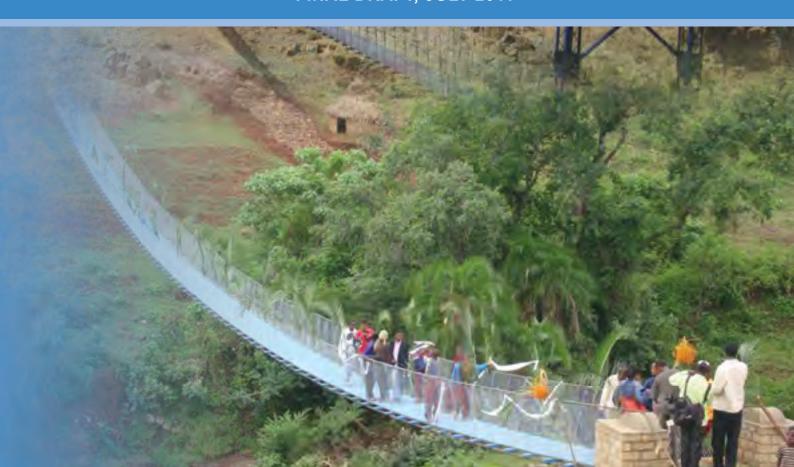


DESIGN MANUAL FOR LOW VOLUME ROADS TRAIL BRIDGES MANUAL - PART F FINAL DRAFT, JULY 2011



Part F

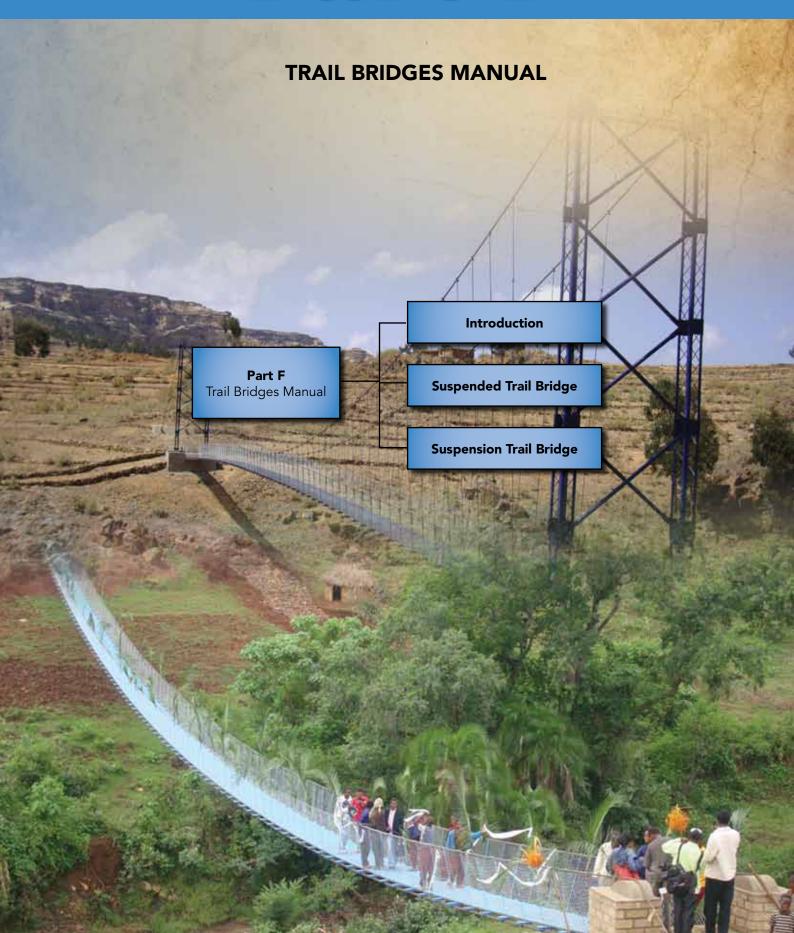




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1. INTRODUCTION

This Manual provides technical guidelines for the construction of unstiffened pedestrian suspended and suspension type cable bridges (catwalk). It applies for suspension bridges, which require higher towers or pylons on both sides of the bridge. This Manual follows the actual step-by-step processes of constructing a suspended (D-type) and suspension (N-type) bridges. It starts with preparatory work for the site assessment and survey, design and cost estimate and ends with practical guidelines for bridge construction and maintenance. The Manual is structured into three Chapters. Chapter 1 deals with the technical and social issues which are common to D-type and N-type bridges. Chapter 2 and 3 deal with details of specific technical issues of D-type and N-type bridges, respectively. All relevant specific forms are included at the last section of each chapter. The drawings and Bill of Quantity calculation sheet and specific steel and construction drawings are found in a separate folder. The drawings are done using a software called "Claris Draw" and one has to install this software in order to open the drawings.

This Manual along with the Forms and the Drawings is intended to give quick and reliable technical methods of surveying, designing and constructing simple pedestrian bridges for engineers and technologists.

Survey and bridge site selection

1.1

Careful Surveys and Bridge Site Assessments are the basis for proper planning and designing and form the main source for successful bridge construction. The main objective of the Survey and Bridge Site Assessment is to identify the proper bridge site by considering socio-economic as well as technical points of view. Survey and Bridge Site Assessment is done in the two steps:

Step 1 is Social Feasibility Survey and Step 2 is Technical Survey. Both surveys are of equal importance. The social feasibility survey establishes community ownership and responsibility, and the technical survey ensures that bridge construction is sound and safe.

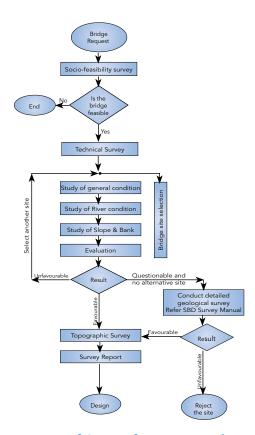


Figure F.1.1: Process of Survey for D-type and N-type Bridges

Step 1: Social Feasibility Survey

A Social Feasibility Survey is necessary to justify the construction of a requested bridge. For ranking and prioritizing the vast number of requests, the socio-economic indicators which have utmost importance are:

- Level of local participation;
- Size of area of influence;
- Size of traffic flow;
- Socio-economic benefits produced by the proposed bridge.

The first step for conducting a social feasibility survey is to introduce the participants, the survey team and other groups who will be involved in the process of bridge construction. This is best done in the form of a mass meeting right at the spot, or nearby the place, where the bridge is going to be built. Agenda of the mass meeting should consist of:

- Verification of the proposed bridge site with official documentation together with the community;
- Explanation of the bridge building process and the role of the community:
 - Phase I: collection of local materials (sand, gravel, stones and boulders), dressing of stones and excavation work.
 - Phase II: carrying (portering) of construction materials from the nearest road head to the site
 - Phase III: masonry and concrete work, cable pulling and fitting
- Explanation of the self-help nature of the project
- Evaluation and explanation of the bridge location regarding technical limitations and requirements, costs and situation of local traffic
- Assessment of capacity of the partners, funds & technical support from outside

One of the major indicators reflecting the real need of the bridge is the degree of participation and the commitment demonstrated by the local community or beneficiaries in the construction of the requested bridge. These indicators are assessed and measured from different points of view depending on the need and purpose of the bridge. However a Social Feasibility Survey is not included in this Manual.

Step 2: Technical Survey

The technical survey includes: Bridge site selection and Topographic Survey of the selected bridge site

1.2 Preparation for survey

Preparatory works to be completed before going to the field for the survey:

- Collect maps with tentative location of the bridge and any available background information.
- Collect the survey equipment.

Materials required along with the survey equipment are:

For Survey by Abney Level	For Survey by Theodolite		
 Abney Level, Survey Form & Checklist Measuring Tape (50 or 100m and 3m) Red Enamel Paint and Paint Brush Marker Pen, Scale and A3 Graph Paper Camera and Film Roll Hammer Ranging Rod (prepared at site) 	 Theodolite, Tripod & Staff Measuring Tape (50m and 3m) Red Enamel Paint and Paint Brush Marker Pen, Scale and A3 Graph Paper Camera and Film Roll Hammer Survey Form and Checklist 		
 Calculator, Note Book & Pencil 	 Calculator, Note Book & Pencil 		
 Nylon Rope (min. 50m) Masons Thread 	 Thread and Plumb Bob 		

1.3 General data collection

General data is required for needs assessment and construction planning of the proposed bridge. The general data and information shall include:

- Location of bridge site
- Availability of local materials
- Temporary crossing
- Transportation distance
- Traffic volume
- Local participation
- Nature of crossing and fordability
- Availability of local bridge builders

1.3.1 Location of bridge site

Describe the location of the bridge site:

	Left Bank	Right Bank
Region		
Woreda		
Village		

Draw a bridge site location map covering the proposed bridge's area of influence. The map should contain information on:

- River system with names and river flow direction;
- Location of proposed bridge and traditional crossing point;
- Location of the nearest bridge (approximate walking distance from the proposed bridge site);
- Existing trail system and, if required, specify length of new trail for access to the proposed bridge;
- Location of the villages, health posts, schools and other important places with approximate distances to the bridge site.

1.3.2 Nature of crossing and fordability

Examination of the present crossing situation is necessary to determine the need and the priority of the requested bridge. Assess period of time the river cannot be crossed in one year.

- a. Whole year
- b. Some months per year only
- c. Some days during high flood only

Situation (a) should be given first priority for construction and least priority given to situation (c).

Study the type of crossing facility available at present and also the location of the nearest bridge. Assess whether the available crossing facility or the existing nearest bridge is sufficient for the crossing or that a new bridge is necessary.

1.3.3 Traffic volume

Traffic volume at the crossing is one of the key indicators in the need assessment of the bridge. Information should be collected by two methods. Count traffic volume at the traditional crossing point for at least <u>one day</u>. And then interview the local people to form a broader impression of the traffic volume throughout the year.

		Average Number of Traffic per Day
Contraction	Porters	
Goods Traffic	Pack Animals	
Non goods Troffic	Persons	
Non-goods Traffic	Animals	

Determine the purpose of the traffic by interviewing the persons crossing and the local people. This will indicate the importance of the crossing.

Access to	Yes	No
Schools		
Hospital / Health posts		
Markets		
Road head		
Farming		
Others (specify)		

The most important crossing is one which provides access to schools, hospital and health posts.

1.3.4 Width of walkway

The standard width of walkway in this handbook is 70 cm or 106 cm. In most cases the 70 cm walkway is sufficient. In stances of heavy traffic, mule and pack animal passage carrying bulky goods, or if the crossing is on a main trail, a 106 cm walkway is necessary.

Discuss this issue with the local people, informing them that more work, especially collection of stones, is required for the 106 cm walkway.

Recommended Width of Walkway: 70 cm		106 cm	
-------------------------------------	--	--------	--

1.3.5 Local participation

The commitment and participation of the local people in the construction of the proposed bridge will truthfully indicate the need of the bridge. The stronger the commitment and participation, the higher is the need of the bridge.

Compute the tentative preliminary number of mandays as:

- Mandays for skilled Labor: = 1.3 x span [m] + 400
- Mandays for unskilled Labor: = 5 x Span [m] + 1300

Assess the availability of local participation for bridge building from within the concerned local community.

By Whom	Type of Participation
Local Community	
Woreda	
Zone	
Kebele	
Individual	
Others (specify)	

1.3.6 Transportation distance

Information on the transportation distance from nearest road head to the site is required for planning the construction of the bridge.

Town of Transmort	Name of nearest road	Distance from site up to road head		
Type of Transport	head.	km	Porter days	Mule, days
Served by Truck				
Served by Tractor				
Other				

1.3.7 Availability of local materials

Assess the availability of local materials needed for the bridge construction. Identify the nearest collection place for these materials.

Description	Moving distance, km	Remarks
Stones		
Natural Gravel		
Sand		
Wood		
Other		

1.3.8 Availability of local bridge builders

In the villages nearby there may be local construction personnel or bridge builders who have already built some structures or bridges. Their skill can be used in construction of the proposed bridge. If such people are available, record their names.

Names	Skill (Mason, Bridge Fitter)	Village / Address

1.3.9 Temporary crossing

Is a temporary crossing necessary			
during the construction of the bridge?	Yes	No	
If yes, what kind of temporary			
crossing do you propose?	Ferry	Other	
	Tempor	ary Bridge, Span	mt

1.4 Bridge site selection

The main purpose of the technical field survey is to select the appropriate bridge site. The site should optimally serve the local people. The selected site must be economically justified and have along life span:

- Fulfill the general condition;
- Have stable bank and slope conditions;
- Have favourable river conditions;
- Have shortest possible span.

1.4.1 General condition

The bridge site should fulfill a number of general conditions:

- Traditional crossing point;
- Minimum free board;
- Maximum bridge span;
- Space for the bridge foundations.

Use this checklist to evaluate the general condition:

Features	Condition
Traditional Crossing Point The bridge site should be selected at or near to the traditional crossing point. Traditional Crossing Point For minor river detour from the traditional crossing point is not acceptable. For major rivers, detour up to 500m up stream and 500m down stream from the traditional crossing point may be acceptable.	Favourable: Selected site is at or nearby the traditional crossing point Unfavourable: Selected site is far from the traditional crossing point
Bridge Span The bridge span in this standard is limited to 120 m span. Max Bridge Span 120 m Provided the span of the span o	Favourable: span, ℓ is equal or shorter than 120 m Unfavourable: span, ℓ is longer than 120 m

Condition Features Level Difference between two Banks The level difference **h** between the two foundation blocks should not be more than $\ell/25$. Bridge Span (1) Favourable: **h** is equal or less than $\ell/25$ **Unfavourable: h** is bigger than $\ell/25$ Locate the tentative position of the bridge foundations at both Measure the level difference h between the foundations of two Compare with the condition. **Space for Foundation** Foundation should be placed at least 3m behind the soil slope and 1.5m behind the rock slope from the front edge of the riverbank. Favourable: Condition can be fulfilled **Unfavourable:** Condition can not be fulfilled Rock Soil Measure tentative span Compare with the limit **Slope Profile** The bridge foundation should be placed behind the line of the angle of internal friction. (Angle of internal friction is the angle of slope of soil or rock at which it is still stable and does not slide). Favourable: Condition can be fulfilled **Unfavourable:** Condition can not be fulfilled Rock Soil 60° Draw a slope line of 35° (angle of internal friction) in case of a Soil slope and 60° in case of a Rock slope. Foundation should be placed behind this line. Check if these conditions can be fulfilled

Features	Con	dition
Free Board The Freeboard between the lowest point of the bridge and the highest flood level should not be less than 5m. For this, sufficient clearance between the lower foundation saddle and HFL should be maintained.		
	Favourable	Unfavourable
Freeboard min. 5 m		ldle and HFL is:
"Ulmants"	not less than:	less than:
span up to 50m 51 - 70m	7.5m 8.0m	7.5 m 8.0 m
71 - 90m		9.0 m
91 - 110m		10.0 m
110 - 120m	11.0m	11.0 m
 Identify HFL by local observation and villagers' information. Calculate available clearance and compare with the requirement. 		
Exception: At flat or wide river banks free board may be reduced.		
At gorges free board may have to be increased.		

1.4.2 RIVER CONDITION

The selected bridge site must have favourable river conditions. Accordingly, a bridge should be located:

- On a straight reach of the river;
- Beyond the disturbing influence of larger tributaries;
- On well defined banks.

Use this checklist to evaluate the river condition:

Features	Condition
River Flow In order to protect the bridge from sudden over-flooding and strong erosion, the bridge site should not be located near the confluence area of two rivers. Right Wrong Right	Favourable: Bridge site far from river confluences Unfavourable: Bridge site near river confluences

Features	Condition
River Bed The river bed at the selected bridge site should be stable without the possibility of erosion or filling up with bed load (boulders, gravel, silt, or sand)	Favourable: River bed is not erosive, not filling up Unfavourable: River bed is erosive or filling up

1.4.3 Slope and bank condition

A bridge should be located at a site with safe and stable slope and bank conditions. The surveyor must identify any potential instability features or failure modes of the soil or rock slope and along the bank.

If the slope and bank is soil, potential instability features and failure modes are:

- Bank erosion;
- Toppling instability of the bank;
- Erosion of the slope;
- Land slide.

If the slope and bank is rock, potential instability features and failure modes are:

- Plain failures in a rock slide along the slope.
- Wedge failure leading to the fall of rock mass.
- Toppling leading to the fall of rock blocks.
- Rotational slide is similar to the landslide in a soil slope. Such failure is likely when the material of the rock is very weak (soft rock) and the rock mass is heavily jointed and broken into small pieces.

To avoid the above instability features, use this checklist to evaluate the slope and bank of the selected site:

	Features		Condition
If the River Bank of Bank Profile The bank profile sh	•		
			Favourable: Bank profile is smooth to partially cut out Unfavourable: Bank profile is strongly cut out
Smooth	Partially cut out	Strongly cut out	
	ur puld be located at the stra rom undercutting or bank		Favourable: River contour is straight or convex Unfavourable: River contour is concave
Straight	Convex	Concave	

Features	Condition
Bank Erosion The River bank should not show any sign of erosion.	Favourable: No sign of fresh erosion
	Unfavourable: Presence of fresh erosion
Slope Profile The slope profile should be smooth.	Favourable: Slope profile is smooth to partially cut out
Smooth Partially cut out Strongly cut out	Unfavourable: Slope profile is strongly cut out
Transverse Slope The transverse slope should be smooth. Transverse slope strongly cut out	Favourable: Transverse slope is smooth to partially cut out
Smooth Partially cut out Strongly cut out	Unfavourable: Transverse slope is strongly cut out
Estimate the slope inclination and compare it with the condition. If the site has an unfavourable slope inclination, it can still be selected provided the general condition of slope profile is fulfilled.	Favourable: Slope inclination is equal or smaller than 35° Unfavourable: Slope inclination is bigger than 35°
River Undercutting The bridge site should be free from river undercutting which may lead to landslide.	Favourable: There is no river undercutting Unfavourable: River undercutting is active or there is potential for river undercutting
Inclined Trees The selected site should not have inclined trees, which indicate an active landslide.	Favourable: Inclined trees are not present
	Unfavourable: Inclined trees are present

Features Features	Condition
Seepage or Swampy Area The bank slope should not have any seepage or swampy area, which may lead to slope instability.	Favourable: No seepage or swampy area is absent
	Unfavourable: Seepage or swampy area is present
Gully Erosion No signs of gully erosion should exist within the vicinity of the selected site.	Favourable: No sign of gully erosion or only light gully erosion
 Observe if any rivulets are within the vicinity of the selected site. If rivulet exists, examine the dimension of the gully cutting. 	Unfavourable: Heavy gully erosion exist
The bridge should not be located on already slipped soil masses. Slope with slipped soil mass back scar	Favourable: There are no back scars or signs of soil mass movement Unfavourable: There are back scars or signs of soil mass movement

Features Condition If the River Bank is ROCK **Favourable:** Plain failure will not take place, **Plain Failure** Plain failures lead to the slide of rock layers along the slope. The rock bank/slope of the selected site should not have any feature of Bedding/fracture plain is plain failure. sub-parallel to opposite to the slope; Bedding plain is **parallel to the slope** and plain failure is active. Bedding/fracture plain is Site is extremely unfavourable! parallel to the slope, but inclination is less than 35°. Side elevation Side elevation **Unfavourable:** Plain failure will take place, if: Bedding/fracture plain is parallel to the slope and Opposite to Sub parallel to Bedding fracture the slope inclination is greater than the slope Plane parallel to 35° the slope Presence of old slided rocks Plain Failure Model Direction of movement ----- Bedding / Fracture Plane Slip Plane Identify bedding/fracture plain (layers of rock) Check its direction and inclination Compare with the condition

Condition Features Wedge Failure Any form of wedge failure leads to sliding of rock masses. The rock bank/slope should not have wedge failures or potential wedge failures. Favourable: Traces of wedge failure Wedge failure will not take Direction of movement place, if ·---- Fracture Plane There are no fracture plains Line of intersection Slip Plane facing each other Plane 2 There are two or more Plane 1 Wedge intersecting fracture plains but the inclination of its line of intersection is less than 35° There are two or more intersecting fracture plains Wedge Failure Model but the inclination of its line of intersection is opposite to the slope Line of intersection **Unfavourable:** Wedge failure will take place, if There are two or more intersecting fracture plains Slope face and the inclination of its intersection line is more than 35° to the slope Presence of old slided Wedge Failure wedge Identify if there are fracture plains facing each other (intersecting) Check the inclination of the intersection line Compare with the condition

Features	Condition
Topling Failure Potential toppling failure Topling Failure model Identify if there is formation of vertically elongated rock blocks (cubes) due to vertical and horizontal fracture planes/joints; Estimate inclination and orientation of the rock block and compare with the conditions.	Favourable: Toppling will not take place, if The Rock slope is less than 60°; There is no formation of rock blocks; There is a formation of rock block but b/h (width of the block/height of the block) is bigger than 1. Unfavourable: Toppling will take place, if There is a formation of vertically elongated rock blocks in a steep slope bigger than 60° and the blocks are tilted towards the slope; Old toppled rock blocks are present.
Translational Failure (Slide) The rock slope should not have any potential of rotational failure. Translational failure (sliding) of soft rock slope back scar failure (slide) model Identify type of rock and its weathering grade; Estimate inclination of the slope; Compare with the conditions.	Favourable: Sliding will not take place, if the Slope is hard rock; Slope is soft rock but not weathered; Slope is soft rock and weathered but not steeper than 40°. Unfavourable: Sliding will take place, if The slope is highly weathered soft rock and steep than 40°; Back scars or old slide are present.

1.4.4 Evaluation of the bridge site

After completing investigation of the site, categories the bridge site as:

Good All or most of the features are favourable and if the surveyor is confident about the

stability of the slopes. Proceed with further survey work.

Bad Most of the features are unfavourable. Reject site.

Questionable

Most of the features are favourable and some are unfavourable. The site is questionable. In this case, further detailed investigation by an experienced geo-technical engineer is necessary.

As far as possible, the bridge site should be selected at a location where protection works will not be required. If protection works are unavoidable determine the required special structures like retaining wall, drainage channels, etc. A tentative design with dimensions and location of these structures should be illustrated in a sketch showing a plan view and a typical section. But it is best to **avoid bridge sites, which require river protection works.**

1.4.5 Classification of soil and rock

Identification of Soil and Rock types is required for appropriate foundation design.

Table F.1.1: Soil classification

Soil Type			Sc				
		How to Identify	Bearing Capacity [kN/m²],	Angle of Internal Friction, φ°	Unit Weight, g [kN/m³]	Applicable Foundation Design	
Coarse Grained Soils More than half of the materials are of individual grains visible to the naked eye (grain size bigger than 0.06 mm)	Gravelly Soils	Estimate the percentage (%) of coarse grains larger than 6 mm. If, more than half of the coarse fraction is smaller than 0.06 mm grain size, the soil is Sandy Soil	400-600 (400)	32-38 (35)	19		
	Sandy Soils	If, more than half of the coarse fraction is larger than 6 mm, the soil is Gravelly Soil	200-300 (200)	31-37 (33)	18	Ancho	
Fine Grained Soils More than half of the materials are individual grains not visible to the naked eye (grain size smaller than 0.06mm)	Silty Soils	Prepare moist soil ball from the soil sample and cut it with a knife. If, the cut surface is dull or scratched, the soil is Silty Soil	50-200 (150)	30-32 (30)	17	Deadman Anchor	
	Clay	Prepare moist soil ball from the soil sample and cut it with a knife. If, the cut surface is smooth and shiny, the soil is Clay.	100-200 (100)	9-25 (22)	16		

For estimating the percentage (%) of coarse grains use Figure F.1.2.

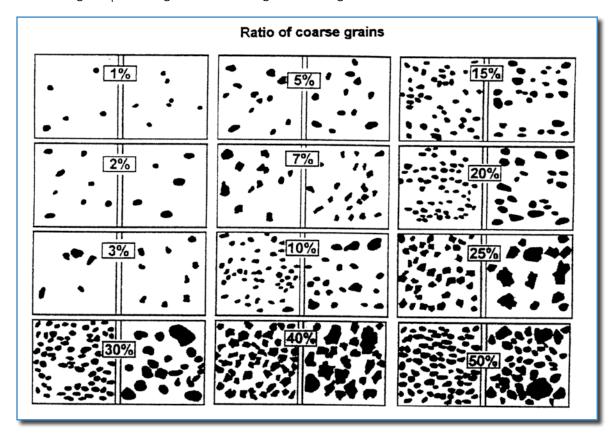


Figure F.1.2: Ratio of coarse grains

Table F.1.2 Rock Classification

					Rock Par		
Rock Type	Examples	les How to Identify Degree of Fractures or Weathering	How to Identify	Bearing Capacity [kN/m²],	Angle of Internal Friction, φ°	Applicable Foundation Design	
rd Rock	Quartzite Limestone Granite, Dolomite etc.	Gives metallic sound after	Rock is sound and fresh to fairly weathered	Rock has no sign of weathering or only faint signs of weathering up to 1-5 cm thickness	1500- 2000 (1500)	35-50 (40)	Drum Anchor in Hard Rock
Har		hammer blow	Highly fractured rock and fresh to fairly weathered	In the rock exists widely open cracks, fractures and bedding	1500	35-50 (40)	Drum Anchor in Fractured Rock
		Gives	Fresh	No sign of weathering	1300	25-40 (30)	Drum Anchor in Fractured Rock
Soft Rock	Phylite Slate Siltstone Claystone Schist etc.	dull sound after hammer blow	Fairly to highly weathered	Most of the original rock has been seriously altered Rock can be broken by hand	600-750 (650)	25-40 (30)	Deadman Anchor

1.4.6 Identification of soil and rock

Excavate a test pit with a depth of up to the estimated foundation level (but not less than 2.0m) or up to the bedrock at the proposed foundation locations. If the bank/slope is soil, investigate each layer of soil in the pit and classify the soil according to the Soil Classification chart, filling in the soil investigation table.

Example for Soil

Location: Main Anchorage Foundation at Right Bank

	Depth		Soil Pa		
Sketch	from Surface, [m]	Soil Type	Bearing Capacity [kN/m²],	Angle of Internal Friction, φ°	Remarks
//////////////////////////////////////	0.0	Top soil			
	0.3	Sandy Soil			
2000	1.1	Gravelly Soil	400	35	Foundation Design Parameter

If the bank/slope is rock, investigate the rock type according to the Rock Classification chart, filling in the rock investigation table as per the example.

Example for Rock

Location: Main Anchorage Foundation at Left Bank

Rock Type	Degree of	Soil Pa	arameter	Applicable	
	Fracture/ Weathering	Bearing Capacity [kN/m²],	Angle of Internal Friction, φ°	Foundation Design	Remarks
Hard Rock	Highly fractured and fairly weathered	1500	40	Drum anchorage foundation in fractured rock	

1.5 Topographic survey

After final selection of the bridge site, the surveyor proceeds with the topographic survey. The purpose is to:

- Provide a topographic map of the bridge site with details relevant to the bridge design;
- Establish axis pegs and bench marks for use during construction of the bridge.

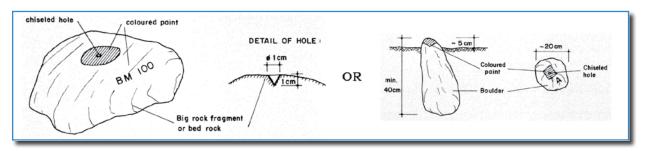
1.5.1 Survey area

Area to be covered by the topographic survey:

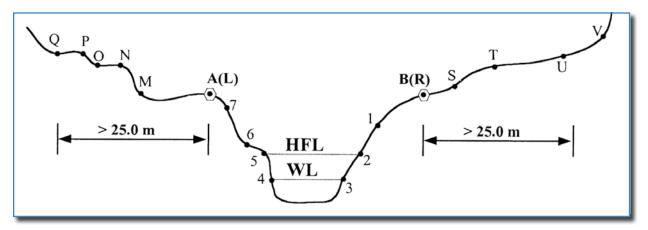
- For bridges without windguy arrangement,
 - A profile along the bridge axis covering up to 25m behind the main anchorage blocks.
- For bridges with windguy arrangement,
 - A profile along the bridge axis covering up to 25m behind the main anchorage blocks and a topographic plan covering the area of 10m upstream and 10m downstream from the tentative location of the windguy foundations.

1.5.2 Setting of bridge centerline

Fix the bridge centerline with two permanent axis points **A** on the left bank and **B** on the right bank. Permanent axis points **A** and **B** should be fixed on rock out crop along the bridge centerline, if available. If rock out crop is not available, these points should be marked on a boulder sufficiently embedded into the ground:

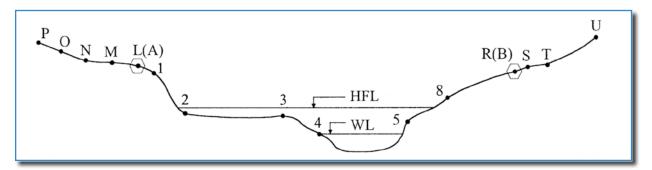


Additional survey points along the centerline should be fixed to survey the bridge axis profile. These survey points should be fixed at breaking points of slope and terraces, which will accurately indicate the topography of the bridge axis. The profile should cover 25m behind the main anchorage block up to the edge of the river flow.



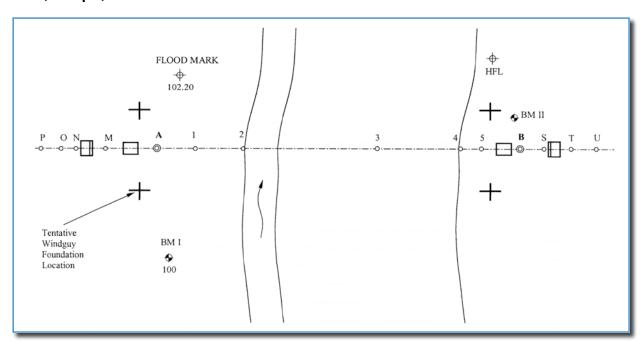
Draw a sketch of the profile/cross section of the bridge axis (centerline) with axis points A and B, with all the survey points and topographic features, including tentative position of the bridge foundations, low water level and high flood level.

Profile/Cross Section (Example)



Draw a plan view with the bridge axis (centerline), axis points A and B, with all the benchmarks and fixed objects like trees, houses etc. Give distances and directions from the reference points so that the axis points and benchmarks can be located during the construction. A plan view is necessary only when a windguy arrangement needs to be considered in bridge design.

Plan (Example)



1.5.3 Survey methods

There are two options for conducting the topographic survey. Depending upon the span and type of bridge, a profile along the bridge axis or a more detailed survey including contour lines will be necessary. In general Windguy Arrangement is not required for bridges with span up to 120m.

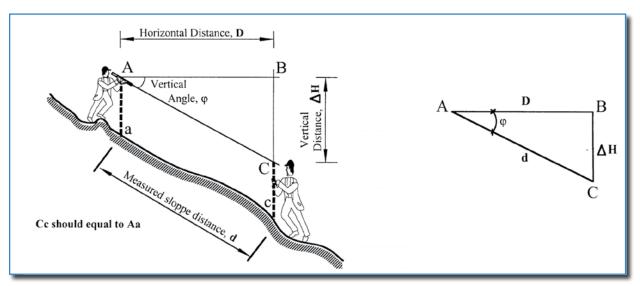
- A detailed **profile** along the selected bridge axis is sufficient for bridges without windguy arrangement. A topographic profile can be made by the Abney level, however for fixing precise levels a Level Instrument is necessary.
- For bridges requiring a windguy arrangement a more detailed topographic survey is necessary, from which a detailed contour plan can be plotted. This type of survey should be done by a Theodolite.

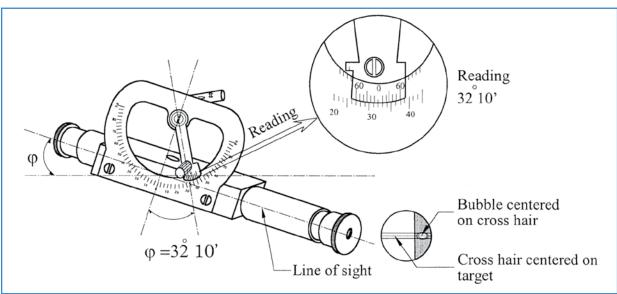
1.5.4 Survey by abney level

The main function of the Abney Level is to measure the **vertical angle** ϕ . By measuring the slope distance d between the survey points with a measuring tape, the horizontal distance **D** and the vertical difference of elevation $\Delta \mathbf{H}$ can be calculated.

Measurement of Vertical Angle:

Illustrations on the principal of measuring the vertical angle by the Abney Level:





The Procedure of measurement:

- The Surveyor stands at point A with the Abney level.
- The Assistant stands at the target point C with a stick (or ranging rod). The target mark at the stick, which the Surveyor sights must be at the same height above the ground as the Abney Level. For this, the height of the ranging rod should be equal to height up to Surveyor's eye level.
- The Surveyor holds the Abney Level to the eye and sights towards the target at point C, centering the cross hair against the target.
- The index arm is then adjusted until the bubble is centered against the target and cross hair.
- When the bubble is centered horizontally and the cross hair is aligned with the target, read the vertical angle on the arc.

Measurement of Slope Distance d:

The slope distance d between the survey points is measured with a measuring tape. Distances larger than 30m should be divided into sub-distances. The total distance can then be calculated by adding the sub-distances. Slope distances should be measured twice and the mean value should be taken as the accurate slope distance.

Calculation of Horizontal and Vertical Distance and Elevations of Survey Points:

Horizontal distance **D** between **a** and **c** $D = d \times cos \phi$ Vertical distance ΔH between a and c $\Delta H = d \times sin \phi$

Elevation of c $H = Elevation of a \pm \Delta H$

Add $+\Delta H$, if sighting is upward and subtract $-\Delta H$, if sighting is downward.

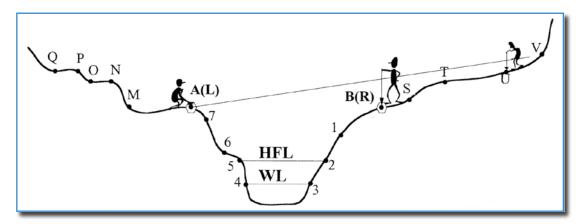
 \mathbf{d} = slope distance from \mathbf{a} to \mathbf{c} $\mathbf{\phi}$ = vertical angle from \mathbf{a} to \mathbf{c}

To take the profile along the bridge axis, the Surveyor should first set the exact centerline. There are two methods of setting the centerline.

By Nylon Rope and Plumb Bob:

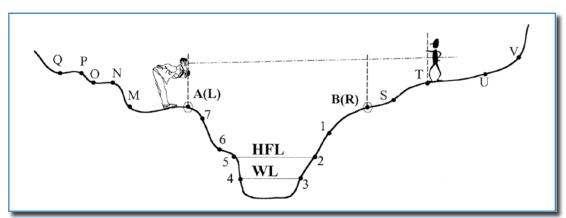
This method is accurate only for spans up to 50m. Survey points along the bridge centerline are fixed with the help of a nylon rope and plumb bob.

The Nylon rope is stretched along the axis point **A** of the left bank and **B** of the right bank. Care should be taken that the tape or nylon rope is hanging freely and does not touch any obstacles. The survey points are then fixed along this rope with the plumb:



By Bamboo or Wooden Sticks or Ranging Rods:

This method is applied for span above 50m. In this method the survey points along the bridge centerline are fixed with the help of Bamboo or Wooden Sticks or Ranging Rods. Fix Stick at each axis point **A** and **B** in **vertical** position. Now the surveyor can aim at other points along the bridge centerline line of **A** and **B**. By fixing in line additional survey points behind and in front of **A** and **B**, more points can be gained along the bridge centerline ranging:



Bridge Axis Profile:

Proceed with the survey of the bridge axis profile after having fixed the centerline.

- 1. The survey starts from the fixed permanent axis points **A** or **B** and proceeds to other survey points **M**, **N**, **O**, **P**, **1**, **3**, **4**, **5** or **S**, **T**, **U**, **V**, **4**, **5**, **6** (refer example sketch of bridge axis profile)
- 2. Measure the vertical angles and slope distances between these survey points of the centerline. It is important that the sighted target is on the same height above the ground as the Abney Level while taking the readings
- 3. Measure all points **M**, **N**, **O**, **P**, **1**, **2**, **3** starting from the permanent axis point **A**, as described in the second step above
- 4. Similarly, measure all points **S, T, U, V, 3, 4, 5, 6** starting from the permanent axis point **B**
- 5. Measure vertical angles from **A** to **B** and **B** to **A** to check the accuracy in vertical angle readings

Before calculating the horizontal and vertical distances, it is necessary to determine the accuracy of the measurement of the vertical angles. This can be done by comparing the measured vertical angle from **A** to **B** with the vertical angle from **B** to **A**. Both angle readings should be equal. Differences in these readings indicate an error in the angle measurements and needs correction.

The error factor 'E' is calculated with the formula:

Example: Error Correction of Measured Vertical Angles

$$E = \frac{[\phi AB] - [\phi BA]}{2};$$
 Corrected angle $\phi' = \phi AB \pm E$ or $\phi' = \phi BA \pm E$

```
measured vertical angle from A to B \phiAB = 0°50′ (Downhill sighted) measured vertical angle from B to A \phiBA = 1°30′ (Uphill sighted) error factor E = (1°30′ - 0°50′)/2 = 0°20′ corrected angle \phi'AB = 0°50′ + 20′ = 1°10′ corrected angle \phi'BA = 1°30′ - 20′ = 1°10′
```

All measured vertical angles should be corrected as:

Corrected angle $\phi' = [\phi] + E$ for downhill sighted (-) angles Corrected angle $\phi' = [\phi] - E$ for uphill sighted (+)angles

Compute the horizontal distances and elevations of the corresponding survey points with the corrected vertical angles as per the example.

