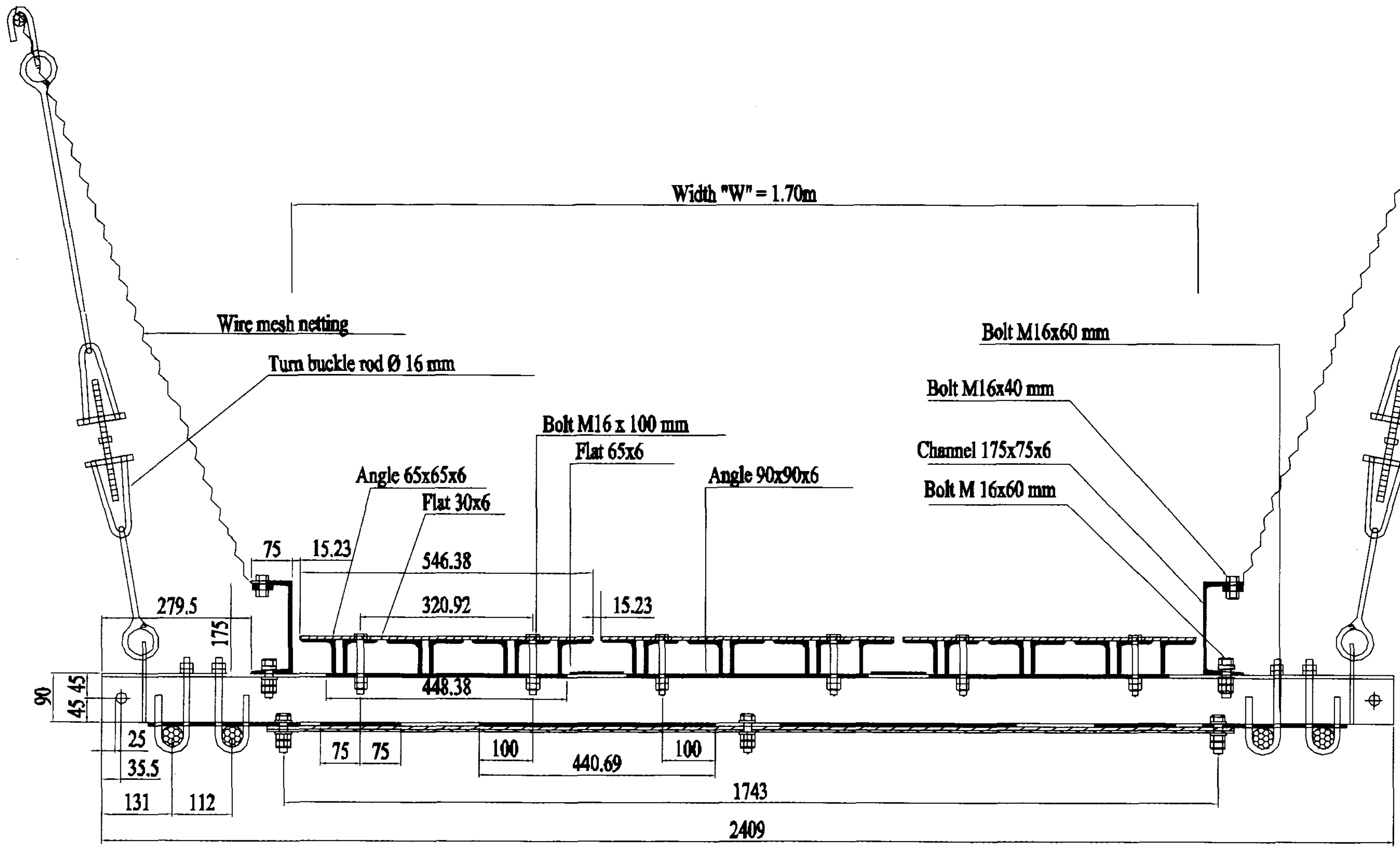
Bridge Name	Gorthongla Zam
Span	90.00m
River	Kurichu
Geog	L/B. Jurmey R/B. Gongdue
Dzongkhag	Mongar