Example: Calculation of Horizontal Distance D and Elevation H of Survey Points:

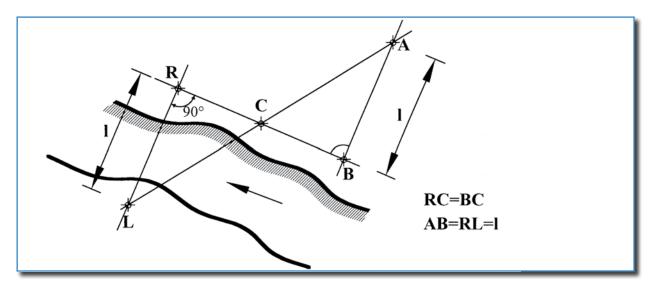
```
Elevation of
                                                          = 100.00 \, \text{m}
measured vertical angle from
                                                φΑΜ
                                   A to M,
                                                          = +7^{\circ}0' (upward sighting)
corrected vertical angle from
                                   A to M
                                                φ'AM
                                                          = +7^{\circ}0' - 0^{\circ}20' = +6^{\circ}40'
                                   A to M
measured slope distance
                                                          = 13.35 \, \mathrm{m}
                                                d
horizontal distance between
                                   A and M
                                                D
                                                          = d \times cos \phi' = 13.35 \times cos 6^{\circ}40' = 13.26m
vertical distance between
                                                          = d \times \sin \phi' = 13.35 \times \sin 6^{\circ}40' = +1.55m
                                   A and M
                                                ΔΗ
Elevation of
                                                          = Elevation of 'A' + \DeltaH
                                    M
                                                Н
                                                                                                 = 100.0 + 1.55
                                                                                                 = 101.55m
```

Enter the measurements and calculations into the **Abney Level** survey sheet.

Measuring the River Width:

In certain cases, it might not be possible to directly measure the river width from one bank to another bank by tape. In such a situation, the river width should be measured by indirect method as described in the example.

How much is the width of the river I = Distance from **L** to **R**?

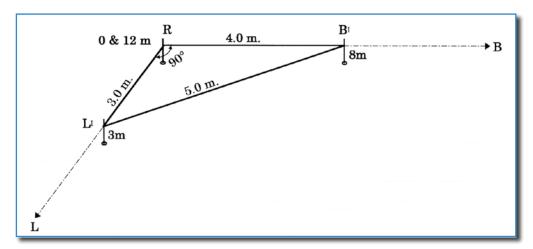


The procedure of the measurement is as follows:

- Set a base line **R B** perpendicular to the line **L R** along the river. This can be done easily by 3-4-5 method (refer **Setting of a Right Angle**).
- On this base line **R B**, mark the mid point **C** so that **RC** is equal to **CB**.
- Set again a base line **B A** perpendicular to the line **R B** similarly to step1.
- Mark exactly point A by ranging through point L C, so that all these three points lie in the same line of sight.
- Measure length $\mathbf{B} \mathbf{A}$. This length will be equivalent to the river width $\mathbf{L} \mathbf{R} = \mathbf{I}$.

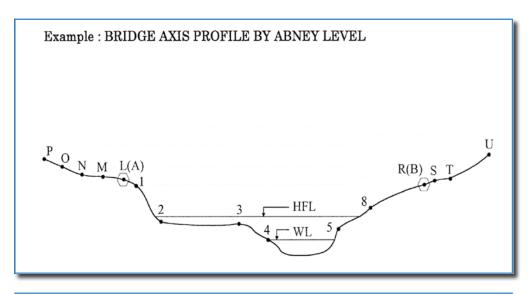
Setting of a right angle:

One simple method to set a right angle from a point of a base line is the 3-4-5 method. One measuring tape and 3 wooden pegs are needed.



The procedure of the measurement is as follows

- The first person should hold '0' and '12'm mark of the measuring tape at point R.
- The second person holds the tape at the 3m mark, and a third person at the 8m mark of the tape. Stretch all these sides of the tape. A right angle triangle will be formed with sides of 3, 4, and 5m.
- Line $\mathbf{R} \mathbf{B'}$ is now perpendicular to the line $\mathbf{R} \mathbf{L'}$.



Bridge Na	ame : Tol	kre Ghat	District : 1	Nawalparas	i	Surv	eyed by	: Chuda Mani	Date: 27.11.2055
STATION	POINTS	SLOPE DISTANCE d m	VERTICAL ANGLE [Observed]	VERTICAL ANGLE [Corrected]	HORIZONTAL DISTANCE D m	DISTANCE DISTANCE		REDUCED LEVEL (ELEVATION) H m	REMARKS (Description of Points)
A	В		-0°50'	-1°10'		_			Observation for vertical
В	A		+1°30'	+1°10'					angle error correction
A								100.00	Datum Level (Assumed)
	M	3.35		+7°0'	3.32	+	0.40		
	N	8.00		+6°0'	7.95	+	0.84	100.84	
	0	13.00		+10°40'	12.77	+	2.40		
	P	17.25	+13°0'	+12°40'	16.83	+	3.78		
	1	4.20	-23°40'	-24°0'	3.84	-	1.70		
	3	27.50	-18°40'	-19°0'	26.00	-	8.95	91.05	HFL= El ₃ +1.0m
	4	34.90	-19°40'	-20°0'	32.80		11.94	88.06	
	5	47.30	-15°10'	-15°30'	45.58		12.64	87.36	Water Level (WL)
В								98.67	
	3		-10°10′	-10°30'	41.10		7.62	91.05	
	8	12.40		-20°0'	11.65	-	4.24	94.43	
	S	2.80	+19°30'	+19°10'	2.64	+	0.92	99.59	
	T	5.45	+14°40'	+14°20'	5.28	+	1.35	100.02	
	U	15.20	+23°30'	+23°10'	13.97	+	5.98	104.65	
3								91.05	
	2	17.00	+1°50'	+1°30'	17.00	+	0.44	91.49	
	В	41.80	+10°50'	+10°30'	41.10	+	7.62	98.67	

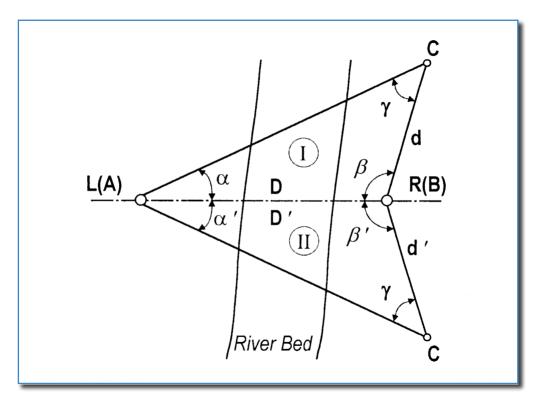
1.5.5 Survey by Theodolite

When the span of the bridge is more than 120m or when a windguy arrangement needs to be included in the bridge design, the survey is conducted with a theodolite.

For proper use of a theodolite, refer to the respective instruction manual that comes with the theodolite.

Profile along bridge axis:

Fix the bridge centerline. Measure the distance between the axis points A and B by horizontal triangulation method. Triangulation is done by measuring all three angles of a triangle and length of one side.



For accuracy double triangulation is necessary. The procedure is:

Ist Triangulation

- 1. Set out a peg at **C** in such a way that the distance **B C** can be easily measured. The length 'd' should be at least 20% of the distance **A B**
- 2. Measure distance $\mathbf{B} \mathbf{C} = \mathbf{d}$ accurately with a measuring tape. Measure this distance several times and calculate the mean distance.
- 3. Set up theodolite at **B** and measure the horizontal angle \angle **ABC** = β from face left and face right
- 4. Set up theodolite at **C** and measure the horizontal angle \angle **ACB** = γ from face left and face right
- 5. Set up theodolite at **A** and measure the horizontal angle \angle **BAC** = α from face left and face right
- 6. Sum up these angles ($\delta = \beta + \gamma + \alpha$), which should be theoretically equal to 180° or 200g. If, the sum is not equal to 180° or 200g, the difference Δ should be equally distributed to all the three angles so that the sum becomes 180° or 200g
- 7. Calculate distance $\mathbf{A} \mathbf{B} = \mathbf{D}$ with the trigonometric formula,

$$\mathbf{D} = \frac{d \times \sin \gamma}{\sin \beta}$$

IInd Triangulation

- 1. Repeat the same procedure as above and calculate distance **A B = D'**
- 2. Calculate final distance

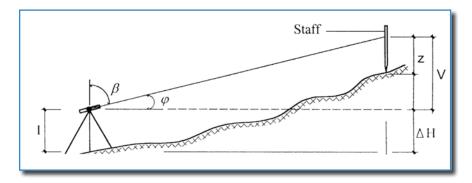
$$\mathbf{D} = \frac{\mathsf{D} + \mathsf{D}'}{2}$$

Use the standard form "Triangulation" for recording the readings and calculation.

	Surveyed by: $\mathcal{L} \cdot \wedge \lambda \cdot 7\pi i \rho_a h_i$ Date: $harck 1997$ 2nd Triangulation Sketch:	If $\delta > \pm~0.02^8$ or 0.018^0 repeat the angle readings
Example: TRIANGULATION	Bridge Name: Kolimora District: Achham Sketch:	If $\delta > \pm~0.02^8$ or 0.018° repeat the angle readings

Elevation of Axis Points and Benchmarks:

It is necessary to establish the elevations of the Axis Points A and B and Benchmarks. This is done by vertical triangulation indicated in this manual.



The procedure is as follows:

- 1. Select a first Bench Mark BM I on a rock or big boulder near to the axis point A and fix it as 100.00m
- 2. Select bench mark **BM II** near to the axis point **B**
- 3. Measure the **horizontal** distance **D** from **A** to **BM I** accurately with a tape
- 4. Measure the horizontal distance D from B to BM II accurately with a tape
- 5. Take the distance **D** between axis points **A** and **B** from the triangulation
- 6. Set up the theodolite at the axis point **A** and measure the vertical angle to axis point **B** and the vertical angle to **BM I**. Take the middle hair reading **Z** and measure the instrument height **I**.
- 7. Set up the theodolite at the axis point **B** and measure the vertical angle to axis point **A** and the vertical angle to **BM II**. Take the middle hair reading **Z** and measure the instrument height **I**.
- 8. Set up the theodolite at **BM I**, measure the vertical angle to axis point **A**. Take the middle hear reading **Z**, and measure the instrument height **I**.
- 9. Set up the theodolite at **BM II**, measure the vertical angle to axis point **B**. Take the middle hair reading **Z**, and measure instrument height **I**
- 10. Calculate the s for all readings:

Vertical Distance
$$V = D \times tan \phi$$

$$V = \frac{D}{\tan \beta}$$

Elevation difference $\Delta H = V - Z + I$ for upward vertical angle reading

 $\Delta H = V + Z - I$ for downward vertical angle reading

11. Calculate Elevations of A, B, BM I and BM II, starting from BM I to A to B to BM II

Elevation of A = El. of BMI $\pm \Delta H$ Elevation of B = El. of A $\pm \Delta H$ Elevation of BM II = El. of B $\pm \Delta H$

Insert the readings and the calculations in the Survey form of "Summary of Triangulation and Elevations of Pegs and Benchmarks".

Example:

SUMMARY of TRIANGULATION and ELEVATIONS of PEGS and BENCHMARKS

1. Summary of Triangulation Bridge Name: Kalimora

District: Achham

2. Elevation

Surveyed by: L. N. Tripathi

Date: March 1997

 $\Delta H = V - Z + I$

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Topographic Detail Survey:

The topographic detail survey is necessary to represent the topography of the bridge site by means of a map (plan) with the contour lines.

The topographic detail survey uses the tachometric method. Tachometric survey is done by Theodolite with stadia hairs (having constant value of 100) and leveling staff.

Checking the Stadia Hair:

Check the stadia hair of the theodolite before doing the detail survey by tachometry. For this, measure a distance of about 40m using stadia readings and compare them with actual tape measurements. If the difference between the stadia measurement and the tape measurement is more than 0.2%, calculation of horizontal and vertical distance needs to be corrected. The distances should be corrected for error Δ as per Formula.

$$\mathbf{D} = (100l \pm \Delta) \times \cos^2 \phi \qquad \mathbf{V} = (50l \pm \Delta) \times \sin^2 \phi$$

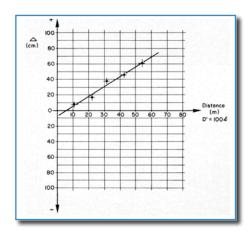
 Δ is calculated before the survey as per procedure:

- 1. Put the theodolite on horizontal ground and level it
- 2. Level the telescope of the theodolite so that the vertical angle is 0
- 3. Put pegs at approximate distances of approx. 10, 20, 30, 40 and 50m
- 4. Measure accurately the distance between the vertical axis of the theodolite and the pegs by tape
- 5. Take the stadia hair readings by theodolite at each peg
- 6. Calculate the horizontal distance to each peg by tachometric calculation
- 7. Determine the difference (error) between the tape measurement and the tachometric measurement for each peg
- 8. Plot the graph for Δ correction

Example: Δ - Corrections

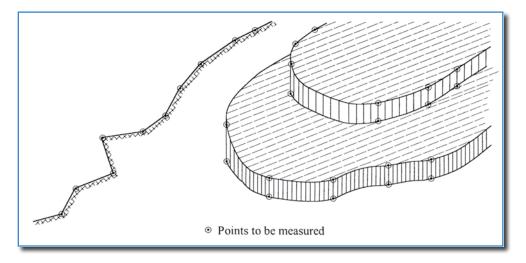
Top hair l¹ (cm)	Bottom hair I ₂ (cm)	Difference =	Distance D' = I x 100 (m)	Tape Measurement Distance, D (m)	Correction
118.70	108.30	10.40	10.40	10.48	+ 8
135.90	114.20	21.70	21.70	21.87	+ 17
140.75	109.80	30.95	30.95	31.33	+ 38
160.25	118.05	42.20	42.20	42.66	+ 46
120.20	66.45	53.75	53.75	54.36	+ 61

The graph is used for the calculation of the tacheometric error for the horizontal distances



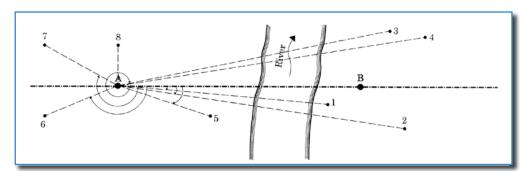
Tachometric Survey:

All topographic details are taken by the tacheometric survey. Tachometric details are mainly taken from the axis point A and B (theodolite stations). If the area of survey cannot be covered by these two points, details should be taken from other additional points. The survey points (staff points) should be taken at break points of slopes, terraces, fields and other features representing the actual topography of the ground. Survey points should also include other details such as houses, trees, foot trails, rocks, river banks, high flood level, water level at survey time etc.

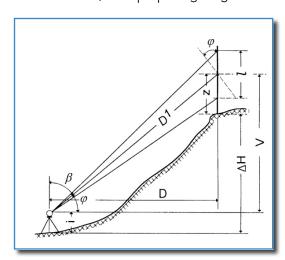


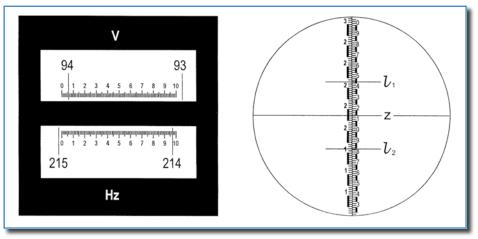
The procedure of survey is:

- 1. Set up the theodolite on the axis point A. Measure the instrument height I
- 2. Fix the 0 reading of horizontal circle along the bridge axis towards B as illustrated in the sketch



3. Take for every survey point (staff point) the readings of the horizontal circle, the vertical circle, the top hair, the middle hair and the bottom hair, after proper sighting to the respective survey points.





Vertical Angle, b = 94g 06c Horizontal Angle a = 214g 97c

Top Hair, | 1 = 2.455 Bottom Hair, | 2 = 1.844 Middle Hair, Z = 2.15

- 4. Record the readings into the "Tachometry" survey sheet.
- 5. Set up the theodolite on the axis point **B**. Measure the instrument height **I**.
- 6. Fix the zero reading of the horizontal circle along the bridge axis towards A.
- 7. Take the details, which were not covered from axis point **A**, the procedure from step 3-4.
- 8. Calculate the horizontal and vertical distances and elevations of the survey points with the help of the tachometric formulas given in the "Tachometry" survey sheet.

1.5.6 TOPOGRAPHIC MAPS

As per the field survey data, it is necessary to prepare the topographic maps in the scale 1:100 or 1:200

- Profile along the bridge axis;
- Contour plan of the bridge site in scale (only when windguy arrangement is necessary).

Profile Along the Bridge Axis:

Plot the profile along the bridge axis as per steps (refer the example in this manual):

- 1. Choose the scale of the drawing. Vertical and horizontal scale should be the same.
- 2. Choose the datum level so that the points with lowest and highest elevations are within the drawing area.
- 3. Choose the position of the axis point A so that most farest survey point of Right Bank and left bank from the axis point A are within the drawing area.
- 4. Plot the axis point B as per its elevation and horizontal distance from axis point A.
- 5. Draw the survey points of the bridge axis according to the horizontal distance and elevations as per the data from the "Bridge Axis Profile by Abney Level" survey sheet or the "Tachometry" survey sheet from axis point A. Refer also to the sketch of the bridge profile prepared during the field survey.
- 6. Similarly, draw the remaining survey points of the bridge axis from axis point B.
- 7. Join all the survey points by straight lines. This will represent the bridge axis profile.
- 8. Draw horizontal lines with the elevation of the high flood level and the water level at the time of survey.

Contour Plan of the Bridge Site:

The contour plan represents the overall topography of the bridge site by means of contour lines. A contour line is a continuous line passing through points of equal elevation.

A contour plan is necessary only when a wind guy arrangement is to be considered in the bridge design. In most of the cases of short span trail bridges, wind guy arrangement will is not necessary, and a contour plan is not required for bridge design.

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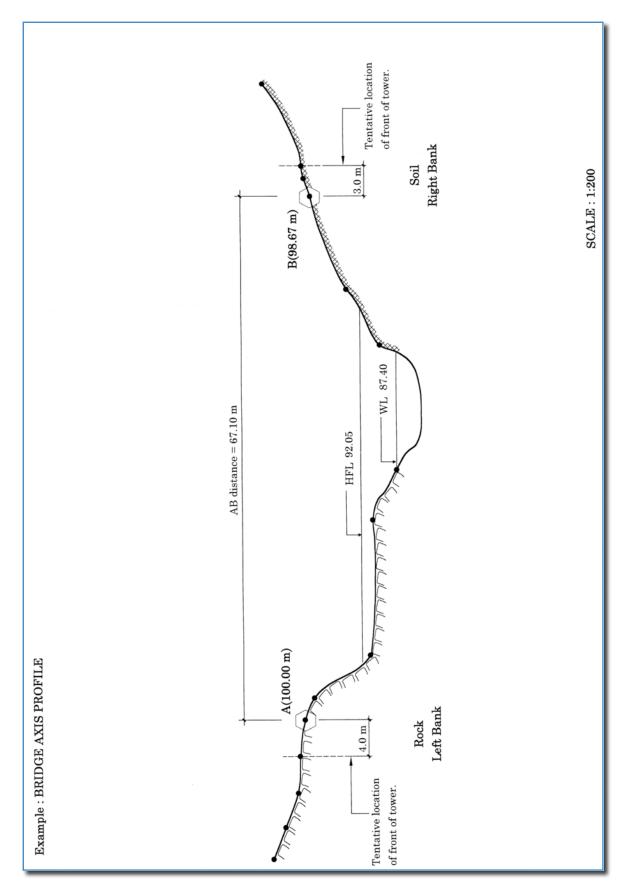


Figure F.1.3: Bridge axis profile

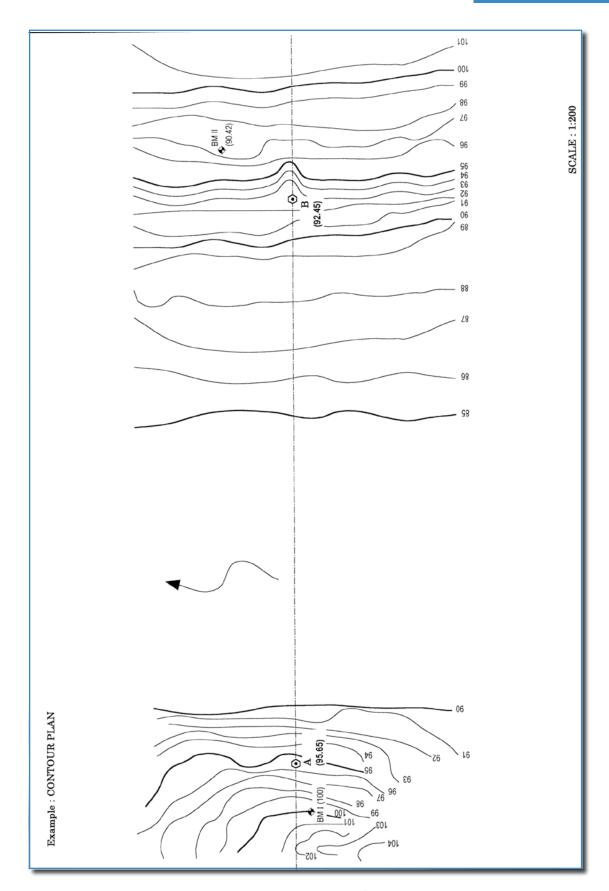


Figure F.1.4: Contour plan

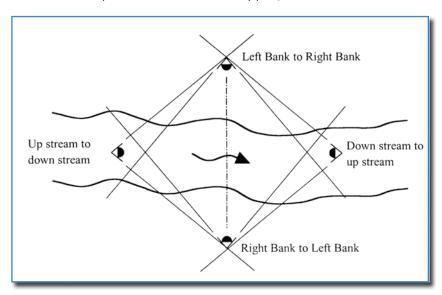
1.5.7 PHOTOGRAPHS

Photographs of the bridge site to support its technical feasibility / topography and facilitate the bridge design.

Take the photographs:

- An overall view of the bridge site from upstream indicating approximate location of bridge foundations and the axis line;
- An overall view of the bridge site from down stream indicating approximate location of bridge foundations the axis line;
- View of the right bank from left bank with an approximate location of bridge foundations
- View of the left bank from right bank with an approximate location of bridge foundations
- An overall top view (if possible)
- A close up view of the axis points and the bench marks
- A view of the soil test pits at the location of the bridge foundation blocks
- Other relevant photos

Take above photographs from the positions. If one picture does not cover the necessary area, take several pictures from the same spot with sufficient overlapping.



Present all the photographs systematically with respective captions.

1.5.8 Survey report

The technical survey report consists of:

- Filled in Survey Forms and Checklist;
- Topographic map
 - Profile along the bridge axis in scale;
 - Contour plan of the bridge site in scale (only if windguy arrangement is necessary)

1.6 Calculation of quantity and cost estimate

Calculation of quantities and cost estimate is required for the purpose of planning and implementation.

- Quantity Calculation
 - Calculate the quantities of the cables from Cable Design Form. Fill in the Quantity Calculation Sheet of Wire Rope (Cables). This sheet will show the cable lengths of each diameter and the total weight of the cables.
 - Calculate the quantities of the Steel Parts and Steel Deck from the corresponding steel drawings. Fill in the Quantity Calculation Sheet of Steel Parts and Steel Deck.

- Calculate the quantities of the Earth Works from the General Arrangement Drawing. Fill in the Quantity Calculation Sheet of Construction.
- Calculate the quantities of other construction works from the corresponding Construction Drawings. Fill in the Quantity Calculation Sheet of Construction.
- Prepare a list of construction materials according to the calculated quantities of construction works.
- Calculate the transportation weights for cables and other construction materials not available locally.
- Calculate the quantities of Works and Labor.

Rate analysis

Prepare the rate analysis for fabrication of steel parts, steel decks and road transportation (items of external support to the community) as per unit quantity, unit cost and standard norms.

Abstract of cost

Compute the abstract of cost of the bridge as per the quantities of works (from Quantity Calculation Sheets) and the rates (from Rate Analysis) for each item of works, and summarize the cost as per the category of works.

Summary of estimated cost

- **Bridge cost:** Calculate the Estimated Bridge Cost by summarizing the Abstract of Cost. Also calculate the bridge cost per m span.
- **Contribution:** Estimate the expected contribution from different partners.
- Breakdown of the contribution:

Break down the contribution as Local Contribution and Outside Contribution.

Summary of actual cost

In the majority of cases, the actual bridge cost will not be the same as estimated. Therefore, calculate the actual bridge cost after completion of the bridge.

1.7 Bridge maintenance

1.7.1 Introduction

Maintenance of trail bridges is very crucial for keeping the bridge and foot trails functional throughout the year. It is extremely essential to guarantee their permanent and safe use, maintain them in usable condition, and to preserve the investment made in these bridges. In order to determine the required maintenance, regular inspection of the bridge should be made after completion of the construction work.

The bridge maintenance work consists of the two categories:

- Routine maintenance
- Major maintenance

A brief description of these two maintenance categories is given in the sub-chapters.

1.7.2 Routine maintenance

Routine maintenance is a preventive type of maintenance and should be done regularly. It is important to protect the bridges from getting big and irreparable damages and assures long-term use by keeping them in serviceable condition. After completion of the bridge construction, routine maintenance should be carried out on regular basis. In general, the works under routine maintenance are simple in nature.

The routine maintenance work includes the important tasks:

Cleaning around the most important bridge elements

Cleaning and removing all sorts of debris, dirt, plants and bushes in and around the drainage channels, the cable anchorage terminals, the tower base, the area around foundations, the area below the bridge entrance and the bridge access trails.

Fixing and re-tightening of bridge parts

Fixing and re-tightening of walkway wire mesh, nuts and bolts, bulldog grips, etc., which are loose.

Repairing the walkway deck

Re-tightening of loose nuts and bolts of steel decks and J-Hooks.

Minor repairing of gabion boxes for bank and slope protection purposes

Inspection and checking of the slope and riverbank protection structures and execution of minor repair work.

Reporting of the bridge condition

Inspection and checking the general condition of all the bridge parts and structures and reporting to the concerned Woreda Administration and/or Rural Roads Authority and seek their necessary support in case of big landslides, bank erosion, etc., which may damage the bridge foundations and structures or even cause the collapse of the bridge.

Routine maintenance work can be carried out either by forming a Bridge Maintenance Committee (BMC) or by appointing a bridge warden. In both cases one trained person must be assigned for regularly inspecting the bridge. S/he should preferably live close to the bridge and should be equipped with some basic tools.

Primarily the concerned Users Committee are responsible for ensuring that routine maintenance is done. The Rural Roads Authority, who bears the overall responsibility, shall monitor the maintenance and shall support the Users Committees for cases beyond their capacity.

1.7.3 Major maintenance

Major maintenance (MM) work includes all works, which need proper - planning, survey, design and cost estimates. A certain level of knowledge and skill is required to execute the major maintenance of the bridges.

The major maintenance work includes the tasks:

- Replacing rotten wooden planks with galvanized steel decks;
- Replacing rotten wooden crossbeams with galvanized steel beams;
- Repairing of wind guy arrangements/system;
- Repair, adjustment or replacement of suspenders including adjustment of camber of for suspension bridges;
- Re-painting of all non-galvanized steel parts;
- Re-tensioning of all loose cables and adjusting bridge alignment;
- Coaltar treatment of all non-galvanized threads;
- River bank and slope protection works.

Major maintenance responsibilities are gradually operationalized at the district level by imparting technical know-how, methods and practices for carrying out maintenance work and providing material support. The Rural Roads Authority are becoming better prepared to implement the major maintenance and are responsible for the execution independently or with the support of the Helvetas Ethiopia Trail Bridge Section (TBS), or other concerned bridge building agencies.

2.

SUSPENDED TRAIL BRIDGE

2.1 Presentation of the suspended type

The Suspended Cable Bridge design presented in this Manual has been adapted from the successful experience of Nepal. The major structural elements are steel wire ropes, which are anchored by gravity blocks or rock anchors at either side of the river. The superstructure is completely unstiffened and thus allows "some" reasonable degree of lateral, vertical and torsional vibrations. For economic reasons the design allows a choice between two options for the width of the walkway. The 70cm walkway is mainly applicable for pedestrian traffic, whereas the 106cm walkway should be applied for crossings where pack animal traffic is also expected.

2.2 Technical features and limitations of suspended type

The Short-Span Trail Bridge Standard as presented in this manual conforms to mainly Indian Standard, but also to Swiss and German Standards, codes and norms. All its components fulfill the necessary safety factors by applying the loadings prescribed in the standard bridge design.

All the construction materials conform to international specifications. Exposed steel parts are painted or hot dip galvanized, and should not be altered unless proven to fulfill standard norms.

For practical, economical and safety reasons the span range for the Short-Span Trail Bridge Standard presented in this Manual is limited to 120m.

Longer spans are possible but would require special engineering input. As with every standard design, not all site conditions are covered with this standard. It is especially not suitable in unfavourable geological site conditions. At such sites, as mentioned above for longer spans, engineers' input is mandatory.

This type of bridge has downward sagging walkway. Sagging walkway cables are suspended below their anchorage. Cables are anchored in to the main anchorage foundation at both banks. The main components of this bridge are: Walkway cables and Handrail cables, Walkway system and Main anchorage foundations. This type of bridge is selected where the bridge foundations can be placed at sufficiently high position giving required free board from the highest flood level. Suspended type is more economic, simple to design and construct than suspension type bridge.



Figure F.2.1: Suspended type bridge, Keleta, Oromia region

Layout and sections

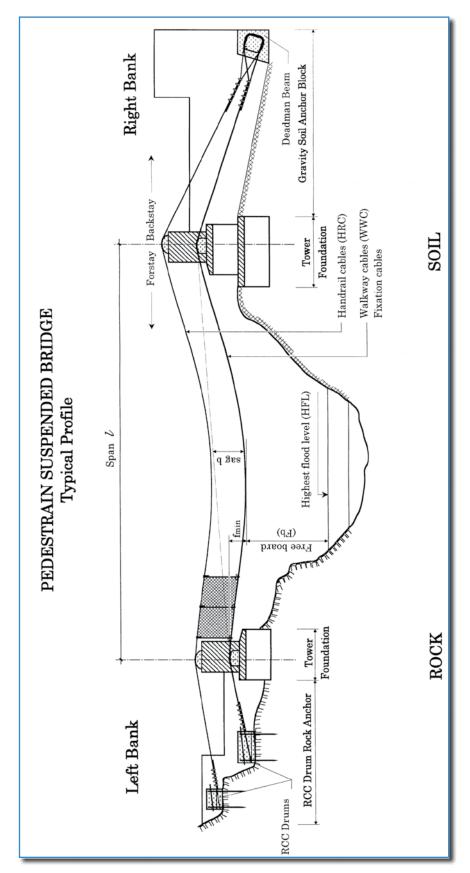


Figure F.2.2: The typical profile of Suspended type bridge

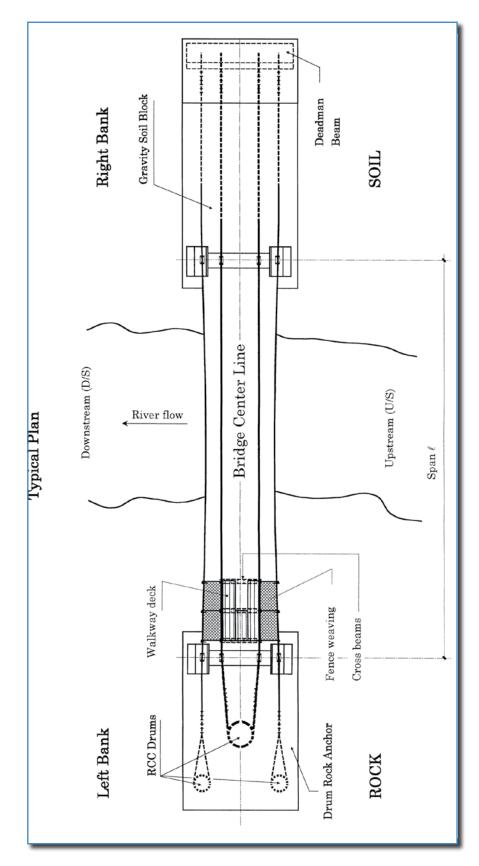
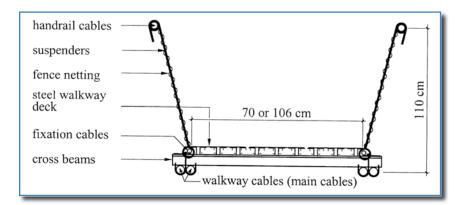


Figure F.2.3: The typical plan of Suspended type bridge

Walkway section

There are two types of walkway width: 70cm & 106cm



2.3 Basic design concept

2.3.1 Loadings

For designing a bridge structure loadings as per Long Span Trail Bridge standard is followed.

Live load

Live load for smaller span up to 50m is equivalent to 400 kg/m2 and for longer span as per formula,

P =
$$300+100 \cdot \frac{50}{l} \text{ kg/m}^2 \text{ or } 3+ \frac{50}{l} \text{ kN/m}^2$$

Dead load

Dead load includes the weight of all permanent components of the bridge structure.

Width of Walkway	34 cm	70 cm	106 cm
Dead Load (without weight of	25 kg/m or	42 kg/m or	57 kg/m or
Handrail- and Walkway Cables)	0.25 kN/m	0.41 kN/m	0.56 kN/m

Wind load

The design wind load is taken as a uniformly distributed load based on a wind speed of 160 km/h acting horizontally to the walkway. This corresponds to a wind pressure of 1.3 kN/m2 acting on the lateral bridge area of 0.3 m2 per meter span. By maintaining a wind coefficient of 1.30 (acc. to Swiss Standard) the actual lateral design wind load is 0.50 kN ($1.3 \times 1.3 \times 0.3$) per meter span. The foundation structures are sufficient to resist this design wind load.

Wind load affects also the dynamic behavior of the bridge. However, practical experience has proven that bridge-spans of up to 120 m, no significant dynamic effects due to wind load has taken place. For minimizing dynamic wind-effects on the bridge sufficient dead load, a steel deck and most favourable span to sag ratios have been introduced. Therefore, no lateral stabilizing measures (windguy system) is considered in this standard suspended bridge design. However, for special cases (spans more than 120m or extreme windy areas exceeding wind speed of 160km/h) there is a provision for fixing a windguy system.

Snow load

The probability of occurrence of a full load on a bridge loaded with snow is low. Moreover, the design live load itself is comparatively high. Therefore, it is considered that the snow load is already covered by the design live load.

Temperature effect

Loading (cable forces) according to temperature effect is negligible in comparison with other loading conditions. Therefore, temperature effect has not been considered for the standard bridge design.

Seismic load

There is low probability of a full live load occurring at the time of an earthquake. Moreover, the design live load itself is comparatively high. Therefore, it is assumed that the seismic load is already covered by the design live load. A separate loading combination with seismic load is not considered.

2.3.2 Construction materials

The construction materials used for the standard trail bridges are wire ropes (cables), steel parts, steel fixtures and fasteners (thimbles, bulldog gripes, nuts and bolts), concrete and stone masonry. Specifications of these materials are based on Indian Standard (IS). However, for frequently referred material, specifications are given for quick reference.

Steel Wire Ropes (Cables)

For more convenient stock keeping, handling and transportation only three cable diameters are applied. This also reduces the number of steelparts, logistics and eventually bridge costs.

Steel wire ropes should comply with all the requirement of:

IS 1835 – 1977 Steel wires for ropes

IS 6594 – 1977 Technical supply conditions for wire ropes and strands

IS 9282 – 1979 Specification for wire ropes and strands for suspension bridges

IS 9182 (part II) –1979 Specification for Lubricants for Wire Strands and Ropes

Nominal diameters: 13 mm 26, 32 mm

Rope Construction 7 x 7 (6/1) 7 x 19 (12/6/1)
Elongation non pre-stretched pre-stretched
Lay RHO, right hand ordinary lay
Core WRC, Wire Strand Core
Tensile strength of wire 160 kg/mm2 or 1.57 kN/mm2

Preforming Preformed

Coating Galvanized 'A' heavy

Impregnation Non-drying type and non-bituminous Lubricant

Nominal Diameter of Cable	Weig	jht	Metallic Area		nimum ng Load in	Permi load	
mm	kg/m	N/m	[mm2]	Tones	kN	Tones	kN
13	0.64	6.3	73	10.5	103	3.5	34
26	2.51	24.6	292	39.3	386	13.1	129
32	3.80	37.3	442	59.6	585	19.9	195
	Modulus o	f Elasticity	y, E = 110 kN/mn	n2 = 11 t	/ mm2		

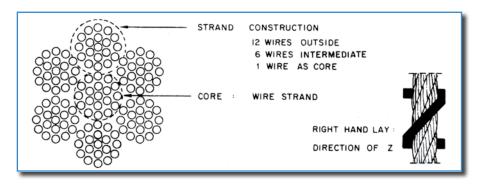


Figure F.2.4: Cross-Section & lay of Wire Rope

Bulldog Grips

Bulldog Grips are used for cable terminal to secure the cable ends.

Bulldog grips should conform to IS 2361-1970, specifications for Bulldog Grips. The bridges must be dropforged and suitably scored to grip a round strand rope of right hand lay having six strands. Bridges, U-bolt and nuts should be hot dip galvanized with minimum zinc coating of $40\mu m$. The size of the bulldog grip is equal to the size of the cable to be anchored or connected.

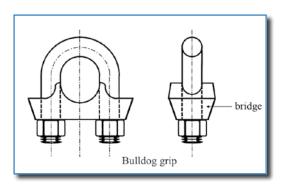


Figure F.2.5: Bulldog Grip

Structural Steel

Steel grade should be of standard quality Fe 410 and structural steel should comply with the requirement of:

IS 226 – 1975 Structural Steel

IS 800 – 1984 General Construction in Steel

The steel should have the mechanical properties:

Tensile Strength : 410 N/mm² Yield Stress : 250 N/mm² Modulus of Elasticity : 200 kN/mm²

Elongation : 23%

Fasteners

Bolts, nuts and washers should be of grade C, property class 4.6 and should comply with the requirement of:

IS 1363 - 1984 (Part 1) Hexagonal Head Bolts and Nuts

IS 1367 – 1983 Threaded Fasteners

All the fasteners should be hot dip galvanized with minimum zinc coating of 40µm.

Reinforcement Steel

Reinforcement Steel should be of steel grade Fe415, high yield deformed bars and should comply with the requirement of:

IS 1786 – 1985 High Strength Deformed Steel Bars for Concrete Reinforcement

IS 456 – 1978 Plain and Reinforced Concrete

The Reinforcement Steel should have the mechanical properties:

Yield Stress = 415 N/mm^2 Modulus of Elasticity = 210 kN/mm^2

Rust Prevention

Rust prevention of steel parts should be done by Hot Dip Galvanization according to: IS 2629 – 1966 Recommended Practice for Hot Dip Galvanization of Iron and Steel

IS 4759 – 1984 Specification for Hot-Dip Zinc Coating on Structural Steel

	Minimum Ma	ass of Coating	Minimum Thickness of
Products	g/m²	N/m²	Coating µm
Structural Steel	610	6.0	80
Threaded work, nuts and bolts	300	3.0	40

Wire Mesh Netting

Wire for wire mesh netting should comply with the requirement of:

IS 280 - 1978 Mild Steel Wire for General Engineering Purposes

IS 4826 - 1979 Hot-dipped Galvanizing Coatings on Round Steel Wire

Diameter of wire should be 12 SWG (2.64mm) and zinc coating should not be less than 270 g/m². The average tensile strength of the wire should not be less than 380N/mm².

Concrete

Concrete should comply with all the requirements of:

IS 456 – 1978 Plain and Reinforced Concrete
IS 269 – 1989 Ordinary Portland Cement

IS 383 - 1970 Coarse and Fine Aggregate

Concrete Grades used in the standard design are:

Concrete 1:3:6 (M10) for miscellaneous use

Concrete 1:2:4 (M15) for structure

Masonry

Masonry should comply with all the requirements of:

IS 1597 – 1967 Code of Practice for Construction of Stone Masonry

IS 2250 – 1981 Preparation and Use of Masonry Mortars

Stone masonry used in the standard design are:

Chisel Dressed Stone Masonry in 1:4 cement : sand mortar Hammer Dressed Stone Masonry in 1:6 cement : sand mortar Dry Stone Masonry.

Unit Weight of Construction Materials

The unit weight of the construction material used in the standard design is given in the table.

Makadala	Unit Wei	ght,
Materials	kg/m³	kN/m³
Concrete	2200	22.0
Stone Masonry	2100	21.0
Steel	7850	78.5
Soil	1800	18.0
Water	1000	10.0

2.3.3 Structural analysis and design

Statical analysis is based on calculation of forces and stresses in the structures due to the external loadings. Calculated forces and stresses are compared with the permissible loads and stresses of these structures with some safety of factors.

The standard suspended bridge has been designed as per the statical analysis and basic design concept.

Cable Design

A cable hanging between two supports and carrying a uniformly distributed load "q" forms a parabola. Thus Main Cables and Walkway Cables are assumed to be of parabolic geometry. In suspended type bridge, the main cables (walkway cables) and handrail cables carry the load equally proportional to their sectional area.

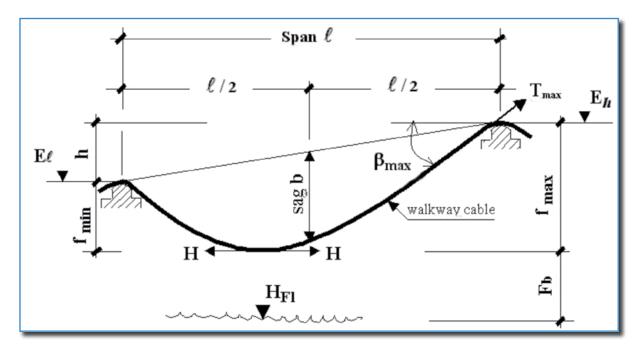


Figure F.2.6: Cable Geometry

Maximum permissible Height Difference of Walkway Cable Saddles,

$$\mathbf{h} = \frac{\mathsf{Span}(l)}{25}$$

Sag of the Cable at Midspan in Dead Load for Spans up to 80m:

$$\mathbf{b} = \frac{\mathsf{Span}(l)}{20}$$

or for Spans over 80m:

$$\mathbf{b} = \frac{\mathsf{Span}(l)}{22}$$

The fundamental equations for the calculation of the cable forces are:

Total Horizontal Tension,

$$\mathbf{H} = \frac{g \cdot l^2}{8 \cdot b}$$

Total maximum Tension at the higher Foundation Saddle,

$$T_{max} = \frac{H}{\cos \beta_{max}}$$

Cable Inclination at higher Foundation Saddle,

$$\beta_{\text{max}} = a \tan(\frac{4b+h}{l})$$

Example:

$$\beta_{\text{max}} = \text{a tan } \frac{4 \frac{1}{22} + \frac{1}{25}}{l} \text{ a tan } \frac{0.1818 \cdot l + 0.04l}{l} \text{ a tan } 0.2218 = \beta_{\text{max}} = 12.51^{\circ}$$

The Safety Factor for Cable Breaking Load is taken as $f_{\epsilon} \ge 3$.

As per above design concept, a simplified cable combination chart has been developed and standardized for suspended type bridge for different walkway width and span up to 120m.

These cable combinations depend only on the span and the chosen walkway width and do not depend on the site condition. The cable combination has been designed to satisfy the worst topographic condition, i.e. considering maximum allowable level difference between the cable saddles of right and left banks. Therefore, in more favourable topographic conditions, the cable may seem to be over designed, but, as per analysis this has no significant effect (less than 1%) on the overall cable strength.

Steel Parts

Steel parts of the suspended type bridge are mainly subject to axial tension, bending stress, shear stress and bond stress. All the steel parts are designed for these forces and stresses with a safety factor of **fs = 1.6**.

All the steel parts have been standardized according to the cable combinations and do not depend on the site condition.

Walkway Structure

Walkway structures (Steel deck, Cross beams, hangers) are designed for local loadings as steel parts with safety factor of, fs = 1.6. Concentrated load $P = 150 \, kg$ (weight of a porter with load) positioned along the walkway as well as across the walkway has been considered.

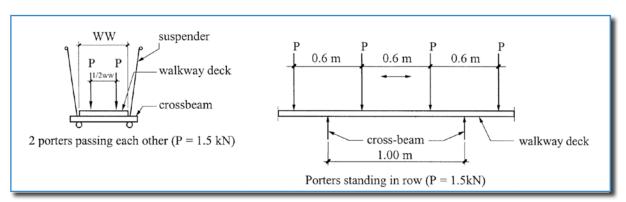


Figure F.2.7: Walkway Structure

Main Anchorage Foundations

There are mainly three basic types of main anchorage foundations:

- Foundation on Soil
- Foundation on Hard Rock
- Foundation on Fractured Hard Rock or Soft Rock

All foundations are designed as per the static analysis and principle of soil / rock mechanics. Soil and rock parameters are determined by the site investigation. mode of failure and respective safety factors are considered in the design:

• Sliding $F_{SL} \ge 1.5$ • Toppling $F_{T} \ge 1.5$

- Bearing Capacity FBC ≥ 2.0

• Maximum Ground Pressure σ_{max} < Bearing capacity of soil or rock The standard design is without windguy system. Therefore, foundations are designed to take the wind load satisfying the worst case from the two load cases.

- dead load + full wind load Load case A
 - Load case B full load + 1/3 wind load

Foundation in Soil

RCC deadman and gravity soil anchor block has been designed as a main anchorage foundation on soil. Consider the design concept of the foundation.

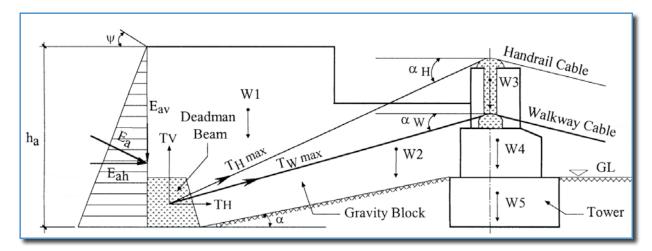


Figure F.2.8: Foundation in Soil

The foundations have been designed to satisfy the safety against sliding with the theoretical basis. Safety factor against sliding:

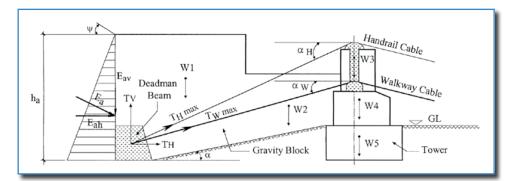
$$\mathbf{F}_{\mathsf{sl}} = \frac{\mathsf{Re\ sisting\ Force}}{\mathsf{Driving\ Force}} = \frac{\mathsf{R'v} \cdot \mathsf{tan} \phi_{\mathsf{sl}}}{\mathsf{R'H}} \ge 1.5$$

The gravity load has also been maintained to resist the uplift force at the dead man beam by providing minimum width (B_{1min}) and height (H_{1min}) .

Safety against uplifting:

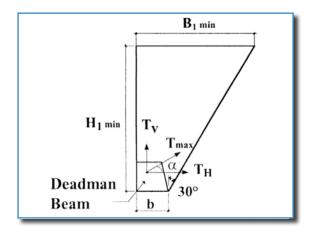
$$Tmax \cdot sin\alpha = (b+B_{1min}) \cdot 0.5H_{1min} \cdot L_{beam}$$

$$B_{1min} = b + H_{1min} \cdot tan30^{\circ}$$



The position of the foundation behind the slope line of the internal angle of friction guarantees the safety against the Ground Shear failure.

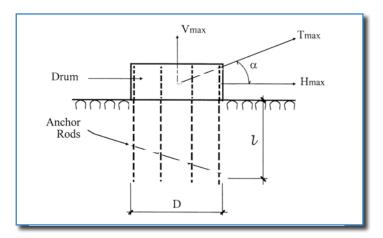
Further, a curtain wall with cement stone masonry of sufficient thickness has been provided to resist the lateral pressure and bulging effect. The lateral pressure has been calculated as lateral pressure against rigid wall as per elastic theory with the formula.



Foundation in Hard Rock

RCC Concrete Drum with rock anchoring is used for foundation on sound hard rock. The sizes of drum and anchorage rods are designed to withstand the shear due to the horizontal tension of the cables. It is also designed to resist the uplift force at Drum.

Required number of anchor rods, N is calculated as:

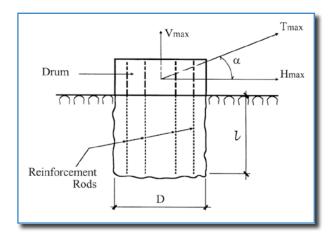


N is adopted from whichever is higher from above.

Foundation in Fractured Hard Rock or Soft Rock

Drum anchorage without rock anchoring is used for foundation on fractured hard rock or fresh soft rock.

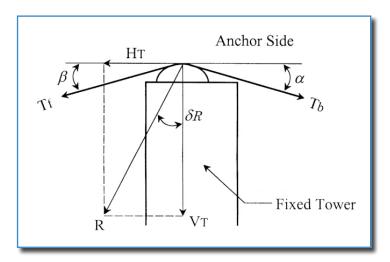
The size of drum is designed to withstand the shear failure due to horizontal tension of the cables. Determine the Drum size and number of reinforcement bars as:



Stone Masonry Tower

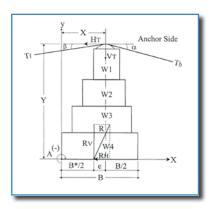
Stone Masonry Tower is designed to be safe against overturning and maximum pressure on foundation. The ground bearing capacity (shear failure) is controlled by placing the tower foundation behind the critical slope line.

Forces on top of the Tower:



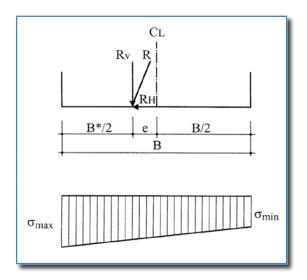
Forces at Tower Base and Soil Pressure

Safety factor against overturning:



Safety against Ground Bearing Pressure:

Eccentricity should be within the permissible limit so that there is no negative pressure on the foundation. It is achieved by meeting the condition.



Reinforced Concrete Works

All the reinforced concrete works are designed as per the principle of RCC design in working stress. For detail refer to the relevant literature of Reinforced Concrete design.

2.4 Design of standard Suspended bridge

2.4.1 The major bridge components

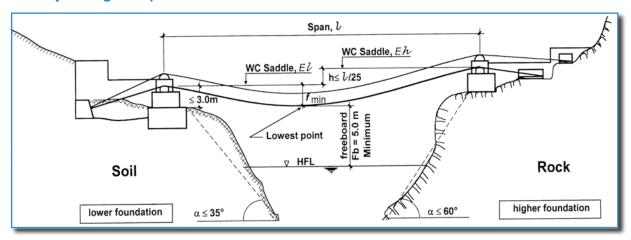


Figure F.2.9: Major Bridge Components & Parameters

2.4.2 Design procedure

For designing a suspended standard bridge:

- Draw the bridge profile from the survey data;
- Fix the position of the bridge foundations and the span;
- Select walkway width;
- Select walkway cables and handrail cables from Design Form;
- Design walkway tower;
- Design main anchorage foundation;s
- Transfer data to the bridge profile and prepare the General Arrangement Drawing;
- Compile and fill in the standard design drawings;
- Calculate the quantities of works and prepare the Cost Estimate.

2.4.3 Designing the position of the bridge foundations

Fix the position of the bridge foundations and the actual span of the bridge in the bridge profile. This bridge profile will be the basis for the layout of the bridge at the construction site. Fulfill criteria while fixing the position of the bridge foundations.

Criteria for fixing the Bridge Foundations

- The Bridge Foundations should be placed at least 3 meter back form the soil slope and 1.5 meter back from the rock slope
- The Bridge Foundations should be placed behind the line of angle of internal friction of the soil or rock. This angle is 35° for soil and 60° for rock.
- Level difference between the walkway cable saddles of two banks, h should not be more than span/25
- Walkway tower height should be as small as possible. However, walkway cable saddle should be at least a height of 1.3 meter from ground but should not be at a height more than 3.0 meter.
- Free board F, between lowest point of the bridge in dead load case and the high flood level should be not less than 5.0 m

Criteria for fixing the location of the bridge foundation

Procedure for fixing the Bridge Foundations

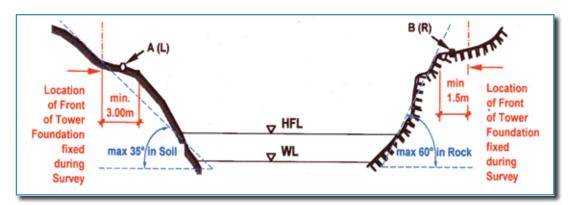
According to the above criteria,

- Draw the bridge axis profile on an A3 size paper in a scale 1:200 (for up to 50m span) or 1: 400 (for span above 50m) with all details like axis points A and B, HFL, WL and tentative location of the walkway towers at both banks based on the survey data.
- Fix location of the walkway towers at both banks.

Case-1: When Tentative Position of the Towers has been fixed during the Survey.

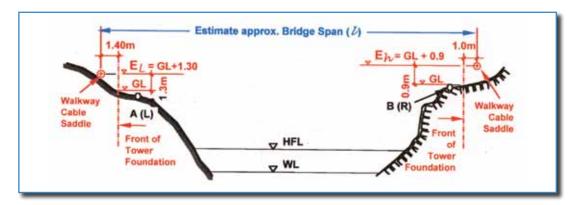
Step 1: Fix the Front of the Tower and check with Slope Line.

Mark front of the tower as fixed during the survey. Check position of the front of the tower as per minimum required distance from bank edge and slope line. If minimum required distance from bank edge is not sufficient, shift its position backward. Towers should be located behind the slope line. If tower is out of the slope line, shift its position backward.



Step 2: Fix the Position of the Walkway Saddle and Bridge Span, I.

Mark position of the walkway cable saddles. Walkway cable saddles should be at height of 1.3m at soil slope and 0.8m at rock slope from the ground at tower front. Thus, fix its elevations, El, Eh & I.



Step 3: Check the Level Difference, h.

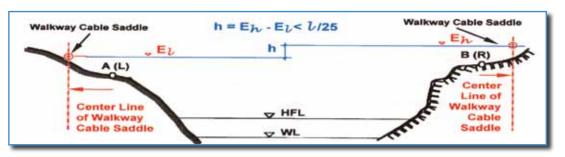
Level difference 'h' between walkway cable saddles of two banks should be less than I/25. If 'h' is found more than the limit:

Rise the elevation of the walkway cable saddle of lower bank by increasing saddle height (in the series of 1.3, 2.3, 3.3 meter) but not more than 3.3 meter from the ground level in case of Flat slope

Shift the position of the tower of lower bank backward to gain the required walkway cable elevation in case of Hill Slope.

Or

Lower the elevation of the walkway cable saddle of higher bank. Avoid deep earth cutting.



Step 4: Calculate the vertical Distance, f_{min} and check the Free Board, f_{b} .

Calculate vertical distance f_{min} between the lowest point of the bridge and walkway cable saddle of lower bank,

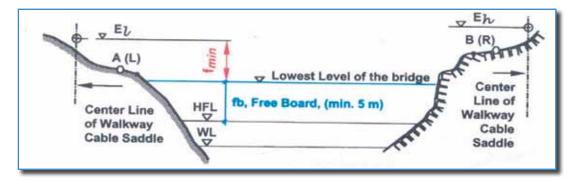
$$F_{min} = \frac{(4 \cdot l - 20h)^2}{320 \cdot l}$$

Draw line of lowest point of the bridge.

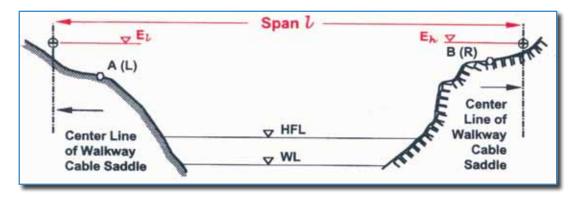
Check available free board between lowest level of the bridge and high flood level.

Freeboard should be not less than 5.0m. If free board is not sufficient:

Raise the elevations of walkway cable saddles at both banks. This can be done either by raising the tower height in case of the flat ground or by placing the tower further back in case of the hill slope.



Step 5: Finalize the Bridge Profile. Finalize bridge profile with final span and elevation of the walkway cable saddles.

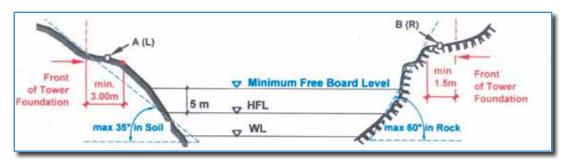


Case-2: When the Position of the Towers has not been fixed during the Survey.

Step 1: Fix the Free Board Line and Front of the Towers.

Mark minimum free board level. Minimum free board from high flood level is 5.0 meter.

Fix the position of the front of the tower maintaining minimum required distance from bank edge and slope line.



Step 2: Fix the approximate Bridge Span, I and minimum Level of Walkway Cable Saddles. Calculate approximate bridge span as distance between the tower fronts. Mark minimum level of walkway cable saddles as per required sag of the cable,

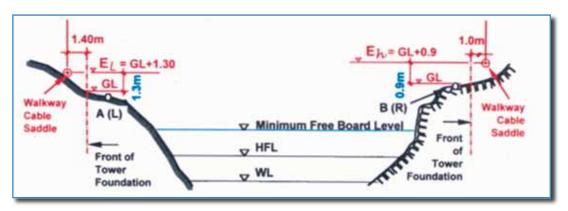


Step 3: Fix the Position of the Walkway and Cable Saddles.

Walkway cable saddles should not be below the minimum level.

Walkway cable saddles should be 1.3 meter above the ground level at soil slope and 0.9 meter at rock slope.

Thus, fix the elevations of the walkway cable saddles, E₁ and E₂.



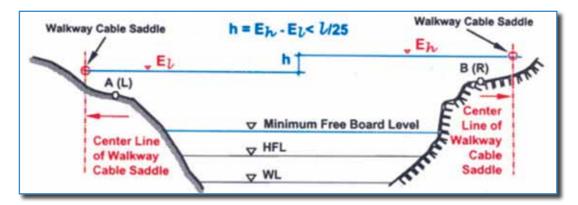
Step 4: Check the Level Difference, h.

Level difference 'h' between walkway cable saddles of two banks should be less than I/25. If 'h' is found more than the limit:

Rise the elevation of the walkway cable saddle of lower bank by increasing saddle height (in the series of 1.3, 2.3, 3.3 meter) but not more than 3.3 meter form the ground level in case of flat ground.

Shift the position of the tower of lower bank backward to gain the required walkway cable elevation in case of hill slope.

Lower the elevation of the walkway cable saddle of higher bank. Avoid deep earth cutting.



Step 5: Calculate the vertical Distance fmin and check the Free Board fb.

Calculate vertical distance fmin between the lowest point of the bridge and walkway cable saddle of lower bank.

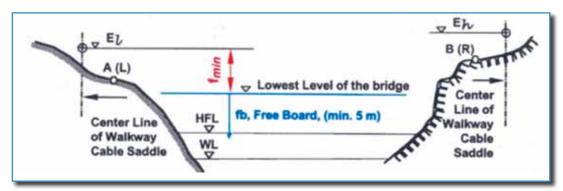
Draw actual line of lowest point of the bridge

$$F_{min} = \frac{(4 \cdot l - 20h)^2}{320 \cdot l}$$

Check available free board between lowest level of the bridge and high flood level.

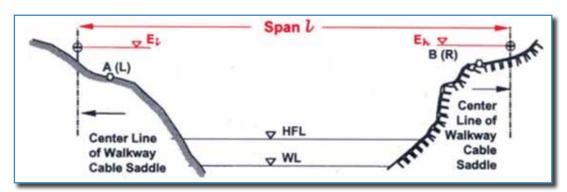
Freeboard should be not less than 5.0 meter. If free board is not sufficient:

Raise the elevations of walkway cable saddles at both banks. This can be done either by raising the tower height in case of the flat ground or by placing the tower further back in case of the hill slope.



Step 6: Finalize the Bridge profile.

Finalize bridge profile with final span and elevation of the walkway cable saddles.



2.4.4 Cable Design

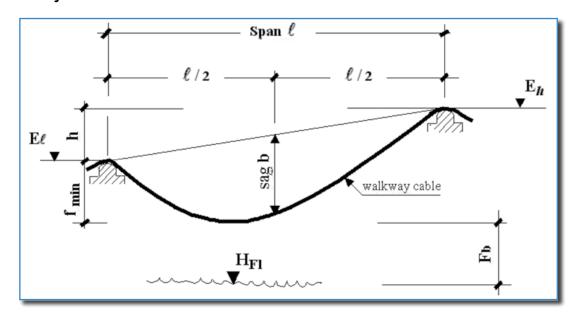
Designing the cable for a bridge involves selecting required numbers and diameter of the handrail and walkway cables for given span and selected walkway width.

To design the cable:

- Select the appropriate walkway width (70cm or 106cm) according to the nature of the traffic and type of trail.
- Fix the span of the bridge and height difference of cable saddles of the right bank and left bank from the bridge profile.
- Select cables from the Table: Selection of Cable according to the span and selected walkway width.

Design the cable structure

1. Survey data & calculation of freeboard



1. Span of the bridge

- m
- Saddle Elevation of the Walkway Cable on the higher Side 2.
- Saddle Elevation of the Walkway Cable on the lower Side

- 4. Difference in Elevation (max. permissible height: $h_{max} = 1/25$)
- $h = E_h E_l = h'$
- 5. Dead Load Sag: for Span up to 80m

$$b_d = \frac{l}{20} = b_d = \dots m$$

for Span over 80m

$$b_d = \frac{l}{22} = b_d = \dots m$$

6. F_{min} in Dead Load case (at the lowest point of the cable)

$$f_{min} = \frac{(4 \cdot b_d - h)^2}{16 \cdot b_d} = b_d = \dots m$$

7. Highest Flood Level but keep the ratio between span and sag always **fixed** at l/b_d =20 or l/b_d =22)

Selection of Cables

Select a cable combination according to the span and walkway width of the bridge from the table. Always select the higher cable combination when the span is in between two values.

Maximum Span for Walkway Width:		Cable Combinations				Weight of all Cables
70cm	106cm	Handrail Cables		Walkway <i>Cables</i>		gh
span [m]	span [m]	nos	Ømm	nos	Ømm	[kg/m]
50	40	2	26	2	26	10.04
90	60	2	26	2	32	12.62
100	75	2	26	4	26	15.06
120	105	2	26	4	32	20.22
	120	2	32	4	32	22.80

3. Calculation of Cable Length

Type of Cable	dia [mm]	Nos	Backstay Length * [m]	Cutting Length** [m/pc]
Fixation Cable	13	2		
Handrail Cable		2		
Walkway Cable				

Notes:

Backstay Length = Cable length between saddle center and center of dead man or drum as per foundation drawing (both banks) + 6.0m.

Cutting Length = 1.1 x Span + Backstay Lengths

Calculation of (f_{\min}) Hoisting Sag

This calculation has to be made after tower and foundation work is completed

1. Actual span measured in the field m Saddle Elevation of the Walkway Cable on the higher side 2. Saddle Elevation of the Walkway Cable on the **lower** side 3.

Difference in Elevation (max. permissible height: $h_{max} = I/25$)

Dead Load Sag: for Span up to 80m 5.

$$b_d = \frac{l}{20} = b_d = \dots m$$

for Span over 80m

$$b_d = \frac{l}{22} = b_d = \dots m$$
 $b_h = 0.95 \times b_d = b_h = \dots m$

Hoisting sag F_{min} in Dead Load case (at the lowest point of the cable)

$$f_{min} = \frac{(4 \cdot b_d - h)^2}{16 \cdot b_d} = f_{min} = \dots m$$

2.4.5 Design of bridge foundation structures

Design of a bridge foundation structure is mainly to select the standard anchor block types for right bank and for left bank and fill in the required data in the selected drawings.

Standard anchor block (bridge foundation structure) types have been developed for all possible cases up to span 120m. The design concept and statical analysis has been used.

There are basically **seven types of anchor blocks** depending upon the soil or rock type, whereof the **typical designs** are illustrated:

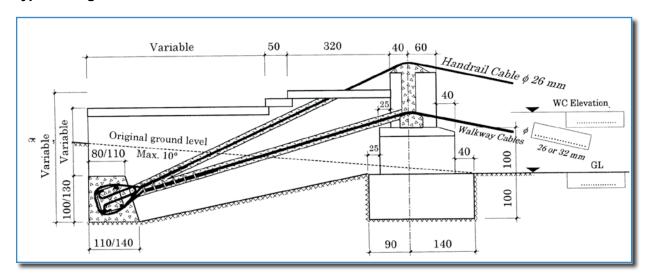


Figure F.2.10: RCC Deadman & gravity soil anchor block on flat topography

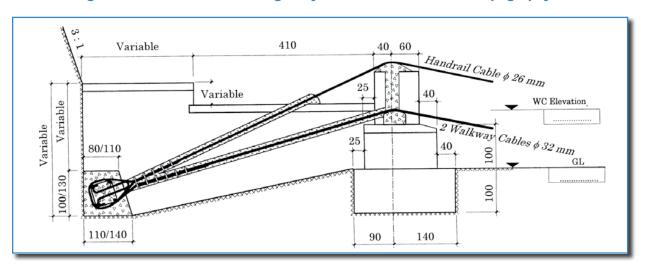


Figure F.2.11: RCC Deadman & gravity soil anchor block on slope topography

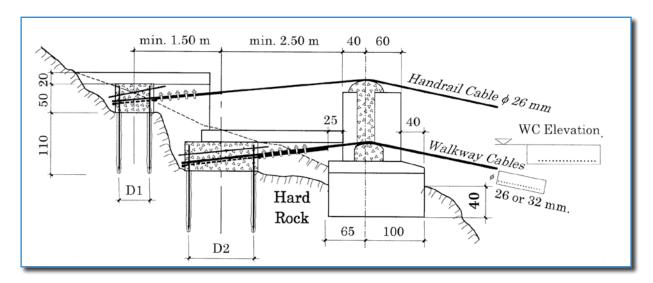


Figure F.2.12: RCC Single Drum Rock Anchor Block in Hard Rock

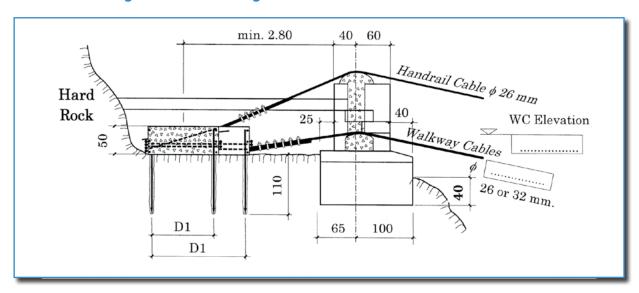


Figure F.2.13: RCC Double Drum Rock Anchor Block in Hard Rock

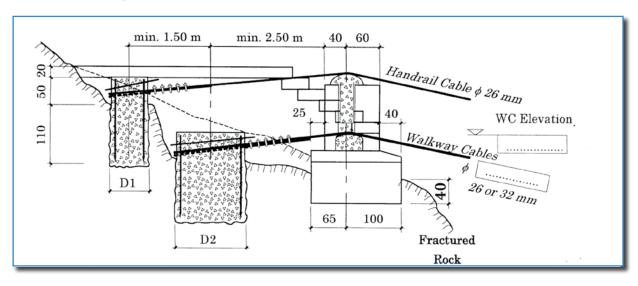


Figure F.2.14: RCC Single Rock Anchor Block in Fractured Hard Rock & Soft Rock

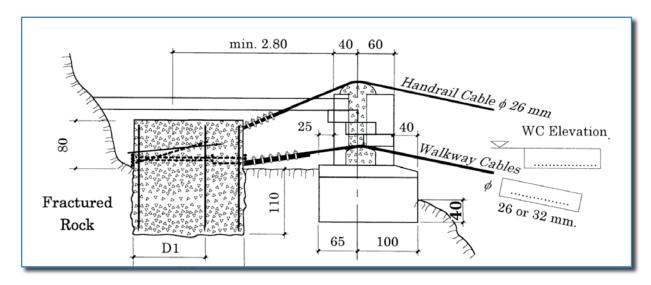


Figure F.2.15: RCC Double Drum Rock Anchor Block in Fractured Hard Rock & Soft Rock

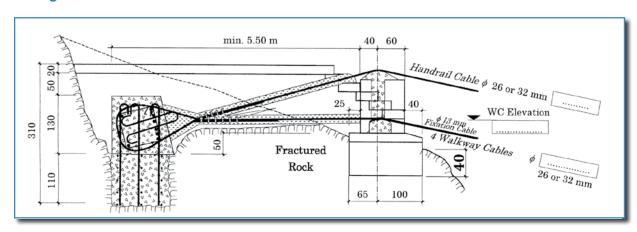


Figure F.2.16: RCC Deadman Anchor Block in Fractured Hard Rock and Soft Rock

To select an Anchor block type:

- Define the walkway width.
- Define the span of the bridge from the bridge profile
- Define the topography of the ground where the anchorage block will be placed as flat or slope.
- The topography is defined as flat if the ground slope is less than 10°, and slope if the ground slope is more than 10°.
- Define the soil or rock type from the survey form and checklist
- Define the tower height from bridge profile. Tower height = Height of walkway cable saddle from the ground + 1.1m in case of soil bank and flat topography. Tower height = 2.4m (fixed) in case of soil bank and slope topography. Tower height = 2.0 m (fixed) in case of rock bank.
- Select the anchor type and the corresponding drawing from the selection tables according to the above design data.

Design the Anchor Types

I. Design Data

• Walkway Width, WW (70 or 106cm):cm							
Bridge Span:m							
Right Bank Condition							
Geology:	Soil						
If Soil, how is the Ground Surface?							
What is the Soil Type?	Flat	Hill slope					
Tower Height from Ground up to H.C.Saddle (data from bridge profile):	(up to 15° slope) or	(more than 15° slope)					
	Gravelly Sandy	Silty					
	2.4m 3.4m	2.4m					
If rock , what is the rock type?	Hard rock Hard rock	Soft rock					
Tower Height	(only a few fractures) (highly fractured)						
rower rieight	2.0m in case of rock						
	Left Bank Condition						
Geology:	Soil						
If soil , how is the ground surface?							
What is the Soil Type?	Flat	Hill slope					
	(up to 10° slope) or	(more than 10° slope)					
	Gravelly Sandy	Silty					
	2.4m 3.4m	4.4m					
If Rock , what is the Rock Type?	Hard rock Hard rock	Soft rock					
Tower Height	(only a few fractures) (highly fractured)						
Tower Height	2.0m in case of rock						

II. Selection of Anchorage Types

Select appropriate anchorage type at Right Bank and Left Bank according to the above design data. Procedure for Selection:

 According to the Soil/Rock type and Slope of the ground, refer to respective tables for selection of Anchorage Block.

for Soil and Flat Ground : **Table F.2.1** for Soil and Hill Slope : **Table F.2.2**

for Hard Rock : **Table F.2.3 or Table F.2.4**

for Fractured Hard Rock or Soft Rock:

Span up to 90m (WW = 70cm) and up to 60m (WW = 106cm) : Table F.2.5 or Table F.2.6

Span Range 91-120m (WW = 70cm), 61-120m (WW = 106cm) : **Table F.2.7**

In the table match the design data:

Selected Walkway Width → Bridge Span → Tower Height → Soil type → Select the corresponding Anchor Type and Drawing No. for right bank and left bank respectively.

III. Anchor Type Selection Tables

In soil and flat ground:

Table F.2.1: Selection of RCC deadman & gravity soil anchor block in flat ground

Span Range, m		Tower	Foundation	Block	Drawing
Walkway: 70cm	Walkway: 106cm	Height [m]	Soil Type	Туре	No.
Up to 45m	Up to 30m	2.4	All	1F	21Dcon
		3.4		2F	22Dcon
		4.4		3F	23Dcon
46 - 90	31 - 60	2.4	All	4F	24Dcon
		3.4		5F	25Dcon
		4.4		6F	26Dcon
91 - 120	61 - 75	2.4	All	7F	27Dcon
		3.4		8F	28Dcon
		4.4		9F	29Dcon
-	76 - 90	2.4	All	10F	30Dcon
		3.4		8F	28Dcon
		4.4		11F	31Dcon
-	91 - 105	2.4	All	12F	32Dcon
		3.4		8F	28Dcon
		4.4		13F	33Dcon
-	106 – 120	2.4	Gravely	12F	32Dcon
			Sandy, Silty	14F	34Dcon
		3.4	3.4 All	15F	35Dcon
				13F	33Dcon

In Soil and Hill Slope:

Table F.2.2: Selection of RCC Deadman & Gravity Soil Anchor Block in Hill Slope

Span Ra	ange, m	Tower	Foundation	Block	Drawing
Walkway: 70cm	Walkway: 106cm	Height [m]	Soil Type	Туре	No.
Up to 60m	Up to 40m	2.4	All	15	41Dcon
61 – 90	41- 60	2.4	All	2S	42Dcon
91 - 120	61-75	2.4	All	3S	43Dcon
	76 - 90	76 - 90 2.4 Sai	Gravely	4S	44Dcon
-			Sandy	5S	45Dcon
			Silty	6S	46Dcon
	01 105	2.4	Gravely, Sandy	7S	47Dcon
_	91 - 105	2.4	Silty	8S	48Dcon
	10/ 120	2.4	Gravely, Sandy	8S	48Dcon
_	106 - 120	2.4	Silty	9S	49Dcon

In Hard Rock for all Span Range:

Table F.2.3: Selection of RCC Single Drum Anchor in Hard Rock

Span Range, m		Tower Height	Dia de Trus	Durania a No
Walkway: 70cm	Walkway: 106cm	[m]	Block Type	Drawing No
up to 90	up to 60	2.0	1HRS	61Dcon
91 – 120	61 - 120	2.0	2HRS	62Dcon

When slope is too steep and there is not enough space for single drum anchorage system, select the double drum system from Table F.2.4.

Table F.2.4: Selection of RCC Double Drum Anchor in Hard Rock

Span Range, m		Tower Height	Plack Type	Duorring No
Walkway: 70cm	Walkway: 106cm	[m]	Block Type	Drawing No
up to 90	up to 60	2.0	1HRD	63Dcon
91 – 120	61 - 120	2.0	2HRD	64Dcon

In Fractured Hard Rock/Soft Rock for Span Range up to 90m (WW = 70 cm) and 60m (WW = 106cm):

Table F.2.5: Selection of RCC Single Drum Anchor in Fractured Hard Rock/Soft Rock

	Span Ra	ange, m	Tower Height	Block Type	Drawing No
	Walkway: 70cm	Walkway: 106cm	[m]	Block Type	Drawing No
ĺ	up to 90	up to 60	2.0	1FRS	65Dcon

When slope is too steep and there is not enough space for a single drum anchorage system (Table F.2.5), select the double drum system from Table F.2.6.