Load case	Load G (kN/m)	Tension T max (kN)	Sag, b (m)	Lowest Point: Horz.dist. e (m)	Lowest Point: Vert.dist. f (m)	Lowest Point: Elevation (m)
Hoisting	0.202	50.16	4.15	45.00	4.15	98.22
dead Load	2.716	588.19	4.78	45.00	4.78	97.78
Full Load	5.216	1039.41	5.22	45.00	5.22	98.85
Live Load	2.50	E = 110kN/mm^2		Free Board = 5.00m		

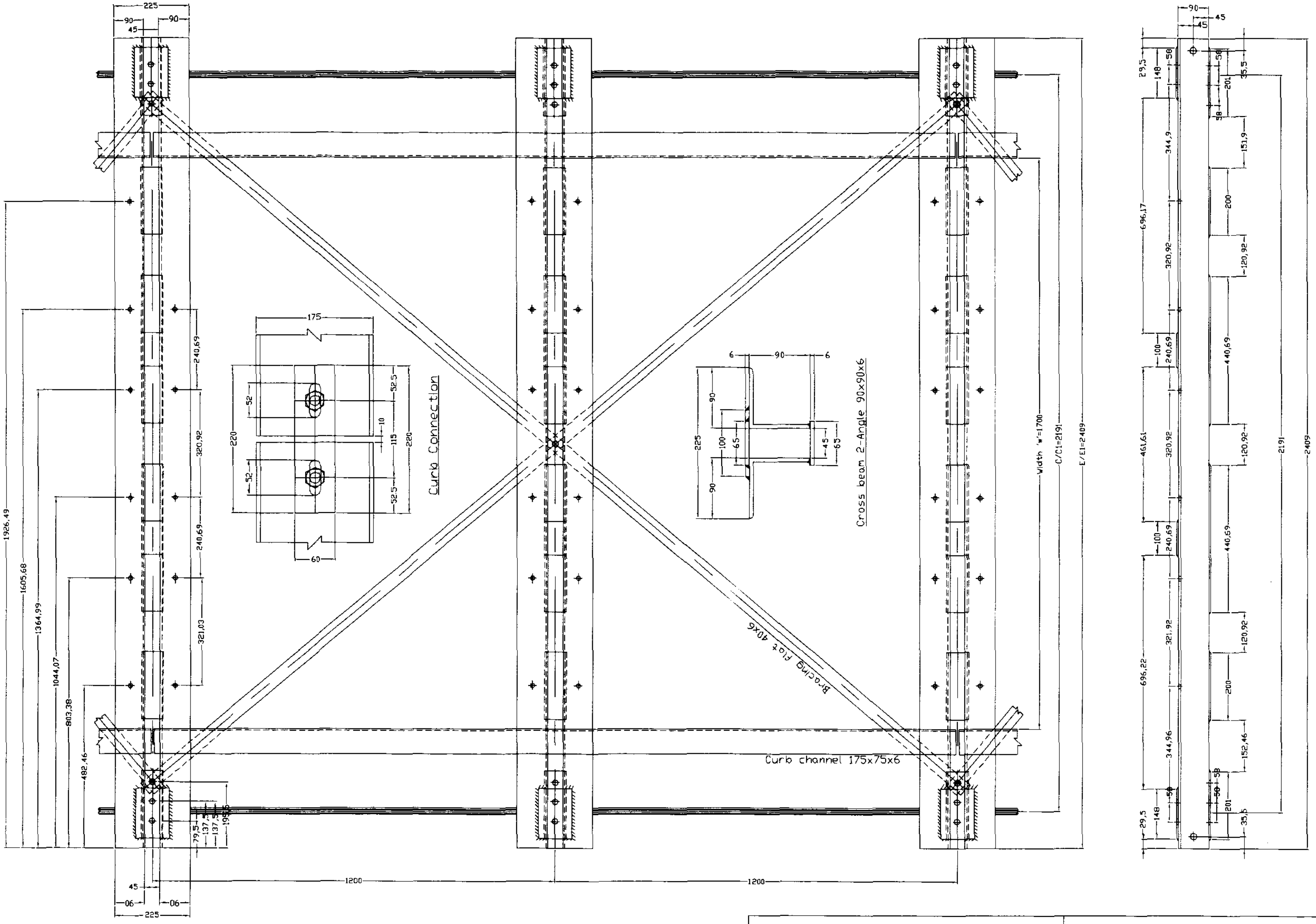
The Study on Agriculture and Farm Road Development in the Lhuntse and Mongar Districts in the Kingdom of Bhutan	Figure XI-7 Gorthongla Zam Planning (Suspended Bridge)
Japan International Cooperation Agency (JICA)	