Table F.2.6: Selection of RCC Double Drum Anchor in Fractured Hard Rock/Soft Rock

Span Ra	ange, m	Tower Height	Plack Type	Drawing No
Walkway: 70cm	Walkway: 106cm	[m]	Block Type	
up to 90	up to 60	2.0	1FRD	66Dcon

In Fractured Hard Rock/Soft Rock for Span Rang of 91- 120m (WW = 70 cm)and 61-120m (WW = 106cm):

Table F.2.7: Selection of RCC Deadman Anchor in Fractured Hard Rock/Soft Rock

Span Ra	ange, m	Tower Height	Block Type	Drawing No
Walkway: 70cm	Walkway: 106cm	[m]	Block Type	Drawing No
91-120	61-120	2.0	2FRD	67Dcon

Selected Anchorage Foundation Type and corresponding Drawings from the Tables above:

Right Bank: Anchor Type......Drawing No......Drawing No......

IV. List of drawings

Select the required Steel Drawings and Construction Drawings according to the walkway width, selected cables and selected Anchorage Block types.

Prepare a General Arrangement drawing for individual bridge design.

2.4.6 Other structures

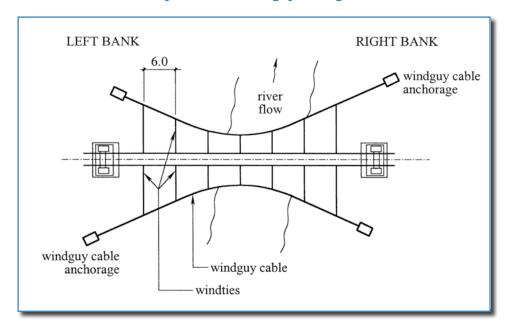
Besides the bridge structure, some other adjacent structures may be required for overall bridge stability and for safety measures. These are the structures.

- Windguy Arrangement
- Retaining Structures
- Slope Protection works
- River Bank Protection

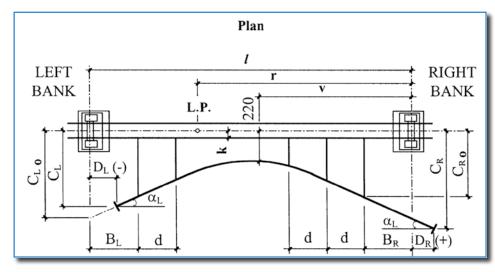
Windguy Arrangement

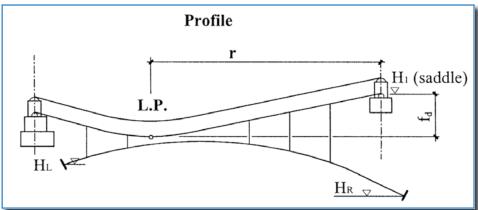
Generally Windguy Arrangements are not required for bridges with span of up to 120m. Therefore, no lateral stabilizing measures (windguy system) is considered in this standard suspended bridge design. However, for special cases (spans more than 120m or extreme windy areas exceeding wind speed of 160km/h) there is a provision for fixing a windguy system. Refer the Steel Drawing for the windtie cable clamps from Drawing No. 11A and respective Construction Drawings for different types of windguy cable anchorages from Drawing Nos 51Acon, 52Acon, 53Acon, 54Acon, 57Acon and 58Acon.

The Layout of the Windguy Arrangement



The Geometry of the Windguy Arrangement





The design of the Windguy Arrangement is to:

- Select the windguy cable and windties cable
- Select the windguy cable anchor blocks
- Calculate geometry of the windguy arrangement

Selection of Windguy Cable and Windties Cable:

Select the windguy & windtie cables from the table according to the span of the bridge.

Selection of Windguy Cable and Windtie Cable

Span, m	Windguy Cable, mm	Windtie Cable, mm
Up to 150	26mm	13
150 - 200	32mm	13

Selection of Windguy Cable Anchor Type:

There are each two types of gravity Soil Anchor Blocks, gravity Rock Anchor Blocks and Drum Anchors depending on the soil or rock type and the diameter of the Windguy Cable.

Select the Windguy Cable Anchorage Type from Tables:

Selection of Windguy Cable Gravity Anchor Block on Soil

Windguy Cable Ø [mm]	Block type	Drawing No
26	Soil Block	51Acon
32	Soil Block	53Acon

Selection of Windguy Cable Gravity Block on Rock *

Windguy Cable Ø [mm]	Block type	Drawing No
26	Rock Block	52Acon
32	Rock Block	54Acon

Selection of Windguy Cable Drum Anchor on Hard Rock*

Windguy Cable Ø [mm]	Block type	Drawing No
26 or 32	Hard Rock Drum	57Acon

Selection of Windguy Cable Drum Anchor on Fractured Hard Rock or Soft Rock*

Windguy Cable Ø [mm]	Block type	Drawing No
26 or 32	Soft Rock Drum	58Acon

f If both banks are rock, select the Drum Anchor for one bank and the Gravity Rock Anchor for the other bank.

If one bank is rock and the other bank is soil, select always the Drum Anchor for the rock bank.

Retaining structures

Retaining structures are necessary to retain the earth (soil, fractured rock and weathered soft rock) behind the anchorage blocks of the bridge. There are many options of retaining structures. But for the trail bridge

construction most feasible are retaining walls. Retaining walls can be of gabion boxes, rubble masonry and dry stone masonry. For the Short-Span trail bridge construction dry stone retaining wall or breast wall are preferable, since they require only local materials.

The choice between retaining wall and breast wall depends on different factors, such as available space behind the blocks, required height of the protection, soil conditions etc.

Retaining walls are used when the earth to be retained is loose soil with large protection height.

Retaining Walls

Туре	Dry Stone	Banded Dry Stone / Masonry
Section	W ₁ W ₂ N N N N N N N N N N N N N N N N N N N	W _b dry Stone
Top width, W _t	0.6 - 1.0m	0.6 - 1.0m
Base width, W _b	0.5 - 0.7H	0.6 - 0.65H
Front batter	varies	varies
Back batter	varies	vertical
Inward dip of foundation, n	1:3	1:3
Foundation depth	≥0.50m	≥0.50 - 1m
Range of height, H	1 - 6m	6 - 8m
Hill slope angle, a	< 35°	20°

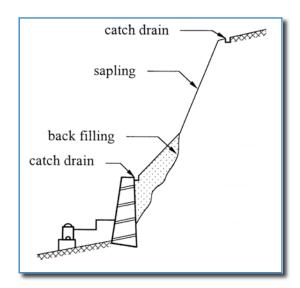
Breast walls are used when earth to be retained is fractured or weathered rock or compact soil with temporarily unstable nature.

Туре	Dry Stone			Banded Dry Stone / Masonry
Section	T W _b			dry Stone mortar W _b
Top width, W _t		0.50m		0.50m
Base width, W _b	0.29H	0.3H	0.33H	> 0.5H
Back batter	3:1	4 : 1	5 : 1	3:1
Inward dip of foundation, n	1:3	1 : 4	1 : 5	1:3
Foundation depth	≥0.50m	≥0.50m	≥ 0.50m	≥0.50m
Range of height, H	<6m	<4m	<3m	3 - 8m
Hill slope angle, a	_	35 - 60°		35 - 60°

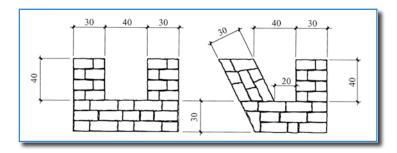
Slope protection measure

Slope protection measure depends on the factors influencing slope instability. It is recommended to select the bridge site, where there are no slope instability features. However, often it is necessary to drain out the surface runoff and seepage water from the slope as a slope protection measure.

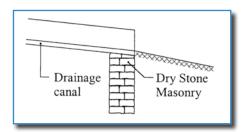
Water should be collected as closely as possible from its origin and safely channeled to a nearby watercourse. The surface drainage can be catch drain on the slope or drainage around the anchorage foundation or combination of both. The choice depends on the position of the anchorage foundation and the profile of the natural terrain.



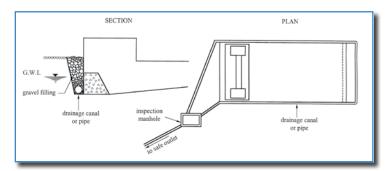
The drain should be open type.



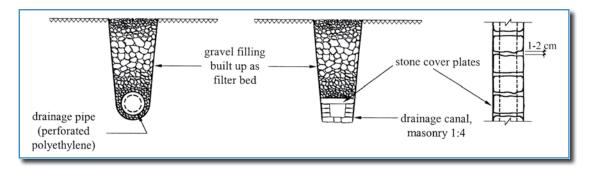
To avoid self-scouring, the drain outlet should be protected.



In seepage area, sub-surface drainage is required around the anchorage foundation. Consider the typical layout design of the sub-surface drain.



A typical design of the sub-surface drain is:



Bio-Engineering

Surface drainage alone may not be sufficient for unstable slopes. The most effective method for stabilizing such slopes is bio-engineering in combination with light civil structures such as catch drains, check dams, cascades etc. This is a cheap and easy method. The main concept of this method is to grow trees, plants such as shrubs or grasses. Deep rooted and fast growing trees and plants are most suitable for this purpose. Proper selection of plant types is most important and should be based upon local experience. Some of the vegetation measures are:

- Planted grass lines: contour/horizontal or down slope/vertical or random planting;
- Grass seeding;
- Turfing;

- Shrub and tree planting
- Shrub and tree seeding
- Fascines (bundles of live branches are laid in shallow trenches)

River bank protection

River protection works are of temporary nature and costly. This requires frequent maintenance to keep the structure functional. Therefore, avoid bridge site, which requires river protection works as far as possible. This is a complex subject and cannot be covered by this Manual.

2.4.7 General arrangement drawing

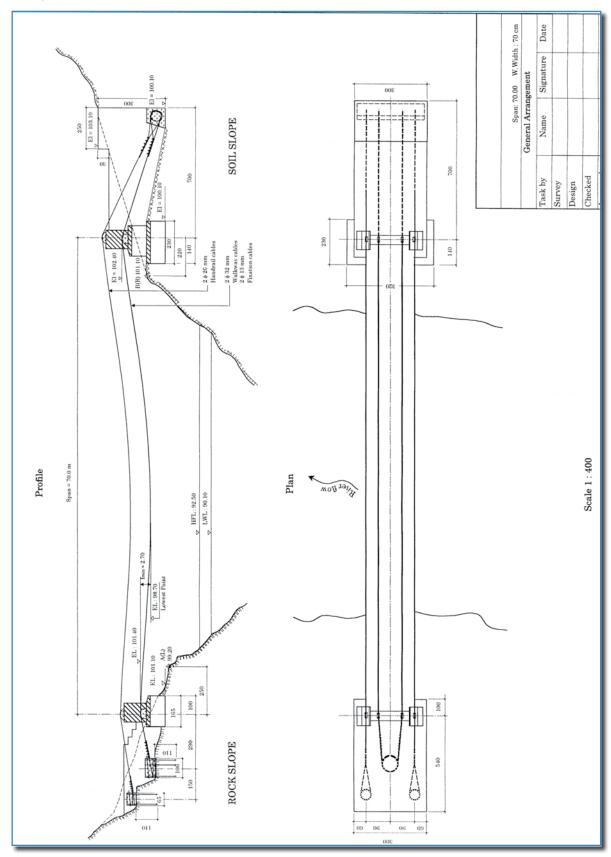
General Arrangement (GA) drawing shows the overall plan and profile of the bridge. The GA should reflect the major components of the bridge and its geometry including the elevations of the foundations at the right and left bank. The GA is required for overall view of the designed bridge and also for layout of the bridge for construction.

Draw the GA on the same bridge profile and mention the data on the plan and the profile of the bridge:

- Span and dead load sag;
- Distance from the axis point A and B (which, were fixed during survey) and the center of the tower,
- Cable elevations at saddles, elevation of the lowest bridge point and all bridge foundation levels,
- Over all dimensions of the bridge structures and its elevations.

The completed GA should be sufficient for the layout of the bridge.

2.4.8 Design example



2.5 Bridge standard drawings

2.5.1 Introduction and overview of drawings

The Bridge Standard Drawings represent the centerpiece of the Short Trail Bridge Standard. They are composed as a unit component system and are categorized in two categories:

- Suspended Bridge Construction Drawings
- Suspended Bridge Steel Drawings

Both drawing categories are linked with each other and depending on the bridge design the required drawings are selected.

Table F.2.8: Suspended Bridge Construction Drawings

		Drawing Titles	Drawing Nos.
	ING AILS	Walkway Fitting for 70 cm Walkway Width Walkway Fitting for 106 cm Walkway Width	19Dcon70 19Dcon106
_	VER AILS	CSM Tower & RCC Core for 70 cm Walkway Width CSM Tower & RCC Core for 106 cm Walkway Width	20Dcon70 20Dcon106
HORS	FLAT GROUND	RCC Deadman & Gravity Soil Anchor Block in Flat Ground for 2 Walkway Cables RCC Deadman & Gravity Soil Anchor Block in Flat Ground for 4 Walkway Cables	21Dcon - 26Dcon (6 Drawings) 27Dcon - 35Dcon (9 Drawings)
SOIL ANCHORS	HILL	RCC Deadman & Gravity Soil Anchor Block in Hill Slope for 2 Walkway Cables RCC Deadman & Gravity Soil Anchor Block in Hill Slope for 4 Walkway Cables	41Dcon & 42Dcon 43Dcon - 49Dcon (7 Drawings)
ROCK ANCHORS	HARD ROCK	RCC Single Drum Anchor in Hard Rock for 2 Walkway Cables RCC Single Drum Anchor in Hard Rock for 4 Walkway Cables RCC Double Drum Anchor in Hard Rock for 2 Walkway Cables RCC Double & Single Drum Anchor in Hard Rock for 4 Walkway Cables	61Dcon 62Dcon 63Dcon 64Dcon
ROCK	FRACTURED ROCK	RCC Single Drum Anchor in fractured Rock for 2 Walkway Cables RCC Double Drum Anchor in fractured Rock for 2 Walkway Cables RCC Deadman Anchor in fractured Rock for 4 Walkway Cables	65Dcon 66Dcon 67Dcon
Anchor Drawings for Windguy	Cables	Gravity Soil Block for Cable ø 26mm Gravity Rock Block for Cable ø 26mm Gravity Soil Block for Cable ø 32mm Gravity Rock Block for Cable ø 32mm RCC single Drum Anchor in Hard Rock, Cable ø 26 or 32mm RCC single Drum Anchor in Fractured Rock, Cable ø 26 or 32mm	51Acon 52Acon 53Acon 54Acon 57Acon 58Acon

Table F.2.9: Suspended Bridge Steel Drawings

		Drawing Titles	Drawing Nos.
		Crossbeam for 2 Walkway Cables for walkway width = 34 cm*	01D*
		Crossbeam for 2 Walkway Cables for walkway width = 70 cm	02D
WALK CROSS		Crossbeam for 4 Walkway Cables for walkway width = 70 cm	02D4
		Crossbeam for 2 Walkway Cables for walkway width = 106 cm	03D
		Crossbeam for 4 Walkway Cables for walkway width = 106 cm	03D4
		Steeldeck Standard Panel, length = 198 cm / width = 34 cm	08A
STEEL	DECK	Steeldeck Standard Half Panel, length = 98 cm / width = 34 cm	09A
		Steeldeck Special Panel, length = 223 cm / width = 34 cm	10A
		Saddles & Reinforcement for RCC Deadman & Gravity Soil Anchor for 2 Walkway Cables	20D2
RENT SOIL		Saddles & Reinforcement for RCC Deadman & Gravity Soil Anchor for 4 Walkway Cables	20D4
DDLES		Saddles & Reinforcement for RCC Deadman Anchor in fractured Rock for 4 Walkway Cables	20D4S
SADDLES & REINFORCEMENT ROCK S		Saddles & Reinforcement for Drum Rock Anchor for 2 Walkway Cables	
		Saddles & Reinforcement for Drum Rock Anchor for 2 Walkway Cables	
	1	Windties Cable Clamps for Windguys Cable ø 26 or 32 mm	11A
optio	onai	Windguys Cable Anchorage for one Cable End ø 26 or 32 mm	50A

^{*} Also a narrow walkway of 34cm width (panel wide only) has been developed, but is not used very often and is, therefore not considered in this Handbook; but can be used, if dimensions of anchor blocks are designed accordingly.

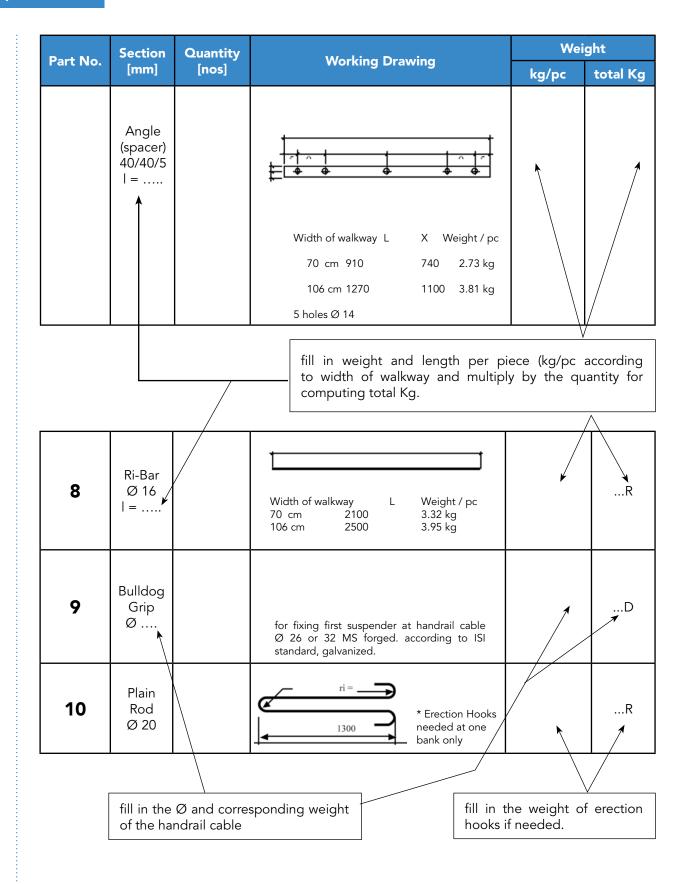
Table F.2.10: Legend for the drawing numbers and suffixes:

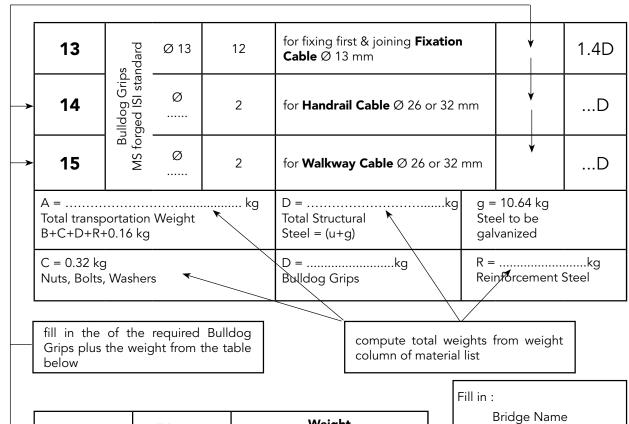
Dr	awing No.	Suffix	Bridge or Drawing Type
Si	11	A	For A ll bridge types
H S	02	D	For suspende d bridge types
	02	D 4	For 4 walkway cables
STEEL ORAWINGS	02	D4 W	Suitable for W indguy cables
Δ	20	D4 S	S pecial
	42	D con	con struction drawings
	20	Dcon 70	For 70 cm walkway width
NO S	Anchor Drawing	gs (Block Types)	
CONSTRUCTION DRAWINGS		3F 5S 1HRS 1HRD 1FRS 1FRD	Block Type 3 in Flat Ground Block Type 5 in Hill Slope Block Type 1 in Hard Rock for Single Drum Block Type 1 in Hard Rock for Double Drum Block Type 1 in Fractured Rock for Single Drum Block Type 1 in Fractured Rock for Deadman

2.5.2 Concept of the standard drawings

Steel drawings

Each Drawing is providing the necessary information and specifications for manufacturing the desired steel parts. Depending on the width of the walkway, the size of walkway cable and the span the empty spaces in the materials list have to be filled in and the total weight has to be calculated.





Cable	Bulldog Grips	Weight			
Ø mm	for two cables	(kg/pc)	Total kg		
26	10	1.10	11.00		
32	12	1.30	15.60		

Fill in :

Bridge Name

No, Bank &

Span

Width of Walkway

No of required foundation

From the total weights of each drawing the grand total for each steel category has to be added up as follows:

- **A:** Means the entire weight of steel including galvanization to be transported to the site.
- **B:** This is the total structural steel raw or untreated. This includes steel profiles, plates and flats but not reinforcement bars and other steel items.
- **C:** This is the weight of Nuts, Bolts & Washers (galvanized weight)
- **D:** This is the weight of Bulldog Grips or Thimbles, if required (galvanized weight)
- **R:** This is the raw weight of Reinforcement Steel or Plain Rods they are never galvanized.

The total transportation weight A = B + C + D + R

g: The little g indicates the weight of structural steel to be galvanized. This weight is part or can be the sum of the total structural steel (B), but is not an additional weight.

Above distinction is made for quotation purposes, because the price per kg (or piece) is varying greatly among each other. Reinforcement steel is much cheaper and Nuts & Bolts are much more expensive than structural steel.

The weight of steel to be galvanized is necessary, to obtain the price for galvanization separately, without the cost of the steel as such.

Usually steel drawings are not necessary at the construction site but for assembly and identification of the steel parts a copy of each steel drawing should be available. Also for maintenance at a later stage copies of the steel drawings are useful.

Construction Drawings

The construction drawings are the actual site drawings of which one complete set is absolutely necessary at the site. Depending on the required width of the walkway the corresponding "Walkway Fitting" & "CSM Tower" drawings have to be selected (either 70 cm or 106 cm).

- Walkway Fitting Drawing;
 (for 70 or 106 cm walkway)
- Details of CSM Tower & RCC Core. (for 70 or 106 cm walkway)

The CSM Tower & RCC Core, drawing no. 20Dcon70 or 20Dcon106, are identical for all bridges.

For the actual anchorage arrangements there are two main categories of drawings:

- Soil Anchor Drawings;
- Rock Anchor Drawings.

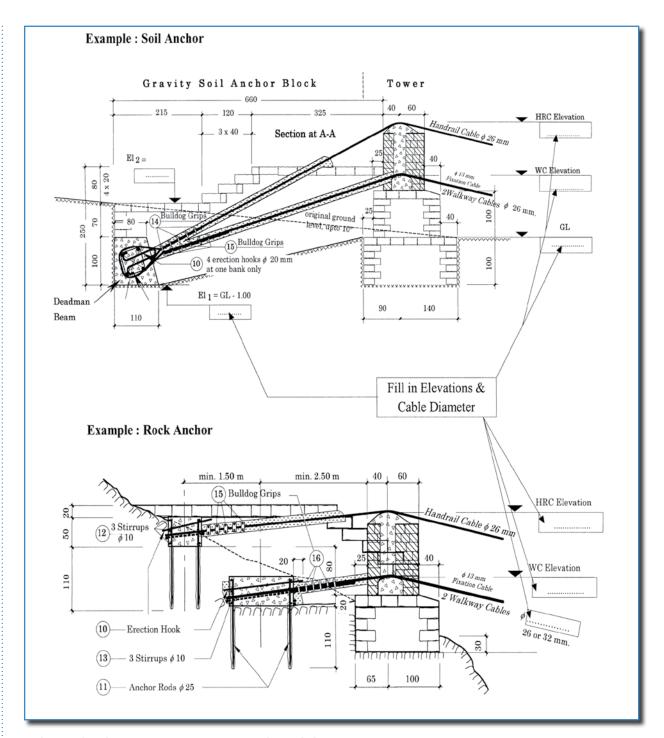
Both drawing types are complete designs and are fulfilling respective parameters selected in the design form. Also in both drawings the necessary quantities of construction materials are already calculated. These have to be filled in respective tables given in the cost estimate Form.

The Soil Anchor Drawings are sub-divided in to:

- Soil Anchor Block in Flat Ground;
- Soil Anchor Block in Hill Slope.

In flat ground with a gradient of max 10° the block types 1F - 15F are applicable, whereas in slopes over 10° the block types 1S - 9S are to be applied.

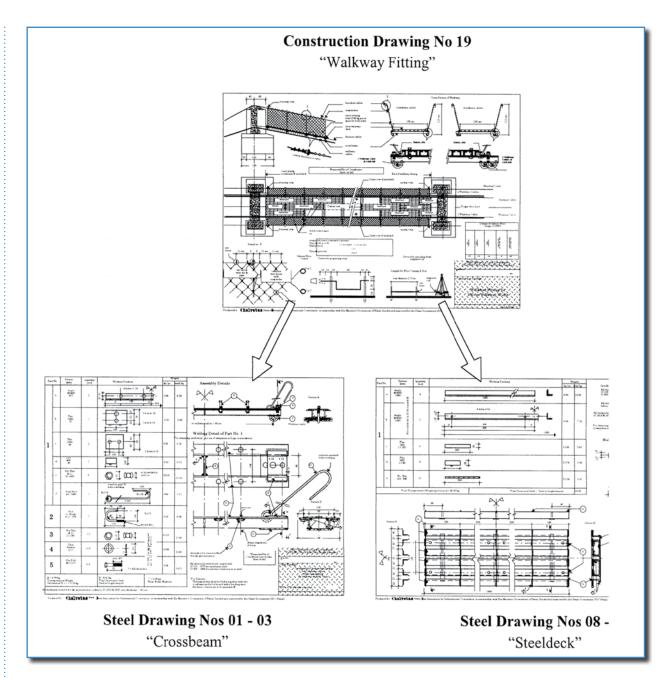
It is absolutely necessary to fill in the Elevation and Cable diameters as indicated in the drawings. The levels are to be determined in the topographic profile of he survey whereas the cable diameter can be taken from the design form.



2.5.3 Relationship between construction and steel drawings

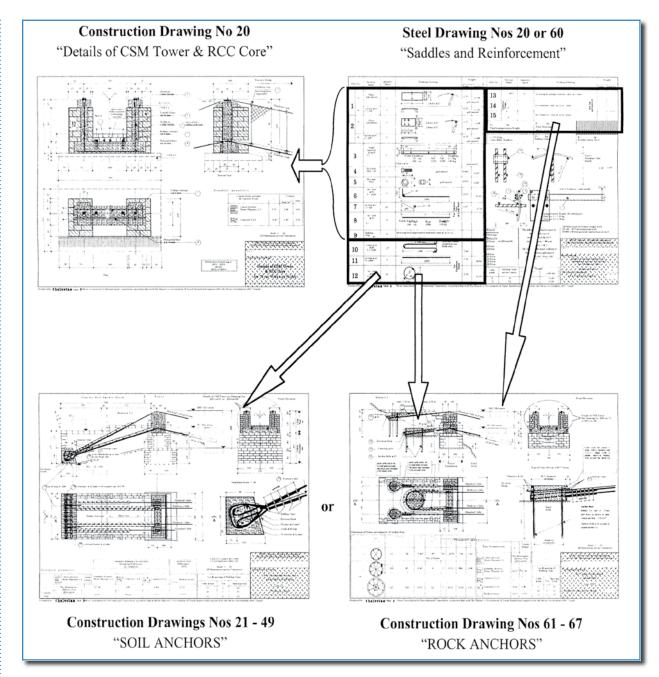
Each Construction Drawing has related Steel Drawings. Respective related drawing numbers are mentioned on the drawing itself and also respective steel parts numbers are indicated on the construction drawing for easy reference.

The Construction Drawing "Walkway Fitting", Nos **19Dcon70** or **19Dcon106** is showing the superstructure of the bridge. The related Steel drawings are the corresponding Steel Crossbeam and Steel deck Drawings.



The Steel Drawings for Saddle and Reinforcement, Nos 20 & 60 are related to the corresponding Construction Drawings Nos 20Dcon70 (70 cm walkway), or 20Dcon106 (106 cm walkway).

Furthermore, depending of the soil conditions (soil or rock), the Steel Drawing Nos 20 & 60 are related either to Anchor Drawings "Soil" or "Rock".



Calculation of quantity and cost estimate

Calculation of quantities and cost estimate is required for the purpose of planning and implementation

2.6.1 Implementation procedure

2.6

Use the Cost Estimate Form to calculate the quantities and to prepare the cost estimate.

Quantity Calculation

- Calculate quantities of cables from Cable Design. Fill in the Quantity Calculation Sheet of Wire Rope (Cables). This sheet will show the cable lengths of each diameter and the total weight of the cables.
- Calculate quantities of Steel Parts and Steel Deck from the corresponding steel drawings. Fill in the Quantity Calculation Sheet of Steel Parts and Steel Deck.
- Calculate quantities of Earth Works from General Arrangement Drawing. Fill in the Quantity Calculation Sheet of Construction.

- Calculate quantities of other construction works from the corresponding Construction Drawings. Fill in the Quantity Calculation Sheet of Construction.
- Prepare list of construction materials according to the calculated quantities of construction works.
- Calculate transportation weights for cables and other construction materials locally not available.
- Calculate quantities of Works and Labor.

Rate Analysis

Prepare the rate analysis for fabrication of steel parts, steel decks and road transportation (items of external support to the community) as per unit quantity, unit cost and standard norms.

Abstract of Cost

Compute the abstract of cost of the bridge as per the quantities of works (from Quantity Calculation Sheets) and the rates (from Rate Analysis) for each item of works and summarize the cost as per the category of works.

Summary of Estimated Cost

- Bridge Cost: Calculate the Estimated Bridge Cost by summarizing the Abstract of Cost. Also calculate bridge cost per m span.
- Contribution: Estimate the expected contribution from different partners.
- Breakdown of the Contribution: Break down the contribution as Local Contribution and Outside Contribution.

Summary of Actual Cost

In the majority of cases, the actual bridge cost will not be the same as estimated. Therefore, calculate the actual bridge cost after completion of the bridge.

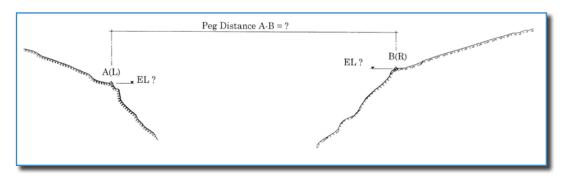
2.7 Construction

2.7.1 Bridge layout

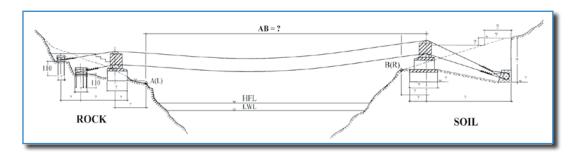
The Bridge Layout is to fix the bridge position and foundations at the site as per design.

Procedure for General Bridge Layout (refer to General Arrangement 'GA' Drawing):

- Find the existing pegs and benchmarks.
- Measure the horizontal distance between axis pegs A (L) and B(R) and compare with the measurement given in the General Arrangement.
- Check the elevations of the axis pegs A (L) and B(R) and compare with the elevations given in the GA.

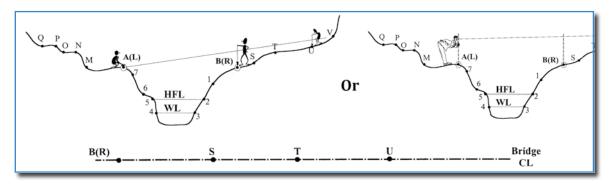


- If the horizontal distance between axis pegs A (L) and B(R) and its elevations is not similar to the measurements given in the GA, readjust the design according to the actual measurements
- If the horizontal distance between axis pegs A (L) and B(R) and its elevations is identical to the measurements given in the GA, fix the position of all foundation blocks.



Procedure for Detailed Foundation Layout:

• Align the centerline of the bridge by joining the permanent points with mason threads or by ranging between axis pegs 'A' and 'B'.



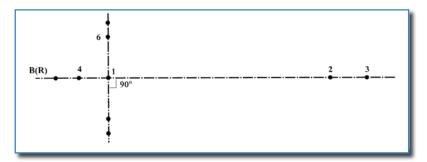
Mark the front of the tower foundation on the bridge centerline (peg 1) with reference to the axis peg. The distance between front of the tower foundation and axis peg is given in the GA.



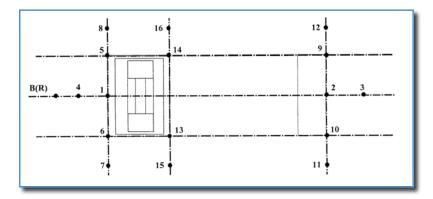
- Check the location of the front of the tower to ensure it has sufficient distance (minimum 3 m for soil slope and 1.5m for rock slope) from the bank edge.
- Measure the length of the foundation from peg 1 and fix peg 2. Set up two additional centerline pegs at safe distance for the excavation works (peg 3 and 4).



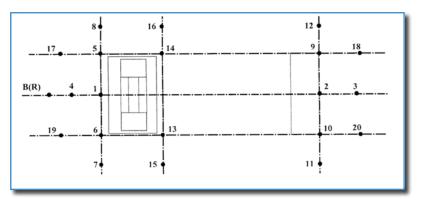
Draw offset line (right angle) through peg 1 by 3-4-5 method. Starting from peg 1 set out pegs 5, 6, 7, and 8 for the reference line of the front edge.



• Draw offset line through peg 2 for reference line of the back edge. Starting from peg 2 fix the pegs 9, 10, 11 and 12. Similarly, fix the reference line of the tower foundation with pegs 13, 14, 15, 16.



• Determine the reference line at the downstream edge with the help of pegs 5 & 9, for the upstream edge, use pegs 6 & 10 (peg 19 & 20).



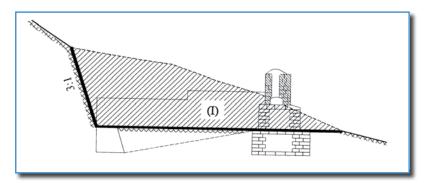
• Fix the elevation line (datum level) and indicate the depth of the excavation work for tower and dead man or drum anchorage as per elevations in the GA and Anchorage Block drawings.

2.7.2 Foundation excavation

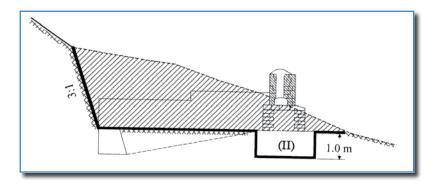
In Soil:

Foundations should be excavated with slopes to provide stability of the cut slope. The cut slope in soil should not exceed to 3:1 (V:H). The foundation should be excavated stage wise.

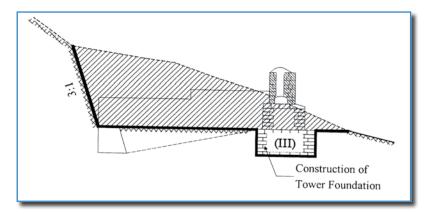
1st Stage – See all excavation.



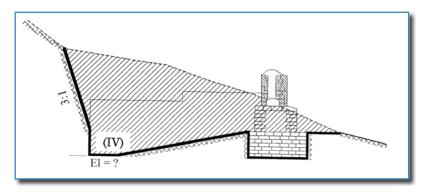
2nd Stage – Foundation excavation for tower.



3rd Stage – Construction of tower as per design.



4th Stage – Final Excavation for dead man beam



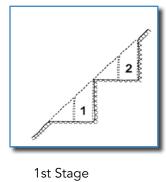
In all of the above excavation stages, excavation depth should be accurately maintained. For this, establish an elevation line (datum level) and measure the foundation depths with fixed stick.

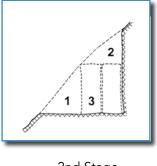
All the excavated soils should be safely disposed without damaging the existing vegetation at down hillside, thus not effecting the environment.

In Rock:

Rock excavation is necessary to prepare the platform for the drum anchorage. Rock should be excavated manually without blasting.

Excavation in rock is done by first drilling holes to weaken the rock and then using the crowbars to break up and dig out the rock parts. The cutting can be carried out by forming steps.





2nd Stage

2.7.3 Local material collection

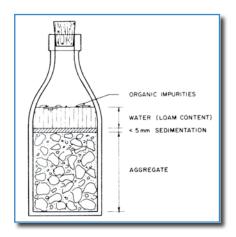
The required local materials for the bridge construction are sand, gravel (river gravel or broken aggregate), and stones/boulders.

Stone/Boulders: The best stone collection is from the rock quarry. The rock should be unweathered, hard and dense with metallic sound.

In unavoidable case, boulders from the river deposits can also be collected. However, this can be used only for filling purpose (broken stone filling). In any case, stones from rock quarry are necessary for masonry works.

Sand: Sand can be collected from river deposits or from a quarry. The quality of the sand should be assessed before sand collection. Check visually the content of the impurities such as mica, clay, loam, mud organic materials etc. If such impurities are unavoidable, it is recommended to wash the sand before use. Sand containing significant quantity of mica should be rejected. The grain size of the collected sand should not be too fine.

Fill a bottle with sand and water and shake vigorously and leave to settle. If the sand is clean the sedimentation will be less than 5mm after two hours. And the water above will only be lightly cloudy.



Gravel: Gravel can be collected from river deposits or by breaking boulders into the necessary size. The required sizes and their proportion should be

from organic contaminants like clay, loam, mud or stone dust etc.

5 to 20mm - 40% 20 to 40mm - 60%

Gravel should be of hard rock origin. Gravel of unsuitable rock such as mica, marl and sand stone should be rejected. Likewise flat and flaky particles should also be rejected. The collected gravel should be free

2.7.4 Transportation and storage of the materials

Material other than local materials has to be transported from road head to the site by porter or other means. These materials are mainly Cement, Steel Parts and Wire Ropes.

Cement Transportation and Storing: Utmost care should be given for transportation and storing of the cement. The prime importance is the proper packing of the cement before transportation to make it watertight and airtight. For this, cement bags as received from the market or factory should be double packed by additional packing with Nylon Bags and plastic layer inside. Re-opening the bags (especially when transporting by mules) is not permitted before use at the site.

The conditions must be met for the storing of the cement:

- Cement must always be stored under a roof with adequate protection from rain. A raised plank floor is necessary to prevent cement from damp.
- Storage must be arranged in such a way, that the oldest cement can be used first.

Steel Parts Transportation and Storing: There is a great chance of damage of steel parts during loading/unloading and transportation. The most common damage is:

- Deformation of cross beams and steel decks due to mishandling during loading and unloading,
- Deformation of suspenders and reinforcement bars due to mishandling during loading and unloading

The steel parts should be loaded or unloaded carefully to avoid above damages. Do not allow steel parts to fall from a height. Suspenders should be bound together with the crossbeam.

Similarly, the conditions must be met for the storing of steel parts to avoid any damage.

- Galvanized and non-galvanized steel parts must always be stored under a roof with adequate protection from rain and should not be in contact with the ground.
- Galvanized steel parts should not be transported and stored together with salt or acid.
- Steel parts should be stacked and stored element/component-wise separately, avoiding the mix up of different elements. Thus, any element or component can be easily located during the bridge erection.
- All fixtures (nut/bolts, washers, thimbles and bulldog grips) should be packed/marked and stored separately according to its sizes.
- Steel parts, particularly suspenders and reinforcement bars, should not be permitted to bend during portering and storage.

Wire Rope Transportation and Storing: It is vital to handle and transport the cable carefully to avoid any defects like kinks, splices and broken strands. Consider some examples of defects on cables due to mishandling and improper transportation.

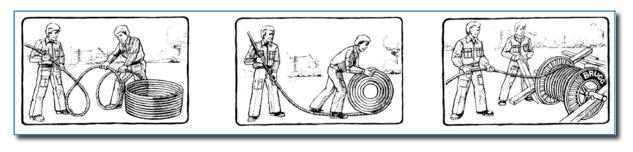
Also pulling or dragging the cable along the road for transportation is not permitted.





To avoid such defects, follow handling and transportation methods.

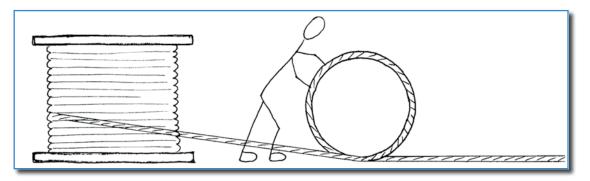
Method of Unreeling Light Cables with the Help of a Reel Support



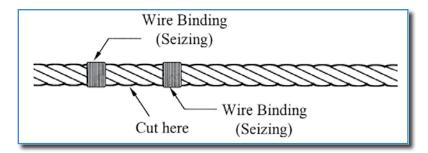
Correct

Correct

Method of Unreeling Cables by Unrolling Each Loop Taken from the Reel.



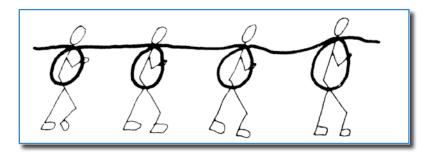
Before cable cutting, the cable ends should be tightened by a binding-wire (seizing) to avoid loosening of the cable wires.



Method of Transportation by Porters

Wrong

Such kinds of wrong cable transportation should not be practiced.



Wrong method of transportation

2.7.5 Masonry and Stone dressing work

Requirements for Building Stones: Building stones must be of high strength, density and durability. A good building stone should be hard, tough, compact grained and uniform in texture and color.

Crystalline stones are superior to non-crystalline stones. Metamorphic rocks are more durable than sedimentary rocks. Sedimentary rocks have been formed by water sediments of clay, sand or gravel, which got cemented together by lime, silica etc. Originally metamorphic rocks are either of volcanic or sedimentary origin but have subsequently been formed and shaped by movements of the earths' crust imposing high pressure and heat.

A good building stone absorbs no or very little water and must be free from decay, cracks and sand-holes.

Quarrying: Rocks for stone masonry works should be broken from a quarry by crowbars and wedges. Natural fractures and bedding planes of stratification are the weak features of rock. These natural joints are taken as advantage to break and separate one block from the other.

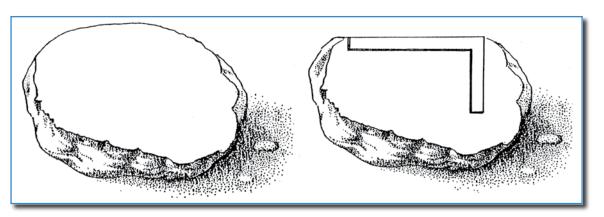
It is advised that only when natural joints do not exist those artificial fissures be made by drilling a line of holes in rows along the desired breaking line. By inserting conical wedges and driving them in succession with a hammer the rock will crack along the face of the holes.

However it is generally worthwhile to search for quarries with existing natural joints like dominant bedding planes, since the broken stones are much easier for dressing.

Boulders fallen from rocky slopes can also be used as building stones.

Building stones are first dressed to obtain two parallel planes, and then outward faces must be dressed well with the help of the square bottom.

outward face



Stones from the riverbed are generally very hard and durable and can be used as filling stone, but are not suitable for stone dressing.

Stone Dressing: Broken stones from the quarry are to be dressed by hammer or chisel to required sizes. Depending on the function of the stone in stone masonry construction the types of stones have to be prepared:

• **Corner Stone:** The corner stone is placed at each corner of the stone masonry structure. Recommended sizes are:

Length: 30 - 85 cm Width: min. 30 cm Height: min. 10 cm • Face Stone: Only one face of this stone faces outside; recommended sizes are:

Length: 30 - 75 cm Width: min. 30 cm Height: min. 10 cm

Bond Stone: Like the face stone only one face is outside, but the bond stone extends to the

interiors of the structure. Bond stones, also called through stones, go right

through walls of up to 85 cm thick or more. Recommended sizes are:

Length : 45 - 85 cm

Width: min. 30 cm (face side)

Height: min. 10 cm

Coping Stone: Copingstones are put on top or at steps of stone masonry structures. They

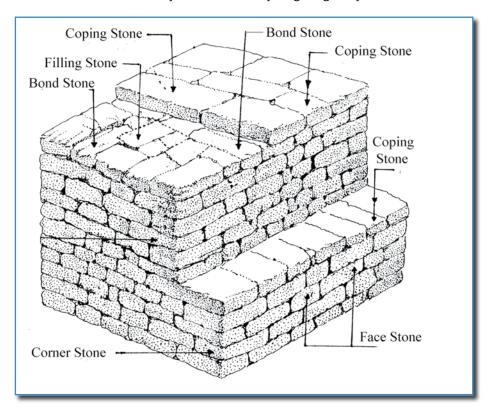
should be larger and heavier than the stones:

Length : as large as possible Width : as large as possible

Height: min. 10 cm

• Filling Stone: Filling stones do not need to be dressed and are placed in the inner part of the

stone masonry structure mainly to gain gravity load.



Stone Masonry Laying: There are many different kinds and types of stone masonries. For constructing anchor blocks and towers, only coursed (in layers of equal height) stone masonry is applied.

There are two types of stone masonry used for bridge construction:

Coursed Random Rubble Stone Masonry

The stones are hammer-dressed, except the inside face. Gaps between beds and joints shall not exceed 12 mm. All **Face Stones** tail into the wall twice their height.

Bond Stones running right through the wall are inserted at least at every 150 cm intervals.

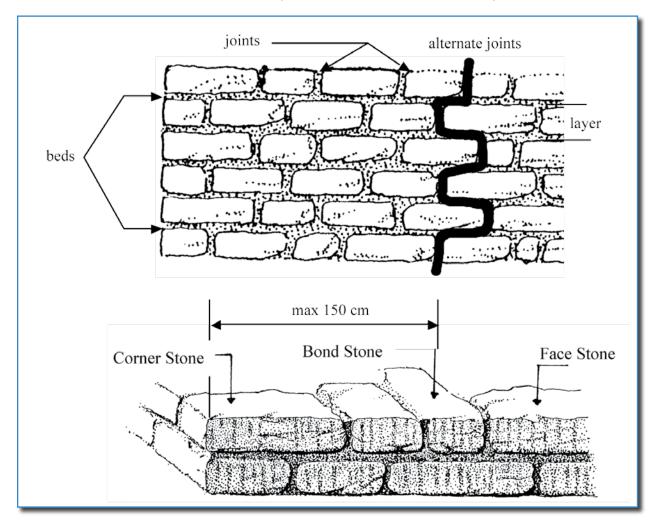
Coursed Block Stone Masonry

The stones are chisel-dressed at all faces, except the inside face. Joints are dressed at right angles to the face. Gaps between beds and joints should not exceed 6 mm.

All Face Stones tail into the wall twice their height.

Bond Stones running right through the wall are inserted in each course at least at every 150cm intervals.

Course Stone Masonry must be made in **layers** of equal height. Individual layer heights may vary but should never be less than 10 cm. **Alternate** joints shall be made between the layer above and below.



In a reasonably well made stone masonry the inner friction between the beds amounts to approx. 35°.

The verification of corners as well as faces has to be checked carefully with the plumb-bob.

Correct use of plumb-bob



The Strength of stone masonry structures depends mainly on the qualities.

bigger	The Streng	gth of Stone M	lasonry is	smaller
with rectangular stones.		Form or Shape		with irregular stones.
the less stones are used.		Number		the more stones are used.
the rougher the joints are.		Roughness of joints		the smoother the joints are.
the smaller the beds are.		Bed		the bigger the beds are.
the more compact the stones are.		Height & Width		the slimmer the stones are.
the better the bond across is.		Bond Across (in plan view)		the worse the bond across is.
the higher strength of the mortar is.	→	Strength of Mortar	+	the lower the strength of the mortar is.

2.7.6 Cement works

(A). Composition and Mixtures

Cement concrete is a mixture of 4 components:

- Cement: Ordinary Portland Cement commonly used for general construction works;
- Sand;
- Gravel;
- Water.

Cement is very sensitive to humidity and moisture; therefore it should never be stored for a long time. In the rainy season cement bags have to be packed in additional sealed plastic bags plus additional nylon bags for protecting the cement against water and the plastic bags against damage.

Sand should be clean, sharp, angular, hard and durable. Sand must be well washed and cleaned from mud or any organic material before use. Well-graded sand should be used for cement works. All or most of the sand should pass through a 3 mm sieve or mesh wire. However sand should not be too fine, only max. 15% of the sand can be smaller than 150 microns, which is like dust.

Gravel should be clean, hard, angular and non-porous. Usually riverside gravel makes the best aggregate for preparing concrete. The corn size of gravel should be smaller than 40 mm (1½ inches) but bigger than 5mm.

Water from rivers or lakes is usually suitable for making cement mixtures. Do not use water from ponds or swamps; this water may contain a lot of organic materials.

The main characteristics of any cement work are given by the mix proportions of their components:

- Cement Mortar = Mix between Cement & Sand
- Cement Concrete = Mix between Cement, Sand & Gravel

Of course, Water is added in both cases, but the mix proportions of cement, sand and gravel give the main characteristics of any cemented work.

Mixing above components thoroughly is of utmost importance. Hand mixing should be done on a clean watertight platform. Cement and Sand should first be mixed dry, and then gravel added. Now the whole mixture should be turned over 3 times dry. Then mixing should take place for at least 5 minutes by slowly sprinkling water until the concrete is of a uniform color. The table depicts the most commonly used mix proportions and required quantities:

Table F.2.11: Quantities for various Types of Cement Works

T(Mix.	propo	rtio	ns	Dry required o	quantiti	es for on	e cubic r	meter wet:
Type of Cement Work	Cement		Sand		Gravel	Cement bags @ 50 kg	kg	Sand [m³]	Gravel [m³]	Stones or Boulders [m³]
	1	:	1		_	20.4	1020	0.71	-	-
Cement	1	:	2		-	13.6	680	0.95	_	_
Mortars	1	:	3		-	10.2	510	1.05	_	-
inortars	1	:	4		-	7.6	380	1.05	_	-
	1	:	6			5.0	250	1.05	_	-
Cement Plaster (20 mm includes 12% waste)	1 1	:	4 6		- -	0.18 0.12	9	0.024 0.024		- -
Cement Stone	1	:	4 6		uncoursed stone masonery	2.66 1.75	133 87.5	0.37 0.37	-	1.2 1.2
Masonries	1 1	:	4 6		uncoursed stone masonery	2.28 1.50	114 75	0.32 0.32	- -	1.25 1.25
Cement Concretes (plain or reinforced)	1 1 1	:	4 3 2 1½	:	8 6 (M10) 4 (M15) 3 (M20)	3.4 4.4 6.4 8	170 220 320 400	0.47 0.46 0.45 0.42	0.94 0.92 0.90 0.84	- - - -
"Plum" Concrete	1	: with	3 50% bo	: uld	~	2.64	132	0.28	0.54	0.50

The amount of **Water** should be about 50% or half the volume of cement. One 50 kg bag of cement has a volume of approx. 35 liters, which is equal to approx two kerosene tins.

Concrete and **Mortars** should be placed in its final position within one hour! After placing it should be well compacted by rods in order to remove any air pockets. For a concrete of high quality good compaction is essential. This may mean extra work during placing, but on no account should more water be added for reducing compacting work. Concreting should never be done if it is raining.

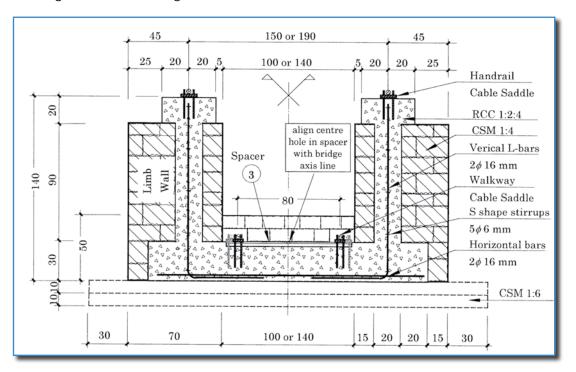
Curing means keeping completed cement works wet until its setting process is completed. If concrete works are not continuously kept wet during its setting process, cement mortars, cement stone masonry work and especially concrete does not develop its full strength. Curing should be done for at least 28 days.

For increasing the strength of concrete, ripped Tor-Steel bars are added which makes Reinforced Cement Concrete or RCC.

(B). Concrete Work for Cement Stone Masonry (CSM) Towers

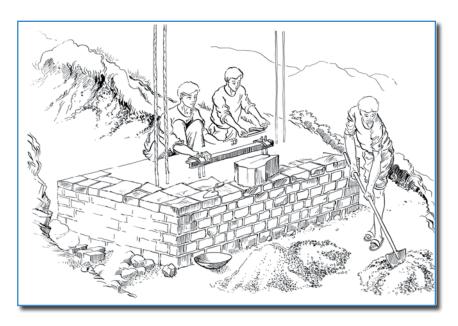
The CSM Towers or Limb Walls are concreted together to form one solid unit (See Drawing Nos. 20Dcon70 & 20Dcon106). The core and the connection of both the towers are made in R.C.C 1:2:4, whereas the limb walls are made in CSM 1:4.

Section through CSM Tower (Bridge Entrance)

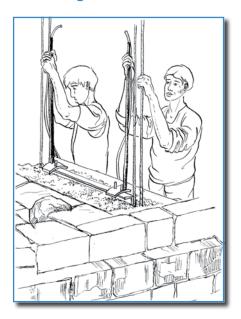


Placing the Saddles for the Walkway Cables

The saddles for the walkway cables are to be placed in between the towers. The position of the saddles has to be checked thoroughly and the levels can be controlled with the help of a transparent plastic pipe filled with water (Level Pipe).



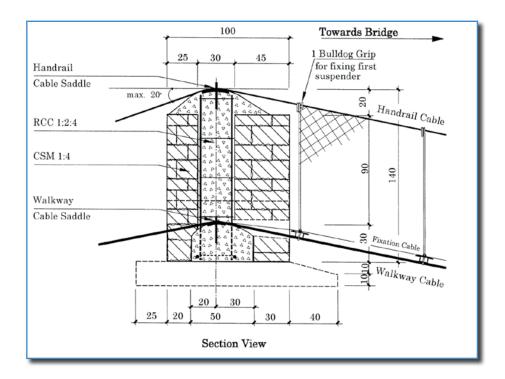
Concreting Work for CSM Tower



Checking Level of Walkway Cable Saddles

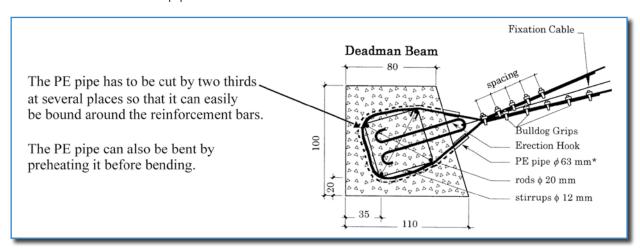
• Construction of Towers and Placing Saddles for Handrail Cables
The Towers or Limb walls support the handrail cables. The limb walls are made out of cement stone masonry 1:4 with a R.C.C. core.

The handrail cable saddles are to be placed on top of the "hump" of the limb wall. Make sure that the position and shape of the "hump" is correct so that the handrail cable touches the saddle plate only.

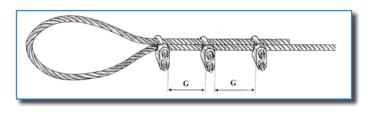


(C). Constructing the Deadman Beam

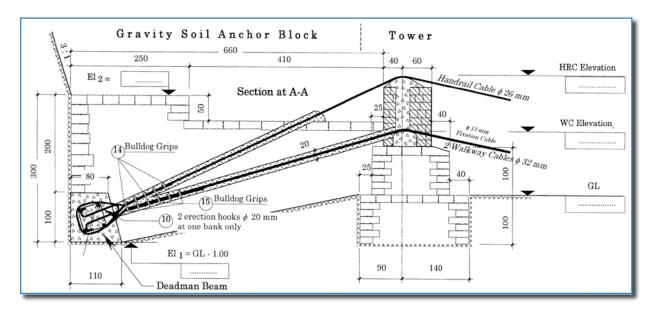
The Deadman Beam is a soil anchor cast in reinforced cement concrete R.C.C that lies buried under the gravity structure. The handrail and walkway cables are placed around the reinforcement bars before concreting the beam. At one bank the cables are inserted into a polyethylene (PE) pipe, so that the cables can still be moved while sag setting. Tensioning cable must be tightened with the bridge of bulldog grip. Use leftover plastic or cloth from cement bags to cover open parts of the pipe so that no concrete can flow into the pipe.



Nos & spacing of Bulldog Grips						
Cable dia mm	Nos	G				
13	5	10 cm				
26	6	15 cm				
32	3	20 cm				



Place and Fix Reinforcement Bars, Stirrups and Erection Hooks.



The Deadman Beam is casted in concrete 1:2:4

The fixation cable can be anchored at the temporary erection hook or fixed at one of the walkway cables.

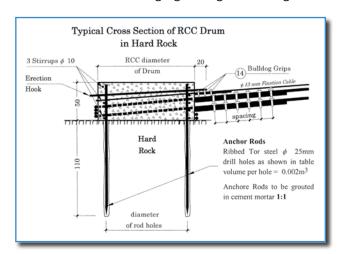
(D). Constructing Drum Anchorages in Rock

There are two types of Drum Anchorages in Rock:

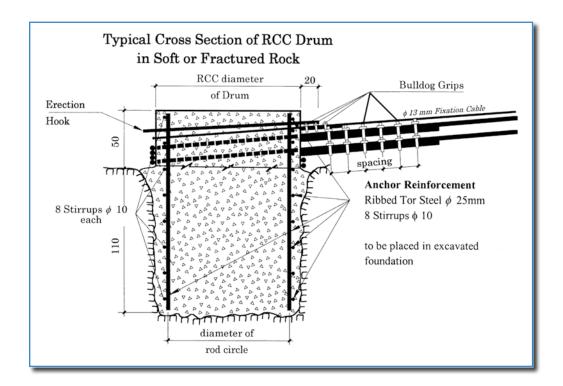
- R.C.C Drum Anchor in Hard Rock;
- R.C.C Drum Anchor in Soft or highly fractured Rock.

Drum Anchorages in Hard Rock are made by drilling holes of 32 mm diameter (= diameter of crowbar) into the rock. Clean boreholes from dust and debris by flushing them with water.

Fill the holes with cement mortar 1:1 before the anchor rods are inserted. The formwork for the drum is made by a chitra (bamboo mat) or plain G.I. sheet inside lined with a plastic sheet. Use binding wire around the chitra to prevent the bamboo mat bulging during concreting.



Drum Anchorages in soft or fractured rock are **not** done by drilling holes but by excavating a round pit instead. The Anchor Reinforcement has to be placed into the pit and is fixed with the help of stirrups. The excavated pit is then filled and well compacted with concrete 1:2:4 up to ground level. At this stage the anchor rods should protrude (stand out) by approx. 40 cm. The formwork for the drum is made by a chitra (bamboo mat) inside lined with a plastic sheet bound together with a binding wire.



2.7.7 Cable hoisting and sag setting

Cables are hoisted and the prescribed sag set after the Deadman Beams or the Drum Anchors have been concreted. Please note that it takes 4 weeks until cast concrete develops its full strength. Therefore, the final cable pulling is done after a minimum of 4 weeks.

(A). Calculation of Hoisting Sag

Before starting any hoisting work, the actual span l from saddle to saddle of the bridge and the actual difference of elevation h between the walkway cable saddles have to be measured first and filled into Design Form: Calculation of Hoisting Sag .

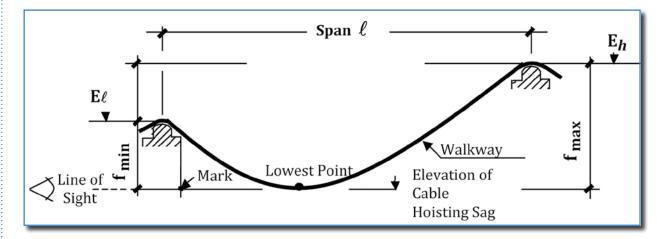


Table F.2.12: Calculating Elevation of Low Point for Cable Hoisting

1. Actual Span measured in the Field		1	= m
2. Saddle Elevation of the Walkway C	Cable on the higher side	$\mathbf{E}_{\mathbf{h}}$	= m
3. Saddle Elevation of the Walkway C	Cable on the lower side	$\mathbf{E_l}$	= m
4. Difference in Elevation	$\mathbf{h} = \mathbf{E_h} - \mathbf{E_l} =$	= h	= m
5. Dead Load Sag			
For Span up to 80 meters:	$b_d = \frac{\ell}{20}$	= b _d	= m
For Span over 80 meters:	$\mathbf{b_d} = \frac{\ell}{22}$	= b _d	= m
6. Hoisting Sag	$b_h = 0.95 \times b_d$	= b _h	= m
7. f _{min} in hoisting case	$f_{min} = \frac{(4 \cdot b_h - h)^2}{16 \cdot b_h} =$	= f _{min}	= m
8. f _{max} in hoisting case	$\mathbf{f}_{\max} = \mathbf{f}_{\min} + \mathbf{h}$	$= \mathbf{f}_{max}$	= m
9. Elevation of Cable low point in hois	sting case = $\mathbf{E_l} - \mathbf{f_m}$	in	= m

- Mark the calculated elevation of the cable hoisting sag (low point) on a prepared stick, tree or at the tower foundation.
- Now set up the Abney Level or Leveling Instrument at the Elevation of the cable hoisting sag so that the line of sight can easily see the mark and the low point of the cable. Setting up the Leveling Instrument at the calculated Elevation has to be done by trial and error and may take several attempts.

(B). Cable Hosting

Cables are first pulled by hand and for final sag setting with the help of the cable pulling machine or tirfor, which is fixed at the erection hook.

- Pull the cable until it reaches a level of about 20 cm higher than the calculated Elevation. Each cable should be left in this "over-pulled" position for at least 12 hours. "Over-pulling" is done to prevent any later relaxation of the cable, which may lead to a tilted walkway.
- For actual and precise sag setting first firmly clamp the special cable belonging to the tirfor machine to the backstay portion of the cable to be pulled. Then fix the tirfor machine at the erection hook and insert the special cable through the cable-pulling machine. Now apply force until the special cable is firmly under tension. Now loosen, **do not remove**, the bulldog grips. The cable should now be held by the tirfor machine only. Slowly release some force by carefully moving the lever of the cable-pulling machine until the desired pre-calculated Elevation has been reached. When this is the case immediately retighten the bulldog grips, then completely release the tension applied by the tirfor machine.

The cable should now hang in proper hoisting position. If the low point has gone below the hoisting Elevation the whole process has to be repeated.

That means the cable has again to be over-pulled and then slowly released.

Check also that parallel cables have equal hoisting sag.

2.7.8 Finalizing the cable anchorage

After the cables have been pulled and the hoisting sag is firmly set the Cable Anchorage has to be fully completed before any fitting works for the walkway can start.

(A). Rust Protection for the Cable

To achieve optimal rust protection, paint the cables in the gravity structure with coal tar and then cover with 20×20 cm cement concrete 1:3:6. Before painting, the bulldog grips need to be checked and retightened if required.

(B). Completing the Gravity Structure

The actual gravity structure on top of the Dead Man Beam or Drum Anchors is constructed according to the respective construction drawing. The side and back walls as well as the top are made of coursed cement stone masonry 1:6, whereas the inside is filled with broken stones. The cement stone masonry work for the walls has to be made with hammer dressed stones of equal layer height. The broken stones for filling the inside should not be thrown but laid and interlocked as for as possible.

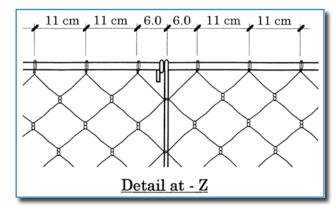
Only after the gravity structure is completed can fitting work for the walkway structure start.

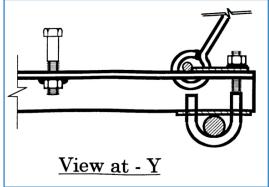
2.7.9 : Walkway fitting

The fitting work for the walkway must only start after the gravity structure of the cable anchorage has been completed. Walkway fitting is simple and self-explanatory. Refer also to the construction Drawings No. 19Dcon70 or 19Dcon106 respectively.

Points must be observed:

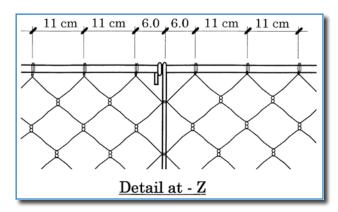
- Start fitting from one bank only
- First fit crossbeam, steel panels or wooden planks as close as possible to the bridge entrance.
- Always start fitting walkway deck with a "Half Panel" then continue with "Standard Panels" only.
- Fix J-bolts at crossbeams first loosely and hang pre-bent suspender over handrail cable.
- Avoid accidents by bolting panels loosely immediately after placing.
- Maintain equal vertical distance between handrail and walkway cable by using a support guide ("Tokche") made of wood or bamboo.
- Always finish walkway fitting with "Special Panels" and cut off extra length by hacksaw.
- Check and retighten all Nuts and Bolts after completion of walkway fitting.
- If wood is used for the bridge deck, the planks should be 2 meter long and min. 4 cm thick and should be fitted in staggered way. Use washers below Bolt Heads. Distance between Crossbeams is 1 meter.





Fencing is woven on the spot with gabion wire (12SWG) between the handrail cable and the fixation cable. First fix the fixation cable by pulling it through the bottom eye of the suspender along either side of the walkway, and then join it with the short piece at the other end of the bridge.

...for Fence weaving



2.7.10 Water management backfilling and general finishing works

(A). Water Management

The life expectancy of the bridge largely depends on proper water management.

Any **water seepage** encountered during excavation should be intercepted as close as possible to its origin and channeled safely to a nearby watercourse. Especially vulnerable is the place **behind the Deadman Beam**! If in doubt, or in case of unusual humidity of water seepage, provide a drain behind the Deadman Beam with side outlet. Sometimes water seepage occurs during rainy season only. Inquire with the local people.

Divert surface water and provide drainage channels as necessary. Do not hamper existing irrigation channels, rather improve and adjust them with some cement works. Discuss solutions with local people and decide on the spot.

As a general rule divert water as far away from bridge foundations as possible.

For managing surface water well, also fill the gaps around completed anchor blocks well above the existing surface. Back filling prevents surface water to flush out excavations.

Do Back Fill !!!

(B). Finishing Work

Provide finishing structures like retaining walls, staircases, small trail improvements, adjustments to nearby houses etc., if it adds functional value to the bridge.

Never do cement pointing or other non-functional works.

Also check the vegetation and plant life in the vicinity of the bridge. Plant some new trees if possible, especially if some had to be cut for bridge construction.

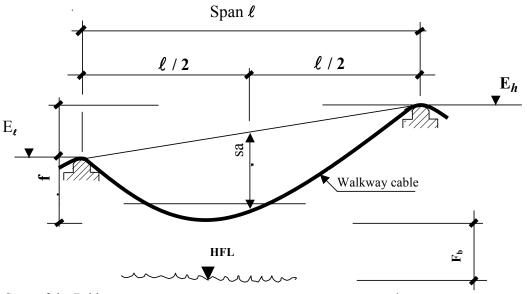
Suspended Trail Bridge Design Form

- 1. Cable Design
- 2. Anchor Block Design
- 3. Bridge Standard Drawings

Bridge Name:
River Name:
Woreda Name:
Designed by:
Data

1. Cable Design for Suspended Bridge Type

A. Survey Data & Calculation of Freeboard



1. Span of the Bridge

- ℓ = m
- 2. Saddle Elevation of the walkway cable on the **higher** side
- $\mathbf{E_h} = \dots m$
- 3. Saddle Elevation of the walkway cable on the **lower** side
- $\mathbf{E}_{\ell} = \dots m$

4. Difference in Elevation (max. permissible height: $h_{max} = \ell/25$)

$$\mathbf{h} = \mathbf{E}_{\mathbf{h}} - \mathbf{E}_{\boldsymbol{\ell}} = \mathbf{h} = \dots$$
 m

5. Dead Load Sag (fixed ratio) (in the middle of the bridge)

$$\mathbf{b_d} = \frac{\ell}{22} = \qquad \qquad \mathbf{b_d} = \dots$$

6. f min in Dead Load Case (at the lowest point of the cable)

$$f_{min} = \frac{(4 \cdot b_d - h)^2}{16 \cdot b_d} = f_{min} = \dots m$$

7. Highest Flood Level

$$\mathbf{H}_{\mathbf{Fl}} = \dots m$$

8. Free Board (min. 5.00m)
$$\mathbf{F_h} =$$

$$\mathbf{F_b} = \mathbf{E_\ell} - \mathbf{H_{Fl}} - \mathbf{f_{min}} = \mathbf{F_b} = \boxed{\dots m}$$

(if freeboard is less than 5.00m, try either to raise the saddle elevations or to adjust the span, but keep the ratio between span and sag always fixed, $\ell/b_d=22$)

B. Selection of Cables

Select a cable combination according to the span and walkway width of the bridge. Always select the higher cable combination, when the span is in between two values.

	Span for / Width:		Cable Combinations		Weight of all Cables	
70cm	106cm	Handrail Cable		Handrail Cable Walkway Cable		gh
span [m]	span [m]	nos	Ø mm	nos	Ø mm	[kg/m]
50	40	2	26	2	26	10.04
90	60	2	26	2	26	2.62
100	75	2	26	2	26	15.06
120	105	2	26	2	26	20.22
	120	2	32	2	32	22.80

Above cable combinations are calculated for the specifications:

Cables: construction 7 x 19, wire strand core, 160 kg/mm² tensile strength of wire

Safety Factor: minimum 3 or higher than 3

Live load p = (300+5000/span) kg/m2 according to Standard of the Suspension Bridge Division

or p = 400 kg/m2 if the span is 50.0 m or less **Sag to Span Ratio:** = 22 in dead load case; this is a fixed ratio **Max. Permissible Height Difference of Saddles:** h = span/25

Example:

width of walkway = 70cm; span = 88m

Selected cable combination:

 $\begin{array}{lll} \mbox{Handrail Cables} & 2 \varnothing & 26\mbox{mm} \\ \mbox{Walkway Cables} & 2 \varnothing & 32\mbox{mm} \\ \mbox{Weight of Cables} = 12.62\mbox{kg/m} \end{array}$

Selected Cable combination and parameters from the table above:

HRC	Handrail Cables:	nos 2 Ø	mm
WWC	Walkway Cables:	nosØ	mm
Weight of all Cables per meter		g_h	kg/m

C. Calculation of Cable Length

Type of Cable	dia (mm)	Nos	Backstay Length * [m]	Cutting Length** [m/pc]
Fixation Cable	13	2		
Handrail Cable		2		
Walkway Cable		-		

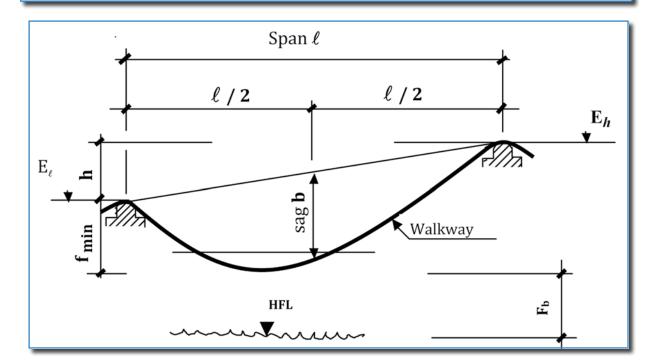
^{*} Backstay Length = Cable length between saddle center and center of dead man or drum as per foundation drawing (both banks) + 6.0m.

^{**} Cutting Length = 1.1 x Span + Backstay Lengths

D. Calculation of (fmin & fmax) Hoisting Sag

This calculation has to be made after tower and foundation work is completed

- 1. Actual Span measured in the Field $\ell = \dots m$
- 2. Saddle Elevation of the walkway cable on the **higher** side $E_h = \dots = m$
- 3. Saddle Elevation of the walkway cable on the **lower** side $\mathbf{E}_{\ell} = \dots$ m
- 4. Difference in Elevation $\mathbf{h} = \mathbf{E_h} \mathbf{E_\ell} = \mathbf{h} = \dots \mathbf{m}$
- 5. Dead load sag $\mathbf{b_d} = \frac{\ell}{22} = \mathbf{b_d} = \dots m$
- 6. Hoisting Sag $b_h = 0.95 \text{ x } b_d = b_h = \dots m$
- 8. \mathbf{f}_{max} in hoisting case $\mathbf{f}_{max} = \mathbf{f}_{min} + \mathbf{h} = \mathbf{f}_{max} = \dots m$
- 9. Elevation of Cable low point in hoisting case = $\mathbf{E}_{\ell} \mathbf{f}_{\min}$ = ______n



Anchorage Block Design (Foundation) for Suspended Bridge Type

A. Design Data

Fill in the design data

 Walkway Width, WW (70 or 106cm):cm Bridge Span:m Bank Condidtion: 						
Right Bank						
Geology:	Soil		or		Rock	
If Soil, how is the Ground Surface?	Flat (up to 10° slo	pe)	or		Hill Slope (more than 10°	slope)
What is the Soil Type?	Gravelly		Sandy		Silty	
If rock, what is the rock type? (data from Survey Form and Check list)	Hard Rock (only few frac	tures)	Hard Rock (highly fract	ures)	Soft Rock	
Tower Height from Ground up to H.C. Saddle (data from bridge profile):	2.4m		3.4m		4.4m	
Left Bank						
Geology:	Soil		or		Rock	
If Soil, how is the Ground Surface?	Flat (up to 10° slo	pe)	or		Hill Slope (more than 10°	slope)
What is the Soil Type?	Gravelly		Sandy		Silty	
If rock, what is the rock type? (data from Survey Form and Check list)	Hard Rock (only few frac	tures)	Hard Rock (highly fract	ures)	Soft Rock	
Tower Height from Ground up to H.C. Saddle (data from bridge profile):	2.4m		3.4m		4.4m	

B. Selection of anchorage blocks

Select appropriate anchorage blocks at Right and Left Bank according to the above design data. Procedure for selection:

According to the Soil/Rock type and Slope of ground, refer to respective table for selection of Anchorage Block:

for Soil and Flat Ground : **Table F.2.13**for Soil and Hill Slope : **Table F.2.14**

for Hard Rock for Fractured Hard Rock or Soft Rock,

Span up to 90m (WW = 70cm) and upto 60m (WW = 106cm) : **Table F.2.17 or Table F.2.18**

: Table F.2.15 or Table F.2.16

Span Range 91-120m (WW = 70cm), 61-120m (WW = 106cm) : **Table F.2.19**

In the table match the design data: selected Walkway Width → Bridge Span → Tower Height → Soil type → select the corresponding Block Type and Drawing No. for right bank and for left bank respectively.