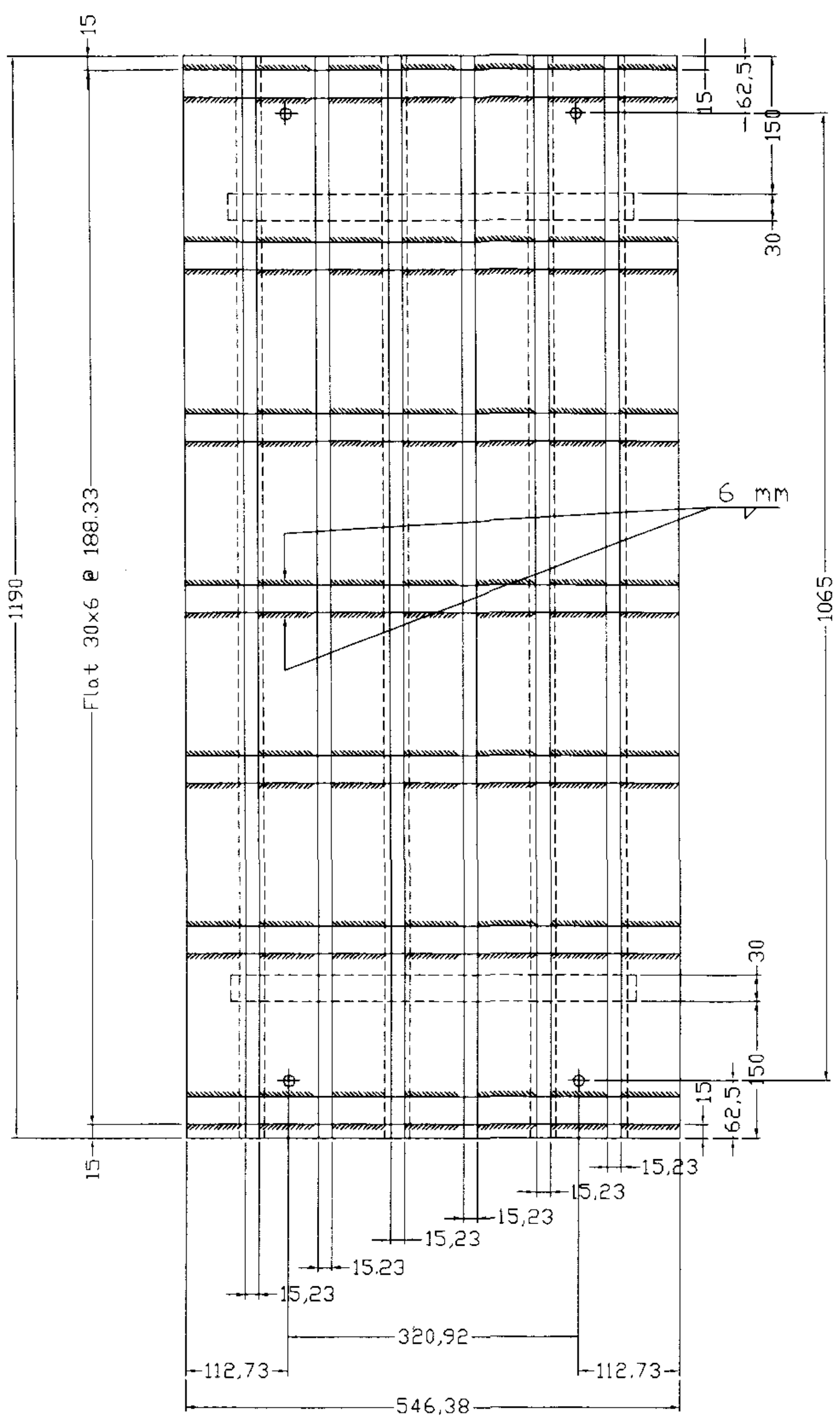
The Study on Agriculture and Farm Road Development in the Lhuntse and Mongar Districts in the Kingdom of Bhutan	Figure XI-8 Detail of Suspension Bridge Cross Beam and Steel Deck
Japan International Cooperation Agency (JICA)	