Selection Tables

In Soil and Flat Ground:

Table F.2.13: Selection of Gravity Soil Anchor Block in Flat Ground

Span R	ange, m	Tower	Foundation		
Walkway:70cm	Walkway:106cm	Height [m]	Soil Type	Block Type	DrawingNo.
		2.4		1F	21Dcon
Up to 45m	Up to 30m	3.4	All	2F	22Dcon
		4.4		3F	23Dcon
		2.4		4F	24Dcon
46 - 90	31 - 60	3.4		5F	25Dcon
		4.4		6F	26Dcon
		2.4	All	7F	27Dcon
91 - 120	61 - 75	3.4		8F	28Dcon
		4.4		9F	29Dcon
	76 - 90	2.4		10F	30Dcon
-		3.4	All	8F	28Dcon
		4.4	4.4	11F	31Dcon
		2.4		12F	32Dcon
-	91 - 105	3.4	All	8F	28Dcon
		4.4		13F	33Dcon
		2.4	Gravely	12F	32Dcon
	10/ 120	∠.4	Sandy, Silty	14F	34Dcon
_	- 106 - 120 3.4	All	15F	35Dcon	
		4.4	All	13F	33Dcon

In Soil and Hill Slope:

Table F.2.14: Selection of Gravity Soil Anchor Block in Hill Slope

Span R	ange, m	Tower Foundation						
Walkway:70cm	Walkway:106cm	Height [m]	Soil Type	Block Type	DrawingNo.			
Up to 60m	Up to 40m	2.4	All	1S	41Dcon			
61 - 90	41 - 60	2.4	All	2S	42Dcon			
91 - 120	61 - 75	2.4	All	3S	43Dcon			
			Gravely	4\$	44Dcon			
_	76 - 90	2.4	Sandy	5S	45Dcon			
						Silty	6S	46Dcon
		2.4	Gravely, Sandy	7S	47Dcon			
_	91 - 105	2.4	Silty	8S	48Dcon			
	10/ 120	2.4	Gravely, Sandy	8S	48Dcon			
_	106 - 120	2.4	Silty	95	49Dcon			

In Hard Rock for all Span Ranges:

Table F.2.15: Selection of RCC Single Drum Anchor in Hard Rock

Span Range, m		Tower Height	Dia de Trus	Drowing No.
Walkway: 70cm	Walkway: 106cm	[m]	Block Type	Drawing No
up to 90	up to 60	2.4	1HRS	61Dcon
91 – 120	61 - 120	2.4	2HRS	62Dcon

When slope is too steep and there is not enough space for single drum anchorage system (Table F.2.15), select the double drum system from Table F.2.16.

Table F.2.16: Selection of RCC Double Drum Anchor in Hard Rock

Span Range, m		i ower rieight		Drawing No.
Walkway: 70cm	Walkway: 106cm	[m]	Block Type	Drawing No
up to 90	up to 60	2.4	1HRS	63Dcon
91 – 120	61 - 120	2.4	2HRS	64Dcon

In Fractured Hard Rock/Soft Rock for Span Range up to 90m (WW = 70 cm) and 60m (WW = 106cm):

Table F.2.17: Selection of RCC Single Drum Anchor in Fractured Hard Rock/Soft Rock

Span Ra	ange, m	Tower Height	Block Type	Drawing No
Walkway: 70cm	Walkway: 106cm	[m]	Block Type	Drawing No
up to 90	up to 60	2.4	1FRS	65Dcon

When slope is too steep and there is not enough space for single drum anchorage system (Table F.2.17), select the double drum system from Table F.2.18.

Table F.2.18: Selection of RCC Double Drum Anchor in Fractured Hard Rock/Soft Rock

Span Ra	Span Range, m		Block Type	Drowing No.
Walkway: 70cm	Walkway: 106cm	[m]	ыоск туре	Drawing No
up to 90	up to 60	2.4	1FRD	66Dcon

In Fractured Hard Rock/Soft Rock for Span Rang of 91-120m (WW = 70 cm) and 61-120m (WW = 106cm):

Table F.2.19: Selection of RCC Deadman Anchor in Fractured Hard Rock/Soft Rock

Span Range, m		Tower Height	Block Type	Drawing No
Walkway: 70cm	Walkway: 106cm	[m]	Block Type	Drawing No
91-120	61-120	2.4	2FRD	67Dcon

Selected Anchorage Foundation type and corresponding drawings from the table above:

Right Bank:	Block Type, Drawing No
Left Bank:	Block Type, Drawing No

If rock, what is the rock type?

 Walkway Width, WW (70 or 106cm): 70 cm Bridge Span: 88m Bank Condidtion: 						
	Right Bank					
Geology:	Soil	or	Rock			
If Soil, how is the Ground Surface?	Flat (up to 10° slope)	or	Hill Slope (more than 10° slope)			
What is the Soil Type?	Gravelly	Sandy	Silty			
If rock, what is the rock type? (data from Survey Form and Check list)	Hard Rock (only few fractures)	Hard Rock (highly fractures)	Soft Rock			
Tower Height from Ground up to H.C. Saddle (data from bridge profile):	2.4m	3.4m	4.4m			
	Left Ban	k				
Geology:	Soil	or	Rock			
If Soil, how is the Ground Surface?	Flat (up to 10° slope)	or	Hill Slope (more than 10° slope)			
What is the Soil Type?	Gravelly	Sandy	Silty			
If rock, what is the rock type? (data from Survey Form and Check list)	Hard Rock (only few fractures)	Hard Rock (highly fractures)	Soft Rock			
Tower Height from Ground up to H.C. Saddle (data from bridge profile):	2.4m	3.4m	4.4m			
==> Selected Anchorage Blocks Right Bank: Block Type 5F, Drawing No. 25Dcon Left Bank: Block Type 1HRS, Drawing No. 61Dcon						

Bridge Standard DrawingsSelect the required Steel Drawings and Construction Drawings from the drawing list.

2.8 **Steel Drawings**

Drawing Title	Drawing No	Required Drawing
Walkway Cross Beams	02D or 02D4 or 03D or 03D4	
Saddle and Reinforcement for RCC Deadman	20D2 or 20D4	RB:
and Gravity Soil Anchor	20D2 of 20D4	LB:
Saddle and Reinforcement for RCC Deadman	20D4S	RB:
Anchor in Soft or Fractured Hard Rock	20043	LB:
Saddle and Reinforcement for Drum Rock	(002 - 4004	RB:
Anchor	60D2 or 60D4	LB:
Steel Deck	11A, 12A and 13A	11A, 12A and 13A

2.9 Construction Drawings

Drawing Title	Drawing No	Required Drawing
Walkway Fitting	19Dcon70 or 19Dcon106	
Details of Cement Stone Masonry Tower & RCC Core	20Dcon70 or 20Dcon106	
RCC Deadman and Gravity Soil Anchor Block	21Dcon35 Dcon	RB:
for Flat Ground		LB:
RCC Deadman and Gravity Soil Anchor Block		RB:
for Hill Slope	41Dcon49Dcon	LB:
PCC Single Drum Pools Anghor in Hard Pools	61Dcon or 62Dcon	RB:
RCC Single Drum Rock Anchor in Hard Rock	61Dcon or 62Dcon	LB:
		RB:
RCC Double Drum Rock Anchor in Hard Rock	63Dcon or 64Dcon	LB:
RCC Single Drum Rock Anchor in Soft or		RB:
Fractured Hard Rock	65Dcon	LB:
RCC Double Drum Rock Anchor in Soft or		RB:
Fractured Hard Rock	66Dcon	LB:
		RB:
RCC Deadman in Soft or Fractured Hard Rock	67Dcon	LB:

Designed by:	Date:
Cable hoisted by:	Date:
Example:	
==> Selected Drawings	
Steel Drawings	

Drawing Title	Drawing No	Required Drawing
Walkway Cross Beams	02D or 02D4 or 03D, or 03D4	02D
Saddle and Reinforcement for RCC Deadman and Gravity Soil Anchor	20D2 or 20D4	RB: 20D2
		LB: x
Saddle and Reinforcement for RCC Deadman Anchor in Soft or Fractured Hard Rock	20D4S	RB: x
Saddle and Reinforcement	60D2 or 60D4	LB: 60D2
for Drum Rock Anchor	0002 01 0004	RB: 60D2
		LB: x
Steel Deck	11A, 12A, 13A	11A, 12A, 13A

Construction Drawings

Drawing Title	Drawing No	Required Drawing
Walkway Fitting	19Dcon70 or 19Dcon106	19Dcon70
Details of Cement Stone Masonry Tower & RCC Core	20Dcon70 or 20Dcon106	20Dcon70
RCC Deadman and Gravity Soil Anchor Block for Flat Ground	21Dcon35 Dcon	RB: 25Dcon LB: x
RCC Deadman and Gravity Soil Anchor Block for Hill Slope	41Dcon49Dcon	RB: x LB: x
RCC Single Drum Rock Anchor in Hard Rock	61Dcon or 62Dcon	RB: x LB: 61Dcon
RCC Double Drum Rock Anchor in Hard Rock	63Dcon or 64Dcon	RB: x LB: x
RCC Single Drum Rock Anchor in Soft or Fractured Hard Rock	65Dcon	RB: x LB: x
RCC Double Drum Rock Anchor in Soft or Fractured Hard Rock	66Dcon	RB: x LB: x
RCC Deadman in in Soft or Fractured Hard Rock	67Dcon	RB: x LB: x

3.2

SUSPENSION TRAIL BRIDGE

3.1 Background

This Chapter follows the actual step-by-step process of constructing a suspension (N-type) bridge. It deals with all the necessary information, drawings and formats for the construction of a suspension type cable bridge.



Figure: F.3.1: Suspension type bridge, Endamayno, Tigray Region

Presentation of the suspension bridge type

This type of bridge has an upward cambered walkway. The main cables are hung over the towers and anchored to the main anchorage foundations. The walkway cables (Spanning cables) are anchored to the tower foundations. The main components of this bridge are: Main cables and Spanning cables, Towers, Walkway system, Main anchorage foundations and Walkway/Tower foundations.

This type of bridge is selected when the bridge site is comparatively flat terrain and the Suspended type bridge is not feasible due to insufficient free board. The Suspension type bridge is more expensive and needs more inputs to design and construct than the Suspended type bridge.

The major structural elements of the suspension bridge presented in this Manual are steel wire ropes of \emptyset 13, 26 and/or 32mm which are anchored by gravity soil or rock anchors at either side of the river. The superstructure is completely unstiffened and thus allows "some" reasonable degree of lateral, vertical and torsional vibrations.

For economic reasons steel has been used as little as possible, and cement has been applied for guarantying the durability of the structures. There are only four towers (pylons) the user can choose from. They are supported by hinged bearings at the bottom. Turnbuckle systems for fine adjusting the main cables are only provided at one anchor, whereas provisions for later adjusting the spanning cables turnbuckles are applied at both the walkway and tower foundations.

For reducing vibrations and uncomfortable swinging, the bridge deck has been reinforced by two 2" G.I. pipes underneath the walkway. These pipes can also be used for carrying drinking or irrigation water across the river.

Adequate measures have been foreseen to install wind-bracings when needed.

Technical features and limitations

3.3

The Short Span Trail Bridge Standard as presented in this Chapter conforms to mainly Indian Standard, but also Swiss and German codes and norms have been applied. All its components fulfill the necessary safety factors by applying the loadings prescribed in the Long Span Trail Bridge standard design. All the construction materials conform to international specifications. The exposed steel parts are all hot dip galvanized, and should not be altered unless proven to fulfill standard norms.

For practical, economic and safety reasons the span range for the Short Span Trail Bridge Standard presented in this Manual is limited to 120 m.

Longer spans are possible but would require special engineering input. As with every standard design, not all site conditions are covered in this book. It is especially not applicable in unfavourable geological site conditions. At such sites, as mentioned above for longer spans, an engineer's input is mandatory.

3.4 Bridge Design

This Chapter along with the Forms and Drawings is intended to provide quick and reliable technical methods for design and bridge-construction for engineers and overseers.

Layout and Sections

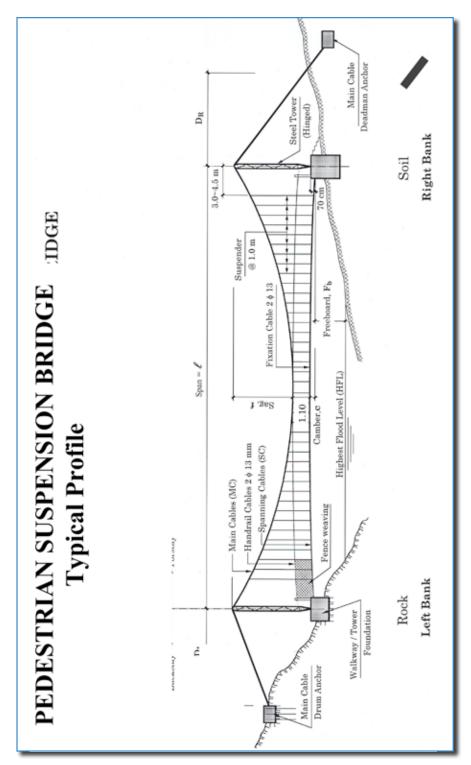


Figure F.3.2: A Typical Profile of Suspension Type Bridge

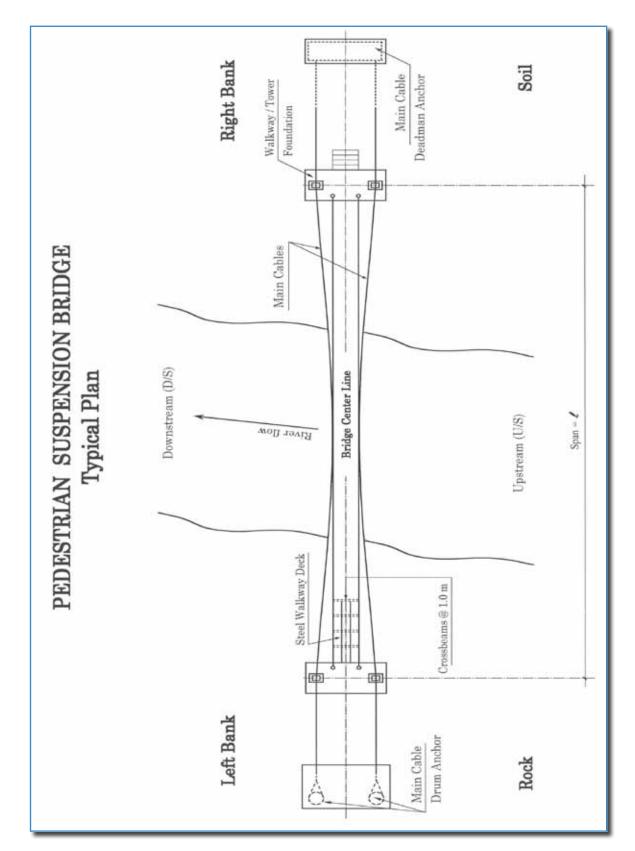
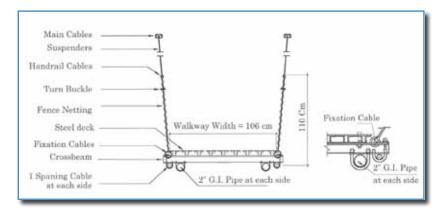


Figure F.3.3: A Typical Plan of Suspension Type Bridge

Walkway Section



3.5 Basic design concept

3.5.1 Loadings

For designing the bridge structure loadings, the Long Span Trail Bridge standard is followed.

Live load

The live load for smaller spans of up to 50m is equivalent to 400 kg/m^2 and for longer spans as per the formula,

P=300+100·
$$\frac{50}{I}$$
 kg/m²or 3 + $\frac{50}{I}$ kN/m²

Dead load

The dead load includes the weight of all permanent components of the bridge structure.

Width of Walkway	106 cm
Dead Load (without weight of Main & Spanning Cables)	~ 75 kg/m or ~ 74 kN/m

Wind load

The design wind load is taken as a uniformly distributed load based on a wind speed of 160km/h acting horizontally to the walkway. This corresponds to a wind pressure of 1.3 kN/m2 acting on the lateral bridge area of 0.3m2 per meter span. By maintaining a wind coefficient of 1.30 (acc. to Swiss Standard) the actual lateral design wind load is **0.50 kN** (1.3 x 1.3 x 0.3) per meter span. The Standard Steel Towers and Foundation Structures are sufficient to resist this design wind load. Wind load also affects the dynamic behavior of the bridge. For minimizing dynamic wind effects on the bridge, sufficient dead load of the walkway, a steel deck and the most favourable span to sag ratios have been introduced. Therefore, no lateral stabilizing measures (windguy system) has been considered in this standard short span suspension bridge design. However, for special cases (spans more than 120m or extreme windy areas exceeding wind speed of 160km/h) there is a provision for fixing a windguy system.

Snow load

The probability of the occurrence of a full load on a bridge loaded with snow is low. Moreover, the design live load itself is comparatively high. Therefore, it is considered that the snow load is already covered by the design live load.

Temperature effect

Loading (cable forces) according to temperature effect is negligible in comparison with other loading conditions. Therefore, temperature effect has not been considered for the standard bridge design.

Seismic load

There is low probability of a full live load occurring at the time of an earthquake. Moreover, the design live load itself is comparatively high. Therefore, it is assumed that the seismic load is already covered by the design live load. A separate loading combination with seismic load has not been considered.

3.5.2 Construction materials

The construction materials used for the standard trail bridges are wire ropes (cables), steel parts, steel fixtures and fasteners (thimbles, bulldog grips, nuts and bolts), concrete and stone masonry. Specifications of these materials are based on the Indian Standard (IS).

Steel Wire Ropes (Cables)

For more convenient stock keeping, handling and transportation only three cable diameters have been used. This also reduces the number of steel parts, logistics, and eventually, bridge costs.

Steel wire ropes should comply with all the requirements of:

• IS 1835 – 1977 Steel wires for ropes

IS 6594 – 1977 Technical supply conditions for wire ropes and strands

IS 9282 – 1979
 Specification for wire ropes and strands for suspension bridges

• IS 9182 (part II) –1979 Specification for lubricants for wire strands and ropes

Nominal diameters: 13 mm 26 / 32 mm

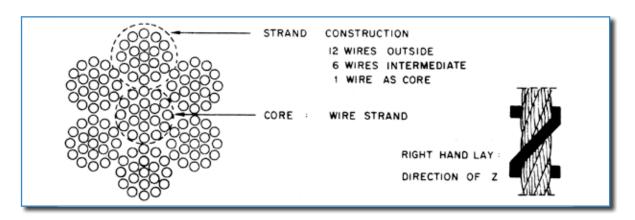
Rope Construction 7 x 7 (6/1) 7 x 19 (12/6/1)
Elongation non pre-stretched pre-stretched
Lay RHO, right hand ordinary lay
Core WRC, Wire Strand Core
Tensile strength of wire 160 kg/mm² or 1.57 kN/mm²

Preforming Preformed

Coating Galvanized 'A' heavy

Impregnation Non-drying type and non-bituminous lubricant

Nominal Diameter of	Wei	ight	Metallic Area	Minimum Loa	Breaking d in	Permissi iı	
Cable Mm	kg/m	N/m	[mm2]	Tones	kN	Tones	kN
13	0.64	6.3	73	10.5	103	3.5	34
26	2.51	24.6	292	39.3	386	13.1	129
32	3.80	37.3	442	59.6	585	19.9	195
Modulus of Elasticity, $E = 110 \text{ kN/mm}^2 = 11 \text{ t/ mm}^2$							

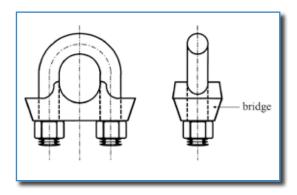


Cross-section and Lay of Wire Rope

Bulldog Grips

Bulldog Grips are used at the cable terminals to secure the cable ends.

Bulldog grips should conform to IS 2361-1970 specifications for Bulldog Grips. The bridges must be dropforged and suitably scored to grip a round strand rope of right hand lay having six strands. Bridges, U-bolt and nuts should be hot dip galvanized with a minimum zinc coating of 40µm. The size of the bulldog grip should be equal to the size of the cable to be anchored or connected.

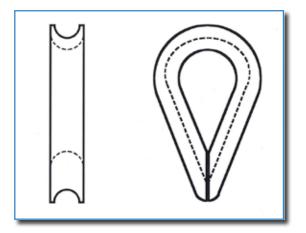


Bulldog Grip

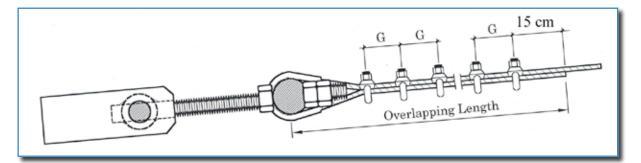
Thimbles

Thimbles are of open type and should confirm to IS 2315-1978 specifications for Thimbles for Wire Ropes. They must be forged and hot-dip galvanized with a minimum zinc coating of $40\mu m$. Thimbles are used at the cable terminals to avoid kinks. The size of the thimbles should be equal to the size of the cable to be anchored.

Thimble



Methods of Applying Bulldog Grips to Wire Ropes



The number of bulldog grips, gap and overlapping length

Diameter of Wire Rope, mm	Required Number, "n" of Bulldog Grips	Gap "G" cm	Overlapping Length "L" cm
13	3	10	60
26	5	15	130
32	6	20	180

The bridge of the bulldog grips must be fitted on to the working part of the wire rope and the U-bolt on to the rope tail. The cable end should be protected from fraying with binding wire.

Structural Steel

The steel grade should be of standard quality Fe 410 and the structural steel should comply with the requirements of:

IS 226 – 1975 Structural Steel

IS 800 – 1984 General Construction in Steel

The tower design is based on the Swiss Standard SIA 161(1979) for Steel Structures.

Mechanical Properties

The steel should have the mechanical properties:

Tensile Strength Yield Stress $f_{\mathbf{t}} \geq 410 \text{ N/mm}^2$ Permissible Tensile Stress $\sigma_{\mathbf{at}} = 150 \text{ N/mm}^2$ Modulus of Elasticity $\sigma_{\mathbf{at}} = 200 \text{ kN/mm}^2$

Elongation $\delta \geq 23\%$

Fasteners

Bolts, nuts and washers should be of grade C, property class 4.6 and should comply with the requirements of:

IS 1363 - 1984 (Part 1) Hexagonal Head Bolts and Nuts

IS 1367 – 1983 Threaded Fasteners

The fasteners should be hot dip galvanized with a minimum zinc coating of 40µm.

Reinforcement Steel

The reinforcement steel should be of steel grade **Fe415**, high yield deformed bars and should comply with the requirements of:

IS 1786 – 1985 High Strength Deformed Steel Bars for Concrete Reinforcement

IS 456 – 1978 Plain and Reinforced Concrete

Mechanical Properties

The reinforcement steel should have the mechanical properties:

Yield Stress $f_y \ge 415 \text{ N/mm}^2$ Permissible Tensile Stress $\sigma_{at} = 230 \text{ N/mm}^2$ Modulus of Elasticity $E = 210 \text{ kN/mm}^2$

Rust Prevention

Rust prevention of steel parts should be done by **Hot-Dip Galvanization** according to:

IS 2629 - 1966 Recommended Practice for Hot-Dip Galvanization of Iron and Steel

IS 4759 - 1984 Specification for Hot-Dip Zinc Coating on Structural Steel

Specifications for Hot-Dip Zinc Coating

Duralizata	Minimum Mass	s of Coating	Minimum Thickness of	
Products	g/m²	N/m²	Coating µm	
Structural Steel	610	6.0	80	
Threaded work, Nuts & Bolts	300	3.0	40	

Wire mesh netting

The wire for wire mesh netting should comply with the requirements of:

IS 280 - 1978 Mild Steel Wire for General Engineering Purposes

IS 4826 - 1979 Hot-dipped Galvanizing Coatings on Round Steel Wire

The diameter of the wire should be 12 SWG (2.64mm) and the zinc coating should not be less than 270g/m². The average tensile strength of the wire should not be less than 380N/mm².

Concrete

The concrete should comply with all the requirements of: IS 456 – 1978 Plain and Reinforced Concrete

IS 269 – 1989 Ordinary Portland Cement of 53 Grade

IS 383 - 1970 Coarse and Fine Aggregate

The concrete grades used in the standard design are:

Concrete 1:3:6 (M10) for miscellaneous use

Concrete 1:2:4 (M15) for structures
Concrete 1:3:6 mixed with 40% boulder

Masonry

The masonry should comply with all the requirements of:

IS 1597 – 1967 Code of Practice for Construction of Stone Masonry

IS 2250 – 1981 Preparation and Use of Masonry Mortars

The stone masonry used in the standard design are: Chisel Dressed Stone Masonry in 1:4 cement: sand mortar Hammer Dressed Stone Masonry in 1:6 cement: sand mortar Dry Stone Masonry.

Unit weight of construction materials

The unit weight of the construction materials used in the standard design is given in the table.

Materials	Unit Weight,		
iviaterials	kg/m³	kN/m³	
Concrete	2200	22.0	
Stone Masonry	2100	21.0	
Steel	7850	78.5	
Soil	1800	18.0	
Water	1000	10.0	

3.5.3 Structural analysis and design

The statical analysis is based on the calculation of forces and stresses in the structures due to external loadings. The calculated forces and stresses are compared with the permissible loads and stresses of these structures with some safety factors.

The Standard Suspension Bridge has been designed as per the statical analysis and basic design concept.

Bridge Geometry

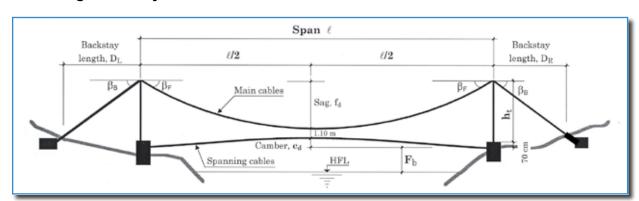


Figure F.3.4: The Geometry of the Suspension Bridge

Where, Bridge Span, the horizontal distance between the tower saddles

> D Backstay distance, the horizontal distance between the tower axis and the hinge of the main cable anchorage or the front of the main cable Foundation

 $\mathbf{D}_{\mathbf{R}}$ Backstay distance of the main cable on the right bank

Backstay distance of the main cable on the left bank

Sag of the Main Cable, the vertical distance from the tower saddle to the lowest point of the Main Cable

 $\mathbf{f}_{\mathbf{d}}$ Sag of the Main Cable in a dead load case

 $\mathbf{f}_{\mathbf{f}}$ Sag of the Main Cable in a full load case

Camber of the Spanning Cable, the vertical distance from the spanning cable anchorage to c the highest point of the spanning cable

 $\mathbf{c}_{\mathbf{d}}$ Camber of the Spanning Cable in a dead load case

Frontstay cable inclination at the tower saddle

Backstay cable inclination at the tower saddle

 β_f Cable inclination at full load

Frontstay Cable inclination at the tower saddle in a full load case $\beta_{\rm Ff}$

Tower Height ht

Freeboard, the vertical clearance from the high flood level (HFL) to the Spanning Cable $\mathbf{F_b}$ Anchor point

Equation of the bridge geometry:

Total Height of Tower =
$$h_t + 0.7m$$
 = $f_d + c_d + 1.1m$

Frontstay Cable Inclination =
$$\beta_F$$
 = $arc tan \left(\frac{4f}{\ell}\right)$

Frontstay Cable Inclination =
$$\beta_F$$
 = $arc tan \left(\frac{4f}{\ell}\right)$

Backstay Cable Inclination = $\beta_B \approx \beta_{Ff}$ = $arc tan \left(\frac{4f_f}{\ell}\right) = \beta_f$

Selection of Bridge Geometry

The selection of the bridge geometry means defining the bridge span "I", Tower height " h_t ", main cable sag "f_d" and camber "c_d" of the spanning cable in a dead load case. The relation between these geometrical parameters of the bridge is given in the above "Equation of the bridge geometry". The optimum and rational design of a suspension bridge largely depends on

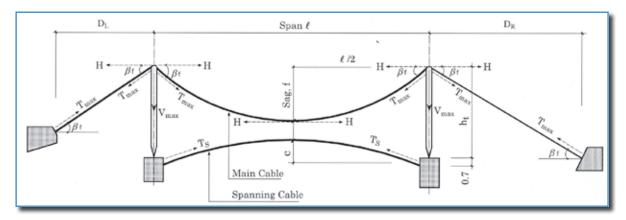
the proper selection of the bridge geometry. For this purpose, many combinations of the bridge geometries are calculated and the final optimal results are presented in the "Table: Selection of Cables and Standard Towers" of this manual.

Bridge Span:

For the sake of simplicity, the spans have been rounded off to the meter in the standard design. One suspender at the middle of the span is a must. Hence, the distance from the tower axis to the 1st suspender will vary as per the odd/even length of the span in meters. The first cross beam is fixed without a suspender. For further details, refer also to the sub-chapter "Suspenders", which will be discussed later.

Cable Design

A cable hanging between two supports and carrying a uniformly distributed load "**q**" forms a parabola. Thus the Main Cables and the Spanning Cables are assumed to be of parabolic geometry. In the suspension type bridge, the main cables carry all the load. The Spanning Cables carry only the pretension load. It is assumed that when a bridge is in full load, the tension in the spanning cable will be zero. The sketch represents the cable geometry and the forces acting on it.



The dead load sag fd is chosen to have an optimal bridge geometry. The hoisting sag fh and the full load sag ff are calculated as per the elastic theory by the iteration method based on the chosen dead load sag fd. The hoisting sag fh is necessary for cable hoisting purpose while erecting the bridge. The full load sag ff is necessary for the calculation of the maximum tension in the cable. The cable combination is designed as per the calculated maximum tension.

Bridge Geometry

⇒ Sag of the Main Cable at mid span in Dead Load,

⇒ Camber of the Spanning Cable at mid span in Dead Load,

⇒ Cable Inclination at Saddles,

$$f_d = 0.075 l \text{ to } 0.14 l$$

$$c_d = 0.015 l \text{ to } 0.03 l$$

$$\beta_F = \arctan\left(\frac{4f}{l}\right)$$

$$\beta_{B} \approx \beta_{Ff} = \beta_{f} = \arctan\left(\frac{4f_{f}}{l}\right)$$

$$L_{md} = l \cdot \left[1 + \frac{8}{3} \left(\frac{f_d}{l} \right)^2 \right]$$

$$L_{sd} = l \cdot \left[1 + \frac{8}{3} \left(\frac{c_d}{l} \right)^2 \right]$$

Forces

The fundamental equations for the calculation of the cable forces are:

⇒ Total Horizontal Tension on the Main Cable in any Load case,
$$H = \frac{g l^2}{8f}$$

⇒ Total Maximum Tension on the Main Cable in any Load case,
$$T_{\text{max}} = \frac{H}{\cos \beta_F}$$

⇒ Total Horizontal Tension on the Main Cable in Full Load case,
$$H = \frac{g l^2}{8 f_f}$$

⇒ Total Maximum Tension on the Main Cable in Full Load case,
$$T_{\text{max}} = \frac{H}{\cos \beta_f}$$

$$\Rightarrow$$
 Total Horizontal Tension on the Main Cable in Full Load case, $V_{\text{max}} = \frac{g_f l}{2}$

The Safety Factor for Cable Breaking Load is taken as $f_s \ge 3$.

The Main Cables are selected to withstand the maximum tension in full load case with a safety factor of

$$f_s = T_{Break} / T_{max} \ge 3$$

The Spanning Cables are selected as per the maximum tension P_s in load case [A] or [B] (" P_s " and loading cases are discussed in sub-chapter "**Steel Towers**") with safety of factor, $f_s = T_{Break} / T_{sA/B} \ge 3$.

As per the above design concept and the optimum bridge geometry, a simplified cable combination chart has been developed and standardized for the suspension type bridge for spans up to 120m (refer to "Table: Selection of Cables and Standard Towers" in this Manual). The Main and Spanning Cable combinations, the dead load sag \mathbf{f}_d , the hoisting sag \mathbf{f}_h of the main cables, the camber cd of the spanning cables, and the cable inclination under full load $\boldsymbol{\beta}_f$ at the tower saddle for a given span is presented in this chart.

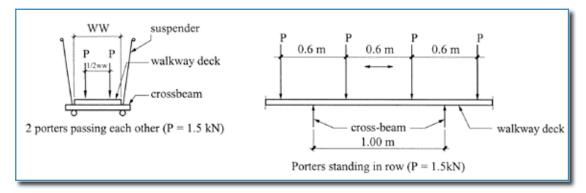
Steel Parts

The steel parts of the suspension type bridge are mainly subject to axial tension/compression, bending stress, shear stress, bond stress and buckling effect. All the steel parts are designed to withstand these forces and stresses with a safety factor of **fs = 1.6.**

All the steel parts have been standardized according to the cable combinations and do not depend on the site condition.

Walkway Structure

The walkway structures (Steel deck, Cross beams, Suspenders) are designed for local loadings like all steel parts with a safety factor of **fs = 1.6.** A concentrated load **P = 150kg** (weight of a porter with a load) positioned along the walkway as well as across the walkway has been considered.



Standard Walkway width (WW) is 106cm.

Steel Towers

The Standard Steel Towers are designed as hinged. Different possible loading cases were considered in order to determine the worst case with respect to buckling and yielding of the most critical elements of the towers. Two loading cases, i.e. load combination with wind load are found most critical. They are:

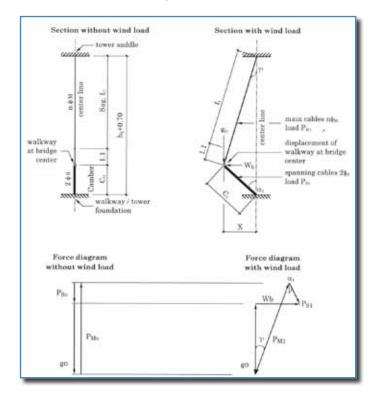
Load Case [A] = Dead Load + Full Wind Load Load Case [B] = Full Load + 1/3 Wind Load

A global wind load of 1.7kN/m2 (170kg/m2) for exposed area, which is equivalent to a wind speed of 160 km/hr has been considered for the design. The wind load is assumed to be a uniformly distributed horizontal load. Wind loads on different bridge elements are calculated based on the global wind load and the area exposed to the wind of the respective elements, which are:

on Walkway, $W_{ww} = 0.50 \text{ kN/m } (50 \text{ kg/m})$ on Main Cable, $W_{M} = 0.075 \text{ kN/m } (7.5 \text{ kg/m})$ on Suspenders, $W_{s} = 0.035 \text{ kN/m } (3.5 \text{ kg/m})$ on Tower, $W_{s} = 1.025 \text{ kN/m } (102.5 \text{ kg/m})$

The calculations are made under the assumption that all the wind loads are taken by the towers and ultimately by the walkway and tower foundations. No windguy arrangement is considered in the calculation.

The simplified model is used for the statical analysis:



With reference to the above Force/Vector diagram, the forces are calculated as:

Forces without wind load

Forces with wind load

Wind load, $W_b = W_M + W_s = 0$,

 $\mathsf{P}_{\mathsf{M1}} \cdot \mathsf{Sin}_{\mathsf{\gamma1}} + \mathsf{P}_{\mathsf{S1}} \cdot \mathsf{Sin}_{\mathsf{\alpha1}} = \mathsf{W}_{\mathsf{b}} = \mathsf{W}_{\mathsf{MO}} + \mathsf{W}_{\mathsf{sO}}$

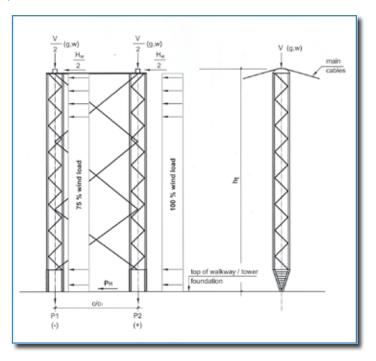
$$P_{MO} - P_{SO} = g_O$$

 $PMO \cdot Cos_{y_1} - P_{S_1} \cdot Cos_{\alpha_1} = g_O$

Where P_M and P_S are the forces on the main cables and spanning cables respectively.

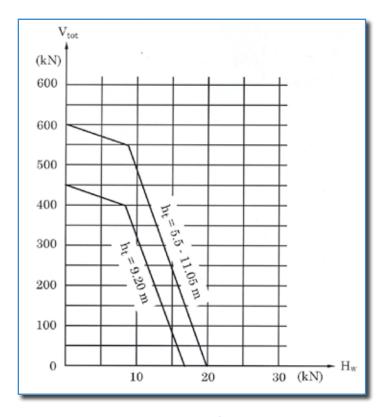
The statical analysis with the above load combination is mainly to compute the displacement " \mathbf{X} " and the sag " $\mathbf{f_1}$ " and the corresponding forces on the main cables $\mathbf{P_{M1}}$ and $\mathbf{P_{S1}}$ for both load case [A] and [B]. The calculation is based on the elastic theory and iteration method. However, while calculating the stiffness, the constant factors " $\mathbf{C_{S0}}$ " of the walkway system, additional stiffness of the steel cross beam/deck reinforced with pipes are also considered.

Further, as per the calculated " $\mathbf{P_{M1}}$ " and " $\mathbf{P_{S1}}$ ", the possible maximum vertical load " $\mathbf{V_{tot}}$ " and the horizontal load " $\mathbf{H_w}$ " on the towers are computed. Similarly, the reactions on the tower base " $\mathbf{P_1}$ ", " $\mathbf{P_2}$ " and " $\mathbf{P_H}$ " are also computed.



Forces on tower

The Tower Capacity Diagram as a function of " $\mathbf{V_{tot}}$ " and " $\mathbf{H_w}$ " of the proposed Standard Towers is presented bellow.



Tower capacity diagram

An appropriate Standard Tower is selected as per the calculated maximum vertical " $\mathbf{V_{tot}}$ " and horizontal " $\mathbf{H}_{\mathbf{w}}$ " loads. The plotted point with the coordinates of " $\mathbf{V}_{\mathsf{tot}}$ " and " $\mathbf{H}_{\mathbf{w}}$ " in the "Tower Capacity Diagram" should be below the capacity line of the selected standard tower.

As per the above statical analysis and design concept, a simplified chart for the selection of towers has been developed and standardized for the suspension type bridge for different bridge spans of up to 120m in the "Table: Selection of Cables and Standard Towers" of this manual.

Design of Walkway and Tower Foundations.

The standard design does not have a windguy system. The foundations are designed to take a wind load satisfying the worst case from the load cases [A] and [B].

The foundations are designed as per the static analysis and the principle of soil and rock mechanics. The design loads on the Walkway and the Tower Foundations are equivalent to the reactions on the tower base " P_1 ", " P_2 " and " P_H " and the tension on the spanning cables "Ts", which are calculated for both the load cases [A] and [B].

Overall stability of the foundation:

The mode of failure and respective safety factors for the overall stability of the foundation block are considered in the design.

Sliding

Toppling

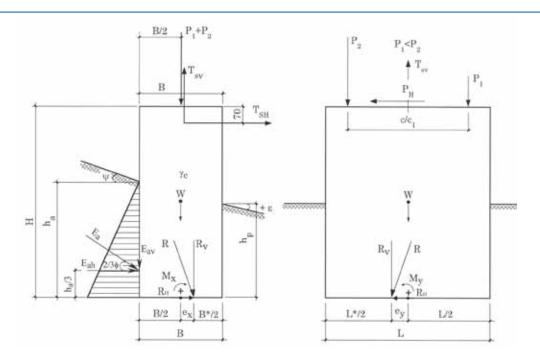
 $F_{SL} \ge 1.5$ B*/2 \ge B/3; L*/2 \ge L/3

Maximum Ground Pressure

 $\sigma_{max} \leq \sigma_{perm}$, Bearing capacity of soil or rock

Ground Shear Failure (Ultimate Bearing Capacity) in case of soil

Consider the design concept of the foundation:



Safety factor against Sliding:

$$F_{sl} = \frac{\text{Re sistingForce}}{DrivingForce} = \frac{Rv \cdot \tan \phi_{sl}}{R_H} \ge 1.5$$

Where

$$\begin{array}{ll} R_V & = W + (-P_I) + P_2 - T_{SV} + E_{av} \\ R_H & = T_{SH} + E_{ah} \end{array}$$

for the calculation of the Active Earth Pressure E_{ah} and E_{av} refer to sub-chapter "Main Cable Deadman Anchor Block in Flat Ground", which will be discussed later in this chapter.

Safety factor against Overturning:

The safety factor against overturning is checked by the eccentricity of the resultant force. The eccentricity should be within the limit of

$$B^*/2 \ge B/3$$
 and $L^*/2 \ge L/3$

Where
$$B^*/2 = B/2 - |e_x|$$
; $e_x = \sum M_X/R_V$; $L^*/2 = L/2 - |e_Y|$; $e_y = \sum M_Y/R_V$

Safety against Ground Bearing Pressure:

$$\sigma_{\text{max}} = Z \cdot \frac{R_V}{B^* L^*} \le \sigma_{perm}$$
, permissible bearing pressure of soil/rock.

Where the Z – factor considers the location of the resultant force and is a function of $(L^*/2)/L$ and $(B^*/2)/B$.

Value of Factor, Z

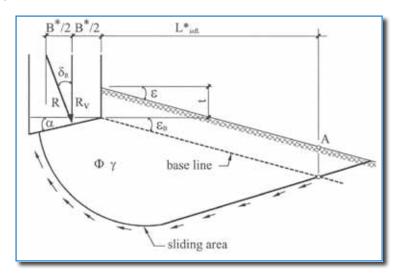
Z-factor	(B* / 2) /B					
(L* / 2) / L	0.50	0.45	0.40	0.35	0.30	0.25
0.5	1	1.17	1.28	1.33	1.33	1.33
0.45	1.17	1.30	1.36	1.39	1.39	1.39
0.4	1.28	1.36	1.41	1.43	1.43	1.43
0.35	1.33	1.39	1.43	1.46	1.47	1.47
0.3	1.33	1.39	1.43	1.47	1.49	1.50
0.25	1.33	1.39	1.43	1.47	1.50	1.50

Nevertheless, the minimum size of the foundation is governed by the geometric requirements to fix the tower, anchorage/other steel parts and also the topography.

Safety against Ground Shear Failure (Ultimate Bearing Capacity):

In our case, the horizontal force acting on the foundation is relatively greater than the vertical load. The safety against ground shear failure or bearing capacity depends mainly on the vertical load on the foundation. Therefore, in a majority of the cases, this failure mode is not the deciding factor in the foundation design. However, there is comparatively high vertical force acting on the walkway and the tower foundation, and ground shear failure may be the deciding factor in its design.

The ground shear failure analysis is carried out by Terzaghi's extended and amplified bearing capacity formula. Terzaghi's formula is extended and amplified with different co-efficient considering the foundation shape and topography of the ground.



Safety against ground shear failure, $F_{BC} = P^*/P \ge 2.0$ for Terzaghi's formula,

where, P* - shear resistance of the ground (ultimate bearing capacity) determined by Terzaghi's formula

P - vertical resultant force on the foundation

Terzaghi's formula for shallow foundation with continuous footing and horizontal ground,

$$P^* = B [c NC + (\Upsilon t + q) Nq + 0.5 B \Upsilon N_x],$$

cohesion factor "c" is not considered since the predominant soil type in Nepal is non-cohesive,

therefore, Terzaghi's formula above will be,

$$P^* = B[(\Upsilon t + q) Nq + 0.5 B \Upsilon N_{\Upsilon}]$$

In our case, safety against ground shear failure, $F_{BC} = P^*/R_v \ge 2.0$

where, P* - shear resistance of the ground (ultimate bearing capacity) determined by Terzaghi's formula with correction factors for topography and shape of the foundation,

R_v - vertical resultant force on the foundation

Terzaghi's formula with correction factors,

$$P^{*} = B^{*} L^{*} \left[(\Upsilon t + q) N_{q} S_{q} d_{q} i_{q} b'_{q} g_{q} + 0.5 \Upsilon B^{*} N \Upsilon S_{\gamma} d_{\gamma} i_{\gamma} b'_{\gamma} g_{\gamma} \right]$$

where, Υ = unit weight of soil

t = embedded depth in front of the foundation

q = surcharge load, q = 0 in our case

Nq = $e\Pi tan \phi tan 2(45^{\circ} + 0.5 \phi)$, co-efficient for embedded depth or surcharge load,

NY \approx 1.8 (Nq - 1) tan φ , co-efficient for effect of the foundation width,

shape correction factors considering limited length (L*) of continuous footing,

$$S_q = 1 + (B^*/L^*) \tan \varphi$$

 $S\gamma = 1 - 0.4 (B^*/L^*)$

depth correction factors considering the embedded depth ($t = h_x$) of the foundation,

$$d_{q} = 1 + 0.035 \tan \phi (1 - \sin \phi)^{2} \arctan(t/B^{*}),$$

$$d_{\gamma} = 1$$

embedded depth in front of the foundation should be guaranteed up to the length of the influence area

$$L_{infl}^{*}$$
 $L_{infl}^{*} = B^{*} tan(45^{\circ} + 0.5\phi) e^{0.5 \Pi tan\phi}$

correction factor for the inclination of the load,

$$i_{\alpha} = [1 - 0.5 \tan(\delta R - \alpha)]^{5}$$

$$i_x = [1 - (0.7 - 0.0022 \,\alpha^{\circ}) \tan(\delta R - \alpha)]^5$$

correction factor for the inclination of the foundation base, α ,

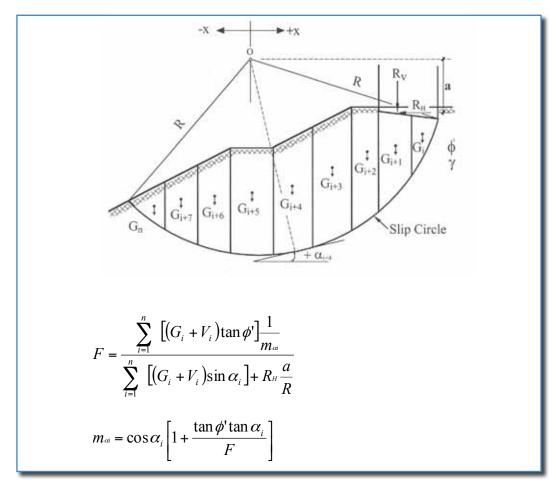
$$b'_{q} = e^{(-0.035 \, \alpha^{\circ} \, tan \, \phi)}$$

$$b'_{\nu} = e^{(-0.047 \, \alpha^{\circ} \, \tan \phi)}$$

correction factor for the inclination of the base line ($\varepsilon_{_B}$), which is approximately equal to the inclination of the ground slope (ε) but limited to the ground slope up to 15° only,

$$g_{\alpha} = g_{\gamma} = (1 - 0.5 \tan \varepsilon B)^5, \quad \varepsilon_{B} \approx \varepsilon$$

Experience shows that Terzaghi's amplified and extended formula with correction factors is no more reliable for foundations on steep slope ground. It gives relatively acceptable results only for a ground with a slope of less than 15°. Therefore, an overall slope stability analysis is made for slope ground of more than 15° inclination. The overall slope stability analysis is carried out by using Bishop's simplified method of slices.



where, in our case

G_i = weight of the soil of the given slice "i"

 $V_i = R_v$ resultant vertical force on the foundation, which is applicable only at one slice and in other slices, $V_i = 0$.

 $H = R_{H}$, resultant horizontal force on the foundation

 $\varphi' = 1.10 \times \varphi$

 φ = angle of internal friction of the soil

α = tangential angle at the slip circle of given slice "i"

R = Radius of the slip circle

 $a = lever arm of "R_{H}"$

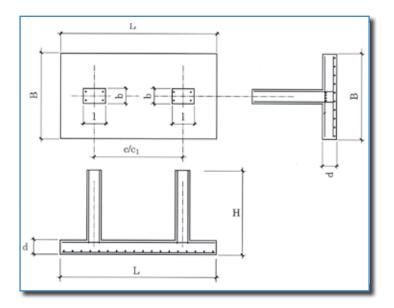
F = safety factor, which is taken as 1.5 for the Bishop's Method

As the factor of safety "F" appears on both the sides, a process of successive approximation is required. It is necessary to fix the center "o" corresponding to the critical slip circle with minimum safety factor. A computer program is also available to do this analysis.

As per the analysis, it is established that if the foundations are placed behind the slope line with the angle of internal friction " ϕ ", shear failure in general, will not occur.

Design of the Reinforced Concrete Frame of the Foundation:

The Concrete Frame of the walkway/tower foundation is designed as reinforced concrete columns and foundation with a combined footing. Consider a typical design of the frame:



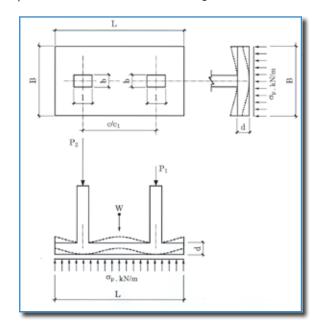
The cross sectional sizes of the columns (b x l) are designed to fulfill the geometric requirement to fix the tower legs and also to fulfill the criteria of the direct compressive stress on the columns:

Direct compressive stress on column, $\sigma ac = P_1$ or P_2 / b x $l \leq \sigma_{ac perm.'}$ permissible direct compressive stress.

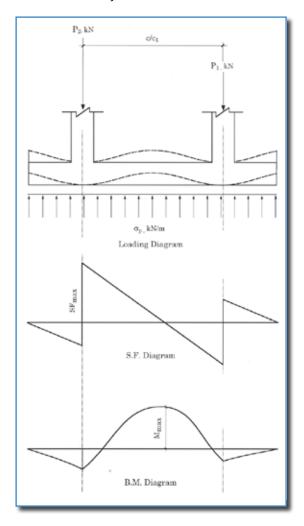
The size of the foundation ($\mathbf{B} \times \mathbf{L}$) is also checked to fulfill the criteria of the maximum bearing pressure at the foundation.

Maximum bearing pressure at the foundation, $\sigma_{max} = (P_1 + P_2 + W) / L \times B \leq \sigma_{perm}$, permissible bearing pressure of soil/rock.

A balanced section has been assumed for the reinforced concrete design of the frame. The concrete grade of M10 has been adopted. The structural and loading model is used for the structural analysis.



Consider a typical result of the structural analysis:



The thickness of the foundation slab and the requirement of reinforcement steel is designed as per the structural analysis (Shear Force and Bending Moment diagram).

Thickness of Foundation Slab:

The thickness of the foundation slab "d" has been designed as per the maximum bending moment, and checked for punching shear due to vertical load from the column.

$$d = \sqrt{\frac{2M_{\text{max}}}{\xi(1 - \xi/3)B\sigma_{c \text{ perm}}}}$$
Where $\xi = n \mu \left(\sqrt{1 + \frac{2}{n\mu} - 1}\right)$;
$$\mu = \frac{A_S}{dB}$$
; Ratio of Area of steel to area of concrete section
$$n = \frac{E_S}{E_C}$$
; Ratio of modulus of elasticity of steel to concrete;

Required Area of steel:

in longitudinal direction of the foundation slab

$$A_S = \frac{M_{\max(Long)}}{\eta d \sigma_{t perm}}$$

in transverse direction of the foundation slab

$$A_S = \frac{M_{\max(Trans.)}}{\eta \, d \, \sigma_{t \, perm}}$$

Where

$$\eta = 1 - \frac{1}{3(1 + \frac{\sigma_t}{n \, \sigma_c})}$$

 σ_t - permissible tensile stress of the reinforcement steel

 σ_c - permissible compressive stress of the concrete

Main Cable Anchor Blocks

There are mainly three basic types of main cable anchor blocks depending upon the soil/rock type and the prevailing topography:

- Main Cable Gravity Anchor Block in soil/rock for Slope Topography;
- Main Cable Deadman Anchor Block in Soil for Flat Topography;
- Main Cable Drum Anchor Block in Rock.

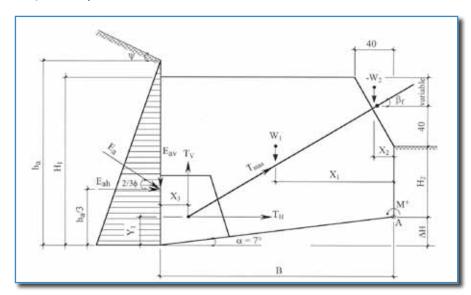
The Main Anchor Blocks are designed to withstand the maximum tension of the main cables based on the cable structure analysis and considering the soil/rock parameters.

Main Cable Gravity Anchor Block in Soil/Rock for Slope Topography:

This type of anchor block is designed for slope topography. The mode of failure and respective safety factors are considered in the design.

- Sliding
- Toppling
- Maximum Ground Pressure σ_{max} < Bearing capacity of soil or rock; Ground Shear Failure (Ultimate Bearing Capacity) in case of soil.

Consider the design concept of the anchor block:



The anchor blocks have been designed to satisfy the safety factor against sliding with the theoretical basis:

Safety factor against Sliding:

$$F_{sl} = \frac{\text{Re sistingForce}}{DrivingForce} = \frac{R^{'}v \cdot \tan \phi_{sl}}{R^{'}H} \ge 1.5$$
 Where
$$R^{'}_{V} = R_{V} \cdot \cos\alpha + R_{H} \cdot \sin\alpha; \quad R_{V} = W_{1} - W_{2} + E_{av} - Tv$$

$$R^{'}_{H} = R_{V} \cdot \sin\alpha + R_{H} \cdot \cos\alpha; \quad R_{H} = T_{H} + E_{ah}$$

Safety factor against Overturning:

$$F_{ovt} = \frac{All \ Re \ sisting \ Moments}{All \ Driving \ Moments} = \frac{\Sigma M_A^+}{\Sigma M_A^-} \ge 1.5$$
 Where
$$\Sigma M_A^+ = W_1 \cdot X_1 - W_2 \cdot X_2 + E_{av} \cdot B$$

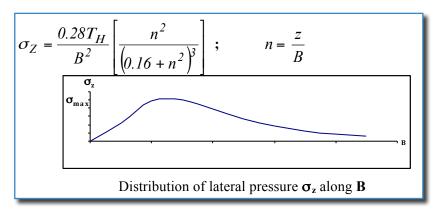
$$\Sigma M_A^- = T_V \cdot (B - X_3) + T_H \cdot (Y_1 - \Delta H) + E_{ah} \cdot (h_a/3 - \Delta H)$$

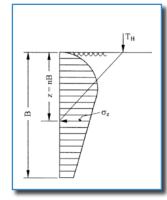
Safety against Ground Shear Failure:

The position of the anchor blocks should be behind the slope line of the internal angle of friction of the soil to guarantee the safety against Ground Shear failure.

Lateral Pressure at Side Walls:

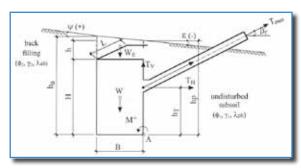
Further, a curtain wall with cement stone masonry of sufficient thickness has been provided to resist the lateral pressure resulting the bulging effect due to tension on the deadman beam. The lateral pressure " σ_Z " along the length of the foundation "B" has been calculated as lateral pressure against a rigid wall as per the elastic theory of soil mechanics with the formula:

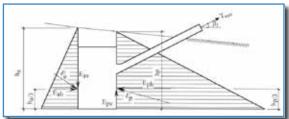




Main Cable Deadman Anchor Block in Soil for Flat Topography

This type of anchor block is designed for soil in a flat topography. The advantage of earth resistance, i.e. passive earth pressure in front of the anchor block, is used in the design. This concept results in very economical anchor block designs.





The modes of failure and respective safety factors have been considered in the design.

- Sliding F_a ≥ 3.5
- To prevent the anchor block from moving towards the soil in front, a high safety factor has been applied.
- Toppling $F_{+} \ge 1.5$

Safety factor against Sliding:

$$F_{sl} = \frac{H_{ult} + (W + W_E - T_V) \tan \phi_1}{T_H} \ge 3.50$$
 Where $H_{ult} = E_{ph} - E_{ah} + 2 E_{oL}$
$$E_{ph} = \lambda_{ph} \frac{h_p^2}{2} L \gamma_1; \qquad \lambda_{ph} = \frac{\cos^2 \Phi_1}{\left[1 - \sqrt{\frac{\sin(\Phi_1 - \delta)\sin(\Phi_1 + \varepsilon)}{\cos \delta \cos \varepsilon}}\right]^2}$$

$$E_{ah} = \lambda_{ah} \frac{h_a^2}{2} L \gamma_2; \qquad \lambda_{ah} = \frac{\cos^2 \Phi_2}{\left[1 + \sqrt{\frac{\sin(\Phi_2 + \delta)\sin(\Phi_2 - \psi)}{\cos \delta \cos \psi}}\right]^2}$$

$$E_{OL} = \frac{1}{6} \lambda_O \gamma_1 h_p^3 \tan \phi_1 \left[\sqrt{\lambda_{ph} + \lambda_{ah}}\right]$$

$$\lambda_o = I - Sin\phi_I$$

Safety factor against Overturning:

$$F_{ovt} = \frac{All \ Re \ sisting \ Moments}{All \ Driving \ Moments} = \frac{\Sigma M_A^+}{\Sigma M_A^-} \ge 1.5$$

$$Where \qquad M_A^+ = W \cdot B/2 + W_E \cdot B/2 + E_{ph} \cdot h_p/3 + E_{av} \cdot B$$

$$M_A^- = T_H \cdot h_t + T_V \cdot 0 + E_{pv} \cdot 0 + E_{ah} \cdot h_a/3$$

$$E_{av} = E_{ah} \tan (2/3\phi_2)$$

$$E_{pv} = E_{ph} \tan (-1/2\phi_1)$$

Main Cable Drum Anchor Block in Hard Rock

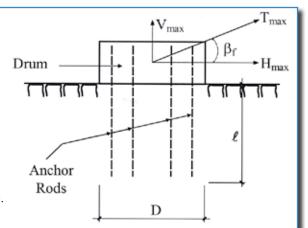
An RCC Concrete Drum with rock anchoring is used for foundations on sound hard rock. The sizes of the drum and anchorage rods are designed to withstand the shear forces due to the horizontal forces of the cables. It is also designed to resist the uplift forces on the Drum.

The required number of anchor rods, N is calculated as:

$$A_{st} = \frac{T_{\text{max}} \cos \beta_f}{\tau_{perm}}$$

$$N = \frac{4 A_{st}}{\pi d^2} \text{ or } N = \frac{T_{\text{max}} \sin \beta_f}{\sigma_{\text{B perm}} \pi d l}$$

N is adopted whichever is greater from the above.



Main Cable Drum Anchor Block in Fractured Hard Rock or Soft Rock

A Drum anchorage without rock anchoring is used for foundations on fractured hard rock or fresh soft rock.

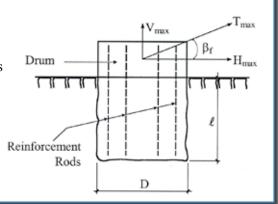
The size of the Drum is designed to withstand the shear failure due to the horizontal forces of the cables.

Determine the Drum size and the number of reinforcement bars as:

$$\left(\frac{\pi D^2}{4}\right) \tau_c + A_{st} \tau_{st} = T_{\text{max}} \cos \beta_f$$

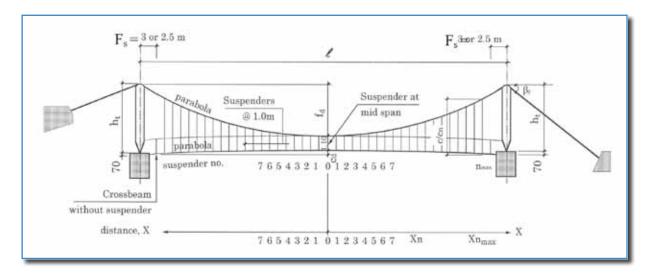
The required number of anchor rods, N is calculated as

$$N = \frac{4A_{st}}{\pi d^2}$$



Suspenders

The suspenders have been designed for the bridge geometry under dead load, i.e. I, fd and cd . The layout of the suspenders is :



The basic equation for the calculation of the suspender length is c/cn vertical center distance between the main cable to the spanning cable.

$$c/c_n = \frac{4(f_d + c_d)}{l^2} \cdot x_n^2 + 1.10 \,\mathrm{m}$$

Where,

$$X_n = (n - 1)$$
, in meters

$$n_{\text{max}} = 0.5 \cdot l - F_s + 1$$

Total Suspender Length,

$$l_{\rm n}=c/c_{\rm n}-1160{\rm mm}$$

Length of standard piece,

$$l_{\rm s} = 1650 {\rm mm},$$

Cutting length of standard piece,

$$l_{\rm sc} = 1800$$
 mm.

Number of standard pieces,

$$j_n = \text{INTEGER} \frac{l_n - 350}{1650}$$

Length of extra piece,

$$l_{\rm r} = l_{\rm n} - 1650 j_{\rm n}$$

Cutting length of extra piece,

$$l_{\rm rc} = l_{\rm r} + 150 \text{ mm}$$

3.6.1

Weight of suspender,

$$W_n = 1.116 j_n + 0.62 \cdot 10^{-3} l_{rc}$$
, kg.

Total number of suspenders,

$$N = (0.5l - F_s) \cdot 4 + 2$$

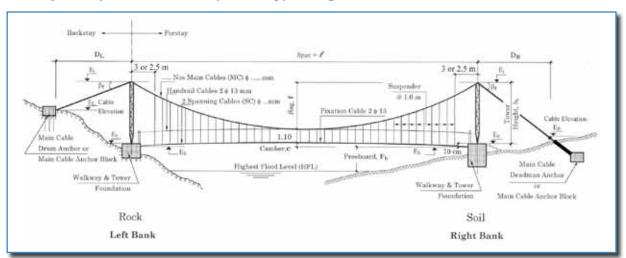
Total weight of the suspenders,

$$W = 2W_1 + 4 \cdot \sum_{n=2}^{n=\max} W_n$$

This chapter on **Structural Analysis and Design** provides the background upon which the precalculations have been based. It is by far not exhaustive, but provides enough information to follow the methodologies applied.

3.6 Design of standard suspension bridge

The major components of the suspension type bridge



3.6.2 Design procedure

Draw the bridge profile from the survey data.

Selection of Bridge Type:

- According to the bridge profile, assess the possibility of designing a Suspended type bridge. It is more preferable due to the economic (cost per meter) reasons and easy construction technology, which is more appropriate for the community bridge building approach.
- Guideline for selection of a bridge type as per the prevailing topography of the bridge site:

Topography	Recommended Bridge Type
	The suspended bridge type (raised foundation blocks on both banks) may be feasible only for small spans. Most likely only the Suspension type may be feasible. It is necessary to assess both the types and adopt whichever is feasible and more cost effective.
	The Suspended bridge type (raised foundation blocks on the lower bank) may be feasible only for small spans. Most likely only the Suspension type may be feasible. It is necessary to assess both the types and adopt whichever is feasible and more cost effective.
	Both the Suspended and Suspension types are feasible. It is necessary to assess both the types and adopt whichever is more cost effective. The Suspended type is preferable.
	The Suspended type is most appropriate. If the Suspended type is not feasible, the Suspension type with one tower may also be feasible. The present handbook does not deal with this. Refer to the Volume A of LSTB (SBD) Manual for the design. The Suspension type with both towers is not feasible.
	The Suspended type is most appropriate.

- If both the Suspended and Suspension types are feasible, make a cost (total cost) comparison and adopt the more cost effective one.
- If the cost is nearly equal for both the bridge types, choose the Suspended type.
- Select the Suspension type only, if the Suspended type is not feasible for the given topography or it is more economical than the Suspended type.

Steps for Designing a Suspension Type Bridge:

- Fix the position of the Walkway and Tower foundations in the bridge profile.
- Determine the span of the bridge.
- Select the Bridge Geometry, i.e., Sag fd, Camber cd and Tower Height ht as per the span.

3.6.3

- Select the Main Cables, Spanning Cables and Tower Type as per the span.
- Design the Walkway & Tower Foundations.
- Fix the position of the Main Cable Anchor Blocks and determine the Backstay Distances.
- Design the Main Anchor Blocks.
- Calculate the lengths of the Suspenders.
- Transfer the bridge data in the bridge profile and prepare the General Arrangement Drawing.
- Compile and fill in the Standard Steel & Construction Design Drawings.
- Calculate the quantities of works and prepare a Cost Estimate.

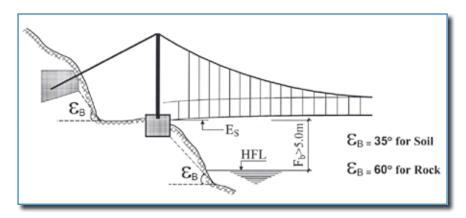
Designing the position of the walkway & tower foundations

Fix the position of the bridge foundations and the actual span of the bridge in the bridge profile. This bridge profile will be the basis for the layout of the bridge at the construction site. Fulfill the criteria while fixing the position of the bridge foundations.

Criteria for fixing the Bridge Foundations

- The Bridge Foundations should be placed behind the line of angle of internal friction (safe slope line) of the soil or rock. This angle in general is 35° for soil and 60° for rock.
- The Bridge Foundations should be placed at least 3 meters back from the soil slope and 1.5 meters back from the rock slope.
- If the bank is flat and prone to flooding or excessive bank erosion, the foundations should be placed sufficiently back from the bank edge to ensure the long term safety of the bridge.
- The top of the Walkway and the Tower Foundation should be at the same level on both the banks.
- The height of the Walkway and the Tower Foundation should be as low as possible. However, it should not be less than 1.0m from the ground level which gives a 0.55m clearance between the spanning cable and the ground. For slope topography (both rock and soil), the Walkway and Tower Foundation height H has been fixed at 1.0m.
- The freeboard Fb, between the lowest part of the bridge, i.e., the anchorage point of the spanning cable and the highest flood level, should generally be not less than 5.0 m

Criteria for fixing the location of the Bridge Foundation



Procedure for fixing the Bridge Foundations

According to the above criteria, draw the bridge profile as per the steps.

- Draw the bridge axis profile on an A3 size paper in the scale 1:200 (for up to 50m span) or 1: 400 (for spans above 50m) with all the details like axis points A and B, HFL, WL and the tentative location of the Walkway and Tower Foundations (if available in the survey data) on both banks.
- Fix the position of the walkway and the tower foundations on both the banks as per the procedure:

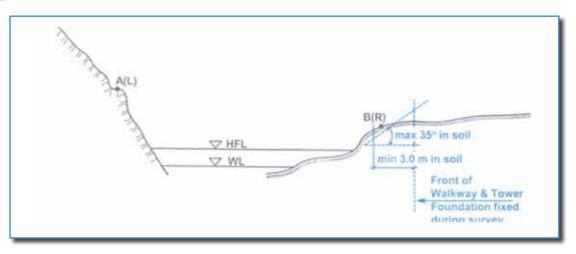
Case-1: When the Tentative Position of the Walkway and the Tower Foundations has been fixed during the Survey.

Step 1: Fix the Front of the Walkway and the Tower Foundations on one bank.

Mark the front of the foundations as fixed during the survey. Check the position of the front of the foundation on the lower bank or the bank which has a limited defined area for positioning the foundation.

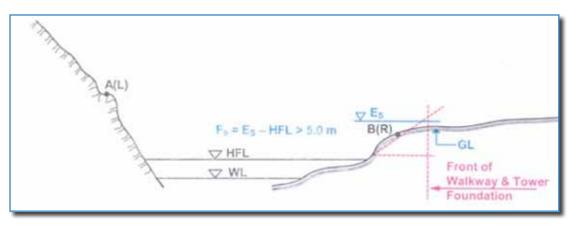
Draw the safe slope line. The front of the foundation should be behind this slope line and also sufficiently back from the bank/slope edge. If the minimum required distance from the bank/slope edge is not sufficient or out of the safe slope line, shift its position backward.

If the bank is flat and the bank height is low and prone to flooding or excessive bank erosion, the foundation should be placed sufficiently back from the bank edge to ensure a long term safety of the bridge.



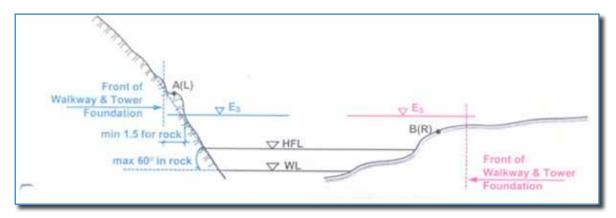
Step 2: Fix the Elevation of the Spanning Cable Anchor point.

Mark the elevation line of the spanning cable anchor point ($\mathbf{E_s}$). $\mathbf{E_s} = \mathbf{G.L.} + \mathbf{0.55m}$. Check the available freeboard $\mathbf{F_b}$. $\mathbf{F_b} = \mathbf{E_s} - \mathbf{HFL}$, which should not be less than 5.0m. If the freeboard is not enough rise the Es. In case of flat topography, raise the Es = G.L. + 1.55 or 2.55 or 3.55 (max.) till sufficient freeboard is achieved. In case of slope topography shift its position backward till sufficient freeboard is achieved.



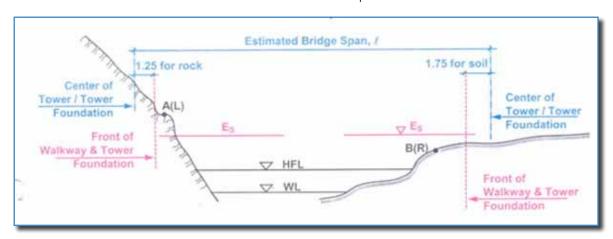
Step 3: Fix the Front of the Walkway and Tower Foundations on the other bank.

Once the elevation of the spanning cable anchor point Es has been established on one bank, draw this elevation line towards the other bank. Draw the safe slope line. Mark the front of the foundation according to the $\mathbf{E_s}$ line behind the safe slope line maintaining the minimum required distance from the bank/slope edge.



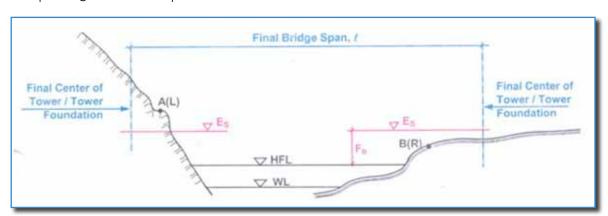
Step 4: Determine the Bridge Span, I.

Mark the center line of the towers on both the banks. The center line of the tower is 1.25m for rock and 1.75m for soil back from the front of the foundation. Calculate the bridge span which is the distance between the center lines of the Towers. Determine the final span round to the nearest meter.



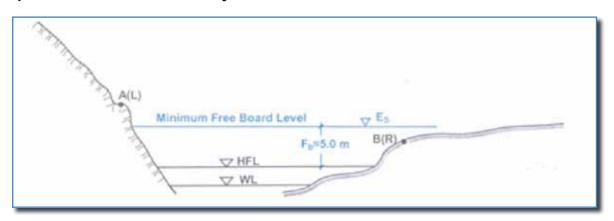
Step 5: Finalize the Bridge Profile.

Finalize the bridge profile with the final span I (span should be fixed round to the meter) and the elevation of the spanning cable anchor points Es.



Case-2: When the Position of the Walkway and the Tower Foundations has not been fixed during the Survey.

Step 1: Fix the Front of the Walkway & Tower Foundations on one bank.

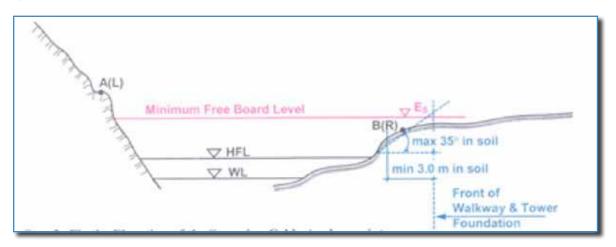


Fix the position of the front of the tower on the lower bank or the bank which has a limited defined area for positioning the foundation.

Draw the safe slope line. The front of the foundation should be behind this slope line and also sufficiently back from the bank/slope edge.

If the bank is flat and the bank height is low and prone to the flooding or excessive bank erosion, the foundation should be placed sufficiently back from the bank edge to ensure the long term safety of the bridge.

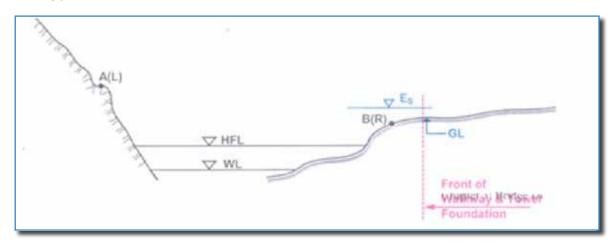
Step 2: Fix the Freeboard Level.



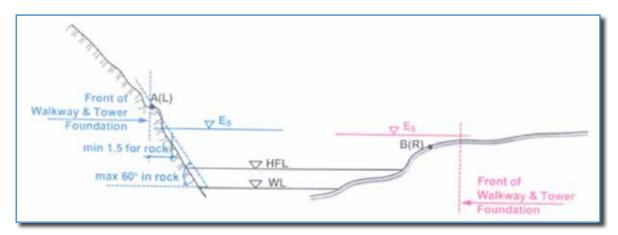
Mark the minimum freeboard level. The minimum freeboard from the highest flood level is 5.0 meters. The minimum freeboard level will be the lowest possible position (Elevation, Es) of the spanning cable anchor point.

Step 3: Fix the Elevation of the Spanning Cable Anchor point.

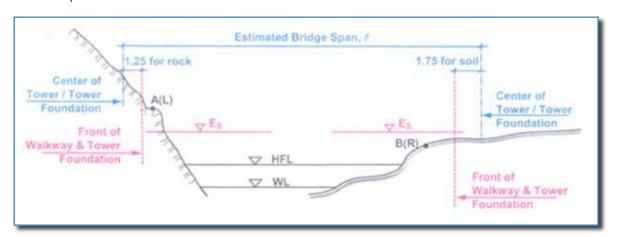
Mark the elevation line of the spanning cable anchor point Es at the minimum freeboard level. Check the height from the ground level (Es - G.L.), which should be 0.55 or 1.55 or 2.55 or 3.55 m (max). Adjust Es accordingly.



Step 4: Fix the Front of the Walkway and the Tower Foundations on the other bank. Same as Step 3 of Case-1.

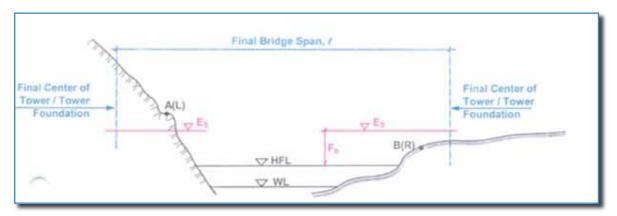


Step 5: Fix the Bridge Span, I. Same as Step 4 of Case-1.



Step 6: Finalize the Bridge Profile.

Finalize the bridge profile with the final span I and the elevation of the spanning cable anchor points Es.



3.6.4 Cable design & standard tower selection

Designing the cables for a Suspension bridge involves the selection of the required number and the diameter of the Main Cables and the Spanning Cables for the given bridge span.