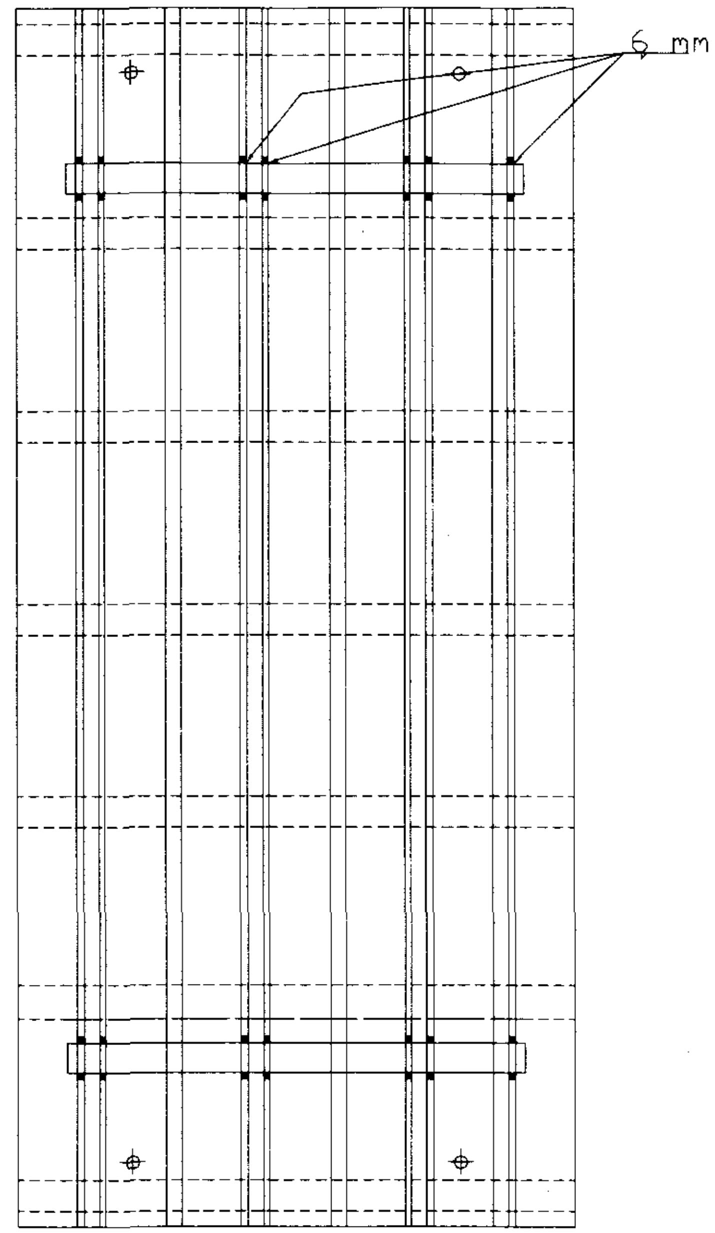
The Study on Agriculture and Farm Road Development in the Lhuntse and Mongar Districts in the Kingdom of Bhutan	Figure XI-9 Suspended Bridge Cross Beam and Steel Deck
Japan International Cooperation Agency (JICA)	



The Study on Agriculture and Farm Road Development in the Lhuntse and Mongar Districts in the Kingdom of Bhutan	Figure XI-10
Japan International Cooperation Agency (JICA)	Cross Beam Side View



Steel Deck



Steel Deck bottom view

The Study on Agriculture and Farm Road Development in the Lhuntse and Mongar Districts in the Kingdom of Bhutan	Figure XI-11 Detail of Steel Deck and Steel Deck Bottom View
Japan International Cooperation Agency (JICA)	