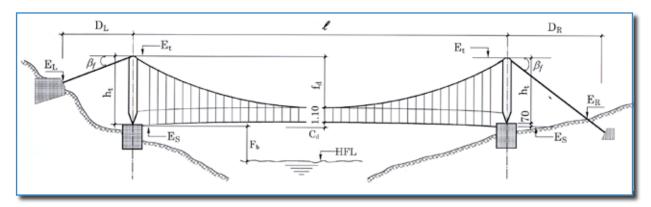
The standard table for the Selection of Cables and Standard Towers and the Bridge Geometry has been developed for spans of up to 120m.

To design the cables and to select the type of standard tower:

- Determine the span of the bridge from the bridge profile.
- Select the number and diameter of the Main Cables, the diameter of the Spanning Cables and the type of Standard Tower from the Selection of Cables and Standard Towers according to the bridge span.

Design the Cable Structure and Select the Standard Tower

I. Survey Data & Calculation of Freeboard



1.	Span of the Bridge	(should be r	ounded off to	the nearest meter	·)	=r
	Span of the Briage	(billould oc 1	ounaca on to	tile ilealest illetel	, ~	

2. Elevation of the spanning cable at anchor point
$$E_s = \dots m$$

4. Freeboard (min. 5.00m)
$$F_b = E_s - HFL = F_b = \dots m$$

(If the freeboard is less than 5.00m, try either to raise the elevation of the spanning cable anchor point by increasing the height of the Walkway & Tower Foundation or to adjust the span.)

II. Selection of Cables and Standard Towers (Pylon)

Select the Main and Spanning Cable combinations, the standard tower height $\mathbf{h_t}$ and the Bridge Geometry according to the span from the table. The bridge geometry refers to the main cable dead load sag $\mathbf{f_{d}}$, the dead load camber $\mathbf{c_d}$ of the spanning cable and the main cable inclination at the tower saddle $\mathbf{B_f}$ in the full load case.

Table F.3.1: Selection of Cables and Standard Tower

Span	Tower Height/ (Type)		Cables Nos. & diam	eter	Dead Load Sag	Hoisting Sag	Camber	Full load Backstay	
l m	h _t m	Main mm	Spanning mm	Windguy mm	f _d m	f _h m	c _d	Angle ß _f deg.	
30.0					4.20	4.13	0.90	29.83	
31.0					4.15	4.07	0.95	28.83	
32.0					4.10	4.02	1.00	27.88	
33.0					4.10	4.01	1.00	27.24	
34.0					4.08	3.99	1.02	26.55	
35.0					4.05	3.95	1.05	25.84	
36.0					4.22	4.12	0.88	26.14	
37.0		26	26		4.19	4.09	0.91	25.49	
38.0		2 2	2 ø 26		4.16	4.05	0.94	24.88	
39.0					4.13	4.01	0.97	24.31	
40.0					4.10	3.97	1.00	23.77	
41.0					4.10	3.96	1.00	23.39	
42.0	5.50				4.10	3.96	1.00	23.03	
43.0	5.5				4.30	4.16	0.80	23.48	
44.0					4.40	4.26	0.70	23.53	
45.0					4.40	4.25	0.70	23.20	
46.0	Not Required	, eq	3.92	3.77	1.18	20.45			
47.0					guir	3.90	3.74	1.20	20.10
48.0							t Re	4.05	3.89
49.0				Ž	4.05	3.88	1.05	20.13	
50.0					4.10	3.93	1.00	20.07	
51.0					4.10	3.92	1.00	19.83	
52.0					4.10	3.91	1.00	19.61	
53.0					4.10	3.90	1.00	19.40	
54.0					4.10	3.88	1.00	19.20	
55.0		ø 32	ø 32		4.25	4.04	0.85	19.46	
56.0		, 2 , 2	, s		5.47	5.30	1.48	22.82	
57.0					5.44	5.26	1.51	22.46	
58.0	7.35				5.41	5.22	1.54	22.12	
59.0					5.38	5.18	1.57	21.79	
60.0					5.35	5.13	1.60	21.48	
61.0					5.35	5.12	1.60	21.26	
62.0					5.45	5.22	1.50	21.32	
63.0					5.65	5.42	1.30	21.65	
64.0					5.85	5.63	1.10	21.97	
65.0					5.95	5.72	1.00	22.01	

Span	Tower Height/ (Type)		Cables Nos. & diam	eter	Dead Load Sag	Hoisting Sag	Camber	Full load Backstay
I m	h _t m	Main mm	Spanning mm	Windguy mm	f _d m	f _h m	c _d m	Angle ß _f deg.
66.0					7.02	6.81	1.78	24.48
67.0					6.99	6.77	1.81	24.15
68.0					6.96	6.73	1.84	23.83
69.0					6.93	6.69	1.87	23.54
70.0	9.20	ø 32		70	7.20	6.97	1.60	23.97
71.0	6.6	2		Not Required	7.40	7.17	1.40	24.22
72.0				<u> </u>	7.60	7.37	1.20	24.47
73.0				Sec .	7.70	7.46	1.10	24.47
74.0				+	7.65	7.40	1.15	24.14
75.0				9	7.65	7.40	1.15	23.93
76.0				-	8.57	8.36	2.08	25.38
77.0					8.54	8.33	2.11	25.07
78.0					8.51	8.29	2.14	24.77
79.0					8.48	8.25	2.17	24.48
80.0					8.45	8.22	2.20	24.20
81.0					8.42	8.18	2.23	23.93
82.0			32		8.39	8.14	2.26	23.67
83.0			2Ø 32		8.36	8.10	2.29	23.41
84.0			2		8.33	8.06	2.32	23.16
85.0		26			8.30	8.02	2.35	22.92
86.0		4 ø 26			8.27	7.98	2.38	22.68
87.0	LC			only)	8.24	7.94	2.41	22.46
88.0	11.05			ō	8.21	7.90	2.44	22.24
89.0	7			nal	8.35	8.04	2.30	22.34
90.0				. <u>ē</u>	8.55	8.24	2.10	22.56
91.0				26 (Optiona	8.85	8.54	1.80	22.96
92.0				9	9.05	8.74	1.60	23.16
93.0				26	9.25	8.95	1.40	23.36
94.0				Ø	9.25	8.94	1.40	23.20
95.0					9.20	8.87	1.45	22.96
96.0					7.98	7.68	2.67	20.00
97.0		2			8.05	7.75	2.60	20.00
98.0		ø 32			8.13	7.82	2.52	20.00
99.0		4			8.20	7.89	2.45	20.00
100.0					8.28	7.96	2.37	20.00

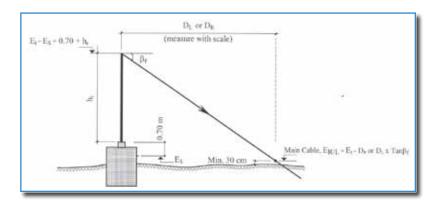
Span	Tower Height/ (Type)	Cables Nos. & diameter		eter	Dead Load Sag	Hoisting Sag	Camber	Full load Backstay
l m	h _t m	Main mm	Spanning mm	Windguy mm	f _d m	f _h m	c _d m	Angle ß _f deg.
101.0					8.35	8.03	2.30	20.00
102.0					8.40	8.07	2.25	20.00
103.0					8.50	8.17	2.15	20.00
104.0					8.57	8.23	2.08	20.00
105.0					8.65	8.31	2.00	20.00
106.0					8.71	8.36	1.94	20.00
107.0				26 (Optional only)	8.80	8.45	1.85	20.00
108.0				o	8.85	8.49	1.80	20.00
109.0	10	~	N	lal	8.94	8.58	1.71	20.00
110.0	Ö	32	32	<u>.</u> o	9.00	8.63	1.65	20.00
111.0	11.05	4 Ø	5	 bt	9.00	8.62	1.65	19.88
112.0				9	8.95	8.55	1.70	19.70
113.0				56	8.95	8.54	1.70	19.60
114.0				Ø	8.95	8.53	1.70	19.50
115.0					8.90	8.46	1.75	19.34
116.0					8.90	8.45	1.75	19.24
117.0					8.85	8.38	1.80	19.09
118.0					8.85	8.37	1.80	19.00
119.0					8.85	8.36	1.80	18.92
120.0					8.85	8.34	1.80	18.83

III. Fixing the Back Stay Lengths (DL and DR) and the Main Cable Anchorage Elevations (EL and ER)

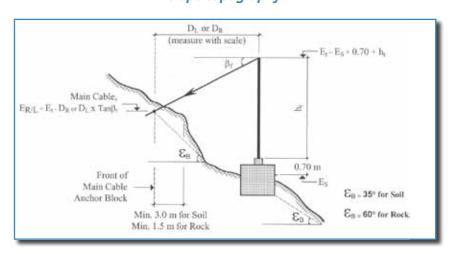
Fix the position of the Main Anchorage Foundation Blocks on both the banks in the bridge profile:

- Draw the centerline of the towers on both the banks in the bridge profile and mark the tower top
- (saddle) with the elevation $\mathbf{E}_{t} = \mathbf{E}_{s} + 0.70 + \mathbf{h}_{t}$. From the tower top, draw a line at the angle \mathbf{G}_{t} towards the ground level. Fix the position of the main cable anchor point along this line by considering the topography and the geological condition of the bridge site.

In flat topography (up to ground slope angle 15°):



In slope topography:



Measure the $\mathbf{D_L}$ or $\mathbf{D_R}$ backstay distance with a scale in the bridge profile.

Calculate the Main Cable Anchor Elevation ($\mathbf{E_R}$ and $\mathbf{E_L}$) as per the formula. $\mathbf{E_R} = \mathbf{E_t} - \mathbf{D_R} \mathbf{x} \tan \beta_f$, $\mathbf{E_L} = \mathbf{E_t} - \mathbf{D_L} \mathbf{x} \tan \beta_f$

$$E_R = E_t - D_R x tan B_t$$

$$E = E - D \times tan \beta$$
.

IV. **Calculation of Cable Lengths**

Turn of Cable	dia	Nes	Backstay Length [m]		Cutting Length*
Type of Cable	(mm)	Nos.	D _L	D _R	[m/pc]
Main Cable					
Spanning Cable		2	0	0	
Handrail Cable	13	2	0	0	
Fixation Cable	13	2	0	0	
Windguy		1 (U/S)	0	0	
Cable** (Optional)	26	1 (D/S)	0	0	
Windties** (Optional)	13	1	0	0	

* Cutting Length:

Main Cable = 1.08 x Span + 1.15 (DL+DR) + Anchorage Length on the Right Bank + Anchorage Length at Left Bank.

Calculate the Anchorage Lengths only after selecting of the Main Cable Anchor Blocks.

Spanning Cable = $1.03 \times \text{Span} + 3.5 \text{ m}$.

Handrail Cable = Span
Fixation Cable = Span

** Windguy Cable = Refer to Design of Wind guy Arrangement

** Windties = Refer to Design of Windguy Arrangement

V. Calculation of (fh) Hoisting Sag

This calculation has to be made after the tower erection is completed.

1	١.	Actual Span measured in the field	l	= m
2	2.	Hoisting Sag (from "Table: Selection of Cables and Standard Tower" as per actual span)	f _h	= m
3	3.	Tower Height	h _t	= m
4	1.	Marking Point on Tower (from steel tower base) at hoisting sag elevation =	$h_t - f_h$	= m

Design of the main cable anchor

3.6.5

The standard designs for the Main Cable Anchor Blocks have been developed for all possible cases for spans of up to 120m. The Standard Anchor Blocks have been developed by the design concept and statical analysis.

The design of the Main Cable Anchor Blocks is mainly to select the standard anchor block types suitable to the given cable combination, geology and topography of the site. Fill in the required data in the corresponding selected drawings.

There are basically six typical designs of the Main Anchor Blocks, depending on the flat or hill slope topography, and the soil or rock type.

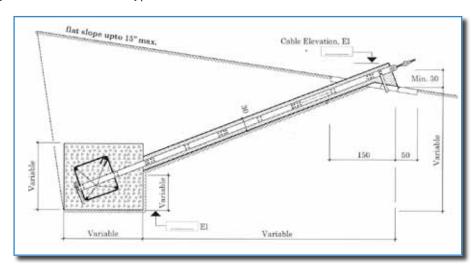


Figure F.3.5: Main Cable Deadman Anchor Block with Turnbuckle on Flat Topography

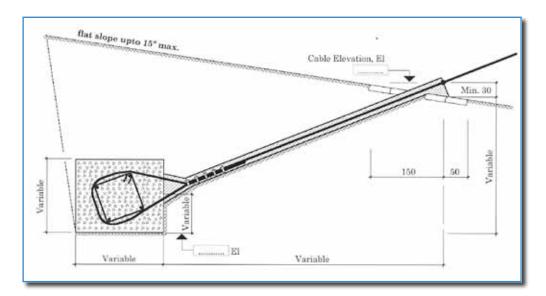


Figure F.3.6: Main cable anchor block with direct cable connection on flat topography

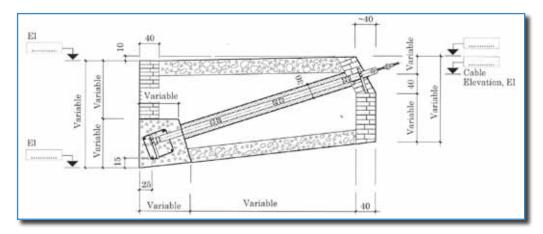


Figure F.3.7: Main cable gravity anchor block with turnbuckle on hill slope topography

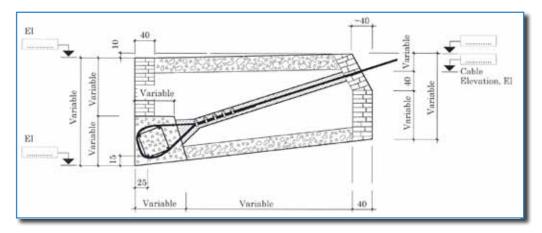


Figure F.3.8: Main cable gravity anchor block with direct cable connection on hill slope

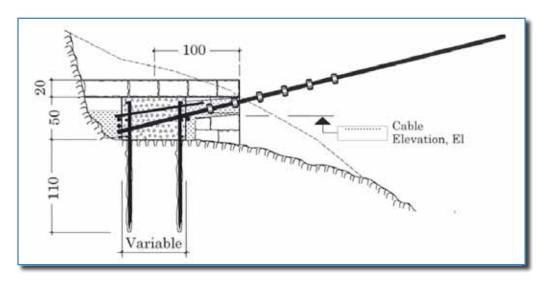


Figure F.3.9: Main cable drum anchor block in hard rock

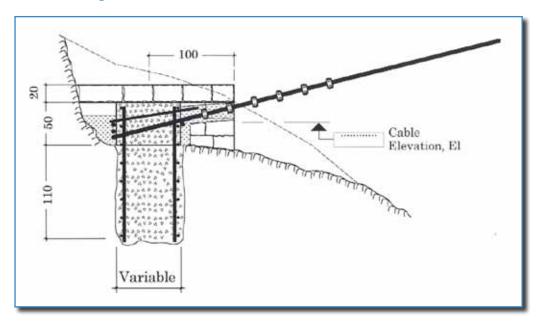


Figure F.3.10: Main cable drum anchor block in fractured hard rock or soft rock

To select the main anchor block type:

- Define the number and the diameter of the main cables.
- Define the topography of the ground where the anchor block will be placed as whether flat or slope. The topography is defined as flat if the ground slope is less than 15°, and slope if the ground slope is more than 15°.
- Define the soil or rock type from Survey Form and Checklist
- Select the anchor block type and the corresponding drawing from the selection tables according to the above design data.

Design the Main Anchor Blocks

(1). Design Data

Main Cables: Nos	Ømm								
	Right Bank Condition								
Geology:	Soil								
If Soil, how is the Ground Surface?	Flat (up to 15° slope)		or		Hill Slope (more than 15° slo	ppe)			
What is the Soil Type?	Gravelly		Sandy		Silty				
If Rock , what is the Rock	Hard Rock	•••••	Hard Rock	••••••	Soft Rock				
Type?	(only a few fractures)		(highly fractured)						
	Left Bank	Con	dition						
Geology:	Soil								
If Soil, how is the Ground Surface?	Flat (up to 15° slope)		or		Hill Slope (more than 15° slo	ope)			
What is the Soil Type?	Gravelly		Sandy		Silty				
If Rock , what is the Rock	Hard Rock		Hard Rock		Soft Rock				
Type?	(only a few fractur	es)	(highly frac	tured)					

(2). Selection of Anchor Types

Select the appropriate Anchor Types for the Right and Left Banks according to the above design data. Except for the Drum Rock Anchors, all Main Cable Anchors are either designed with Turnbuckle or for Direct Cable Connection. One Main Cable Anchor should always have a Turnbuckle for fine adjustment during sag setting, whereas for economic reasons, the cable anchor on the other bank should always have a direct cable connection.

Rules for selecting the anchor blocks:

- Select an Anchor Block with a turnbuckle for one bank and an Anchor Block with a direct cable connection for the other bank. Always choose the more convenient bank for the Main Cable Anchor with turnbuckle.
- If one bank is soil and the other bank is rock, always select a Drum Anchor for the rocky bank.
- If both banks are rocky, select an Anchor Block for one bank and a Drum Anchor for the other bank.

Procedure for selection:

 According to the Soil type and Slope of the ground or the Rock type, refer to the respective tables for selection of the Anchor Types.

for Soil and Flat Ground	(Cable Connection with Turnbuckle)	:	Table F.3.2
for Soil and Flat Ground	(Direct Cable Connection)	:	Table F.3.3
for Soil and Hill Slope	(Cable Connection with Turnbuckle)	:	Table F.3.4
for Soil and Hill Slope	(Direct Cable Connection)	:	Table F.3.5
for Hard, Soft or Fractured Rock	(Cable Connection with Turnbuckle)	:	Table F.3.6
for Hard Rock	(Direct Cable Connection)	:	Table F.3.7
for Fractured Hard Rock or Soft Rock	(Direct Cable Connection)	:	Table F.3.8

- Match the design data in the table: The number and diameter of the Main Cables → if Soil, Soil type → select Anchor type and corresponding. Drawing No. for the right bank and the left bank respectively.
- Fill in the required data in the selected drawings.

(3). Anchor Type Selection Tables

In Soil and Flat Ground

Table F.3.2: Selection of the main cable deaman anchor in soil & flat ground (Cable connection with turnbuckle)

Main Cable	Foundation Soil Type	Anchor Type	Drawing No
2x26	All	DA 1	42/1Ncon
2x32	All	DA 2	42/3Ncon
4x26	All	DA 3	44/1Ncon
4x32	All	DA 4	44/3Ncon

Table F.3.3: Selection of the main cable deadman anchor in soil & flat ground (Direct cable connection)

Main Cable	Foundation Soil Type	Anchor Type	Drawing No
2x26	All	DA 5	42/2Ncon
2x32	All	DA 6	42/4Ncon
4x26	All	DA 7	44/2Ncon
4x32	All	DA 8	44/4Ncon

In Soil and Hill Slope

Table F.3.4: Selection of the main cable anchor block in soil & hill slope (Cable connection with turnbuckle)

Main Cable	Foundation Soil Type	Anchor Type	Drawing No
2x26	All	AB 1	42/5Ncon
2x32	All	AB 2	42/7Ncon
4x26	All	AB 3	44/5Ncon
422	Gravelly or Sandy	AB 4	44/7Ncon
4x32	Silty	AB 5	44/9Ncon

Table F.3.5: Selection of the main cable anchor block in soil & hill slope (Direct cable connection)

Main Cable	Foundation Soil Type	Anchor Type	Drawing No
2x26	All	AB - 6	42/6Ncon
2x32	All	AB - 7	42/8Ncon
4x26	All	AB - 8	44/6Ncon
422	Gravelly or Sandy	AB - 9	44/8Ncon
4x32	Silty	AB - 10	44/10Ncon

In Hard, Soft or Fractured Rock

Table F.3.6: Selection of the Main Cable Anchor Block in Hard, Soft or Fractured Rock (Cable Connection with Turn Buckle)

Main Cable, mm	Anchor Type	Drawing No
2x26 or 2x32	AB - 11	45Ncon
4x26 or 4x32	AB - 12	46Ncon

In Hard Rock

Table F.3.7: Selection of the Main Cable Drum Anchor in Hard Rock (Direct Cable Connection)

Main Cable, mm	Anchor Type	Drawing No
2x26 or 2x32	DR-1	47Ncon
4x26 or 4x32	DR-2	48Ncon

In Fractured Hard Rock or Soft Rock

Table F.3.8: Selection of the Main Cable Drum Anchor in Fractured Hard Rock or Soft Rock (Direct Cable Connection)

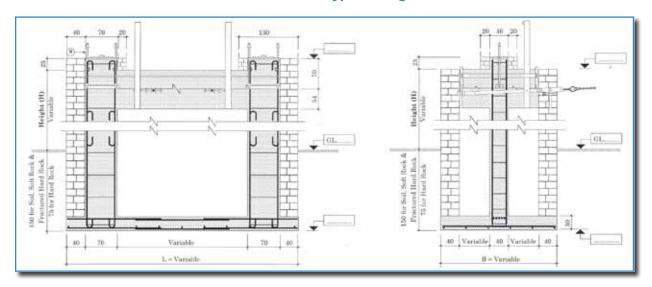
Main Cable, mm	Anchor Type	Drawing No
2x26 or 2x32	DR-3	49Ncon
4x26 or 4x32	DR-4	50Ncon

3.6.6 Walkway and tower foundation design

The standard designs of the Walkway and Tower Foundations have been developed for all possible cases for spans of up to 120m. The standard foundation designs have been developed by the design concept and statical analysis.

The design of the Walkway and the Tower Foundations is mainly to select the standard foundation types as per the cable combinations, geology and topography of the site. Fill in the required data in the corresponding selected drawings.

Illustration of a typical design:



A. Design Data

• Windguy Cable:nos. Ømm			
Right Bank / Upstream			
Geology:	Soil		
If Soil, what is the Soil Type?	Gravelly Sandy Silty		
Block Height from the Ground (data from bridge profile):	1.0m 2.0m 3.0m 4.0m		
If Rock , what is the Rock Type?	Hard Rock Soft Rock		
Block Height from the Ground (data from bridge profile):	(only a few fractures) (highly fractures) 1.0m in case of Rock		
Right Bank / Downstream			
Geology:	Soil		
If Soil, what is the Soil Type?	Gravelly Sandy Silty		
Block Height from the Ground (data from bridge profile):	1.0m 2.0m 3.0m 4.0m		
If Rock, what is the Rock Type?	Hard Rock Soft Rock		
Block Height from the Ground (data	(only a few fractures) (highly fractures)		
from bridge profile):	1.0m in case of Rock		

B. Selection of Walkway & Tower Foundations

Select the appropriate Walkway & Tower Foundations for the Right and Left Banks according to the above design data.

Procedure for selection:

 According to the Soil or Rock type, refer to the respective table for selection of the Walkway and Tower Foundations.

In Soil : **Table F.3.9**In Hard Rock : **Table F.3.10**In Fractured Hard Rock or Soft Rock : **Table F.3.11**

- If the bank is rock, always take the foundation block height H as 1.0m, If the bank is soil and in hill slope, always take the foundation block height H as 1.0m. If the bank is soil on flat ground, but the foundation block height H as needs to be raised, always take the foundation block height as 1.0 or 2.0 or 3.0 or 4.0m (maximum). H is limited to a maximum of 4.0m
- Match the design data in the table: Number and Diameter of Main Cables → Foundation Block Height → if Soil, Soil type → select Foundation type and corresponding Drawing No. for right bank and left bank respectively.
- Fill in the required data in the selected drawings.

C. Walkway & Tower Foundations Selection Tables

In Soil

Table F.3.9: Selection of walkway & tower foundations in soil

Main Cable	Foundation Block Height (H) m	Soil Type	Foundation Type	Drawing No.
	1.0	All	TF-1	92/1Ncon
2x26 and 2x32mm	2.0	All	TF-2	92/2Ncon
2x26 and 2x32mm	3.0	All	TF-3	92/3Ncon
	4.0	All	TF-4	92/4Ncon
	1.0	All	TF-6	94/1Ncon
	2.0	All	TF-7	94/2Ncon
4x26mm	3.0	Gravelly/Sandy	TF-8	94/3Ncon
4x20111111		Silty	TF-9	94/4Ncon
		Gravelly/Sandy	TF-10	94/5Ncon
	4.0	Silty	TF-11	94/6Ncon
	1.0	All	TF-6	94/1Ncon
	2.0	All	TF-7	94/2Ncon
4x32mm	3.0	Gravelly/Sandy	TF-8	94/3Ncon
4x32111111	3.0	Silty	TF-9	94/4Ncon
	4.0	Gravelly/Sandy	TF-10	94/5Ncon
	4.0	Silty	TF-11	94/6Ncon

In Hard Rock

Table F.3.10: Selection of walkway & tower foundations in hard rock

Main Cable	Foundation Block Height (H) m	Foundation Type	Drawing No.
2x26 or 2x32mm	1.0	TF-5	92/5Ncon
4x26 or 4x32mm	1.0	TF-12	94/7Ncon

In Fractured Hard Rock or Soft Rock

Table F.3.11: Selection of walkway & tower foundations in fractured hard rock or soft

Main Cable	Foundation Block Height (H) m	Foundation Type	Drawing No.
2x26 or 2x32mm	1.0	TF-1	92/1Ncon
4x26 or 4x32mm	1.0	TF-6	94/1Ncon

3.6.7 Suspender list

Suspenders are designed for the bridge geometry under dead load, i.e. I, fd and cd. The layout of the suspenders and its geometrical calculation is based on the design calculations done in this manual, as per the said suspender layout and the geometrical calculation for suspender lengths, a computer program "Suspender Design" has been developed.

(a). Calculation of Suspender List

Calculate the Suspender List using the computer program "**SSTB Design**" which is found in another folder.

The calculation is based on the fixed geometry of the bridge as per the table: **Selection of Cables and Standard Towers**. The only input data required for the calculation is the span, *I*.

(b). Procedure for the Suspender List calculation

- Open the computer program SSTB Design > "Suspender Design"
- Enter the input data: Bridge Name, Bridge Span and width of Walkway and Tower Foundation
- Print result.

Attach the printout of the Suspender List with the drawing of the suspenders.

3.6.8 List of drawings

Select the required Steel Drawings and Construction Drawings according to the selected Main Cables, Towers, Main Cable Anchorage Blocks and Walkway / Tower foundations.

In addition, prepare a General Arrangement drawing for individual bridge designs

3.6.9 Other structures

Besides the bridge structure, some other adjacent structures may be required for overall bridge stability and for safety measures. These are the structures.

- (1). Windguy Arrangement
- (2). Retaining Structures
- (3). Slope Protection works

(4). River Bank Protection

(1). Windguy Arrangement (Optional)

The design maximum wind speed is calculated assuming 160km/h, and has favourable nature of the wind flow. Theoretical calculations show that there is no need for a windguy arrangement for Suspension type bridges with spans of up to 120m. Therefore, no Windguy Arrangement is necessary in this standard suspension bridge. All the towers and foundation structures are designed to withstand the maximum design wind pressure without a windguy arrangement. However, during high wind time (the frequency and duration of such times are very low) the comfort while crossing the bridge will be significantly reduced and it may even be risky. Therefore, no traffic should be allowed to cross the bridge during such windy times.

For special cases, i.e., when the bridge span is more than 120m or in extremely windy areas with wind speeds in excess of 160km/hr and unfavourable nature of the wind flow, a windguy system is mandatory.

Design of Windguy Arrangement

The design of the Windguy Arrangement is to

- Select the diameter of the windguy cable and windties cable;
- Calculate the geometry of the windguy arrangement;
- Select the windguy cable anchor blocks.

A general layout of the Windguy Arrangement.

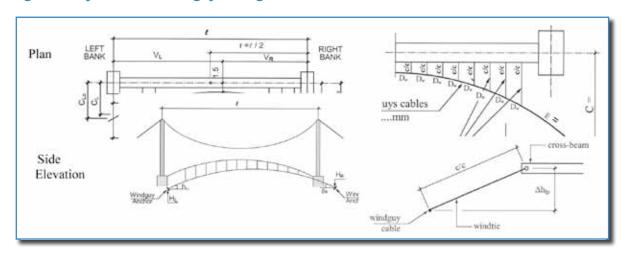


Figure F.3.11: Layout of windguy arrangement

A computer program "Windguy Design" has been developed for the calculation. The calculation is based on the layout of the Windguy Arrangement as per the above and the fixed geometry of the bridge in dead load case as per the **Table: Selection of Cables and Standard Towers** section of this manual..

Calculate the Windguy Arrangement using the computer program "SSTB Design" which is found in a separate folder of this Manual.

Procedure for Windguy Arrangement Design

- Open computer program SSTB Design > "Windguy Design".
- Give input data: Bridge Name, Bridge Span and Elevation of Steel Tower Base.

The calculation procedure:

- Give the tentative of the first windtie position $\mathbf{B_L}$ and $\mathbf{B_R}$ as per the topography. The program will adjust to the nearest actual values.
- Give the level of the windguy anchorage on the right bank $\mathbf{H_L}$ and the left bank $\mathbf{H_R}$. $\mathbf{H_L}$ and $\mathbf{H_R}$ should be at or below the level of the spanning cable at the anchorage point (Es).

- Give (select) the windguy anchor position on the right bank (or the left bank), i.e. C_R and D_R or (C_L) and $\mathbf{D}_{\mathbf{l}}$). Accordingly, the windties listing will be from the right bank to the left bank or vise versa.
- Input the value of V_R (distance up to the vertex of the windguy cable) if the selected windguy anchor position is on the right bank or V_L if the selected windguy anchor position is on the left
- Check the span and sag ratio of the windguy cable, I/b. It should be not less than 8 and not more than 10. If this condition is not met, input a new ${\bf V}$ till the I/b is within the recommended limit.
- Check the lowest point of the windguy cable " Δh_{l_p} ". It should not be negative (-). If the Δh_{l_p} is negative, input new $\mathbf{H_L}$ and $\mathbf{H_R}$ with a lower value.
- Input value of $\mathbf{D_{Lo}}$ (or $\mathbf{D_{Ro}}$) = 0. The result will show $\mathbf{C_{Lo}}$ (or $\mathbf{C_{Ro}}$), and horizontal angle α_{L} (or α_{R}). Draw a straight line with the given $\mathbf{C_{Lo}}$ (or $\mathbf{C_{Ro}}$), and horizontal angle α_{L} (or α_{R}). Fix the windguy anchor position on the left bank (or the right bank) along this line. The anchorage block should be placed on safe ground and at the optimum foundation location so that it has sufficient embedded depth and also so that deep excavation can be avoided.
- After fixing the anchorage position, measure the actual $\mathbf{C}_{_{\mathbf{L}}}$ (or $\mathbf{C}_{_{\mathbf{R}}}$). The result will give the $\mathbf{D}_{_{\mathbf{L}}}$ (or
- Draw longitudinal sections along the windguy cables at the foundations and determine the exact position of the front of the foundations ($\mathbf{D_{R'}}, \mathbf{C_{R}}$ and $\mathbf{D_{L'}}, \mathbf{C_{L'}}$) and the windguy cable elevations ($\mathbf{H_{R'}}$)
- If the final position of the foundations does not match the design as above, repeat the calculation process from the second bullet till all the foundations are located at the optimum positions.
- Print out the results. The results will give:
 - Position of the anchorage blocks,
 - Diameter of the windguy cable,
 - c/c inclined distance (length) of the windties,
 - Cutting length of the windties,
 - Horizontal c/c distance of the windties and
 - Inclined distance Dw (interval between the windties).
- Calculate the Windguy Arrangement for both upstream and downstream.

Attach the printout of the results with the drawing of the Windguy Clamp and also transfer it to the General Arrangement Drawing.

Windguy anchorage foundation blocks design (optional)

The design concept and the statical analysis are the same as for the main anchor blocks. Accordingly, the standard anchor blocks have been developed. Basically, there are four typical standard anchor blocks.

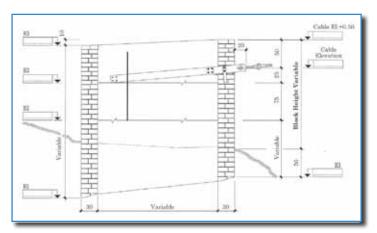


Figure F.3.12: Gravity anchor block in soil

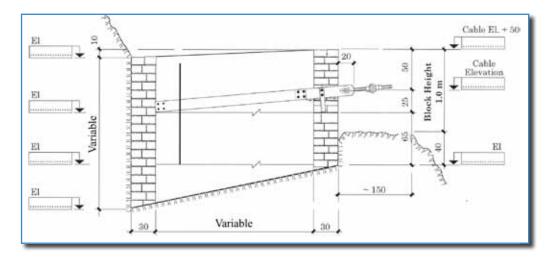


Figure F.3.13: Gravity anchor in rock

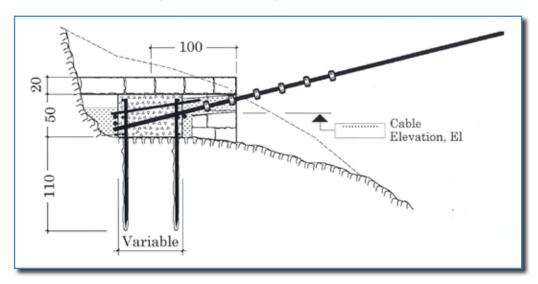


Figure F.3.14: Drum anchor block in hard rock

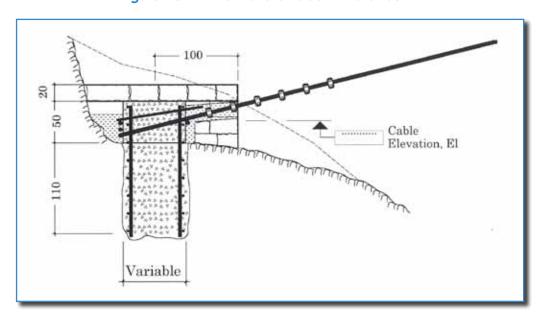


Figure F.3.15: Drum Anchor Block in Fractured Hard Rock & Soft Rock

Design Data Fill in the Design Data from Survey Form and Checklist.

■ Windguy Cable:nos. Ømm			
R	ight Bank / Upstream		
Geology:	Soil		
If Soil, what is the Soil Type?	Gravelly Sandy Silty		
Block Height from the Ground (data from bridge profile):	1.0m 2.0m 3.0m 4.0m		
If Rock, what is the Rock Type?	Hard Rock Hard Rock Soft Rock		
Block Height from the Ground (data from bridge profile):	(only a few fractures) (highly fractures) 1.0m in case of Rock		
Right Bank / Downstream			
Geology:	Soil		
If Soil, what is the Soil Type?	Gravelly Sandy Silty		
Block Height from the Ground (data from bridge profile):	1.0m 2.0m 3.0m 4.0m		
If Rock, what is the Rock Type?	Hard Rock Hard Rock Soft Rock		
Block Height from the Ground (data from bridge profile):	(only a few fractures) (highly fractures) 1.0m in case of Rock		

■ Windguy Cable:nos. Ømm				
Left Bank / Upstream				
Geology:	Soil			
If Soil, what is the Soil Type?	Gravelly		Sandy	Silty
Block Height from the Ground (data from bridge profile):	1.0m	2.0m	3.0m	4.0m
If Rock, what is the Rock Type?	Hard Rock		Hard Rock	Soft Rock
Block Height from the Ground (data from bridge profile):	(only a few frac	tures) ı case of	(highly fractures)	
Left Bank / Downstream				
Geology:	Soil			
If Soil, what is the Soil Type?	Gravelly		Sandy	Silty
Block Height from the Ground (data from bridge profile):	1.0m	2.0m	3.0m	4.0m
If Rock, what is the Rock Type?	Hard Rock		Hard Rock	Soft Rock
Block Height from the Ground (data	(only a few frac	tures)	(highly fractures)	
from bridge profile):	1.0m in	case of	Rock	

- Selection of Standard Windguy Cable Anchor Blocks
 Select appropriate Windguy Cable Anchor Blocks for U/S and D/S for the Right and Left Banks according to the above design data. are the rules for selection of the anchor blocks.
 - If the bank is rock, always take the block height as 1.0m.
 - If the bank is soil on a hill slope, always take the block height as 1.0m.
 - If one bank is soil and the other bank is rock, always select a Drum Anchor for the rocky bank.
 - If both banks are rocky, select an Anchor Block for one bank and a Drum Anchor for the other bank.
 - If the bank is soil but on flat ground and the anchor block height needs to be raised, always take the foundation block height as 1.0, or 2.0, or 3.0, or 4.0 m (maximum).

Procedure for selection:

According to the Soil or Rock type, refer to respective table for selection of Windguy Cable Anchor Blocks.

In Soil : Table F.3.12
In all types of Rock (Anchor Block) : Table F.3.13
In Hard Rock (Drum Anchor) : Table F.3.14
In Fractured Hard Rock or Soft Rock : Table F.3.15

(Drum Anchor)

In the tables match the design data: Diameter of Windguy Cable → Soil or Rock type → Block Height → select Anchor Block type and corresponding Drawing No.

• Fill in the required data in the selected drawings.

Selection Tables for Windguy Anchor Blocks

In Soil

Table F.3.12: Selection of windguy cable anchor block in soil

Windguy Cable [mm]	Anchor Block Height	Soil Type	Anchor Type	Drawing No.
	1	All	WAB - 1	55/1Acon
27	2	All	WAB – 2	55/2Acon
26	3	All	WAB – 3	55/3Acon
	4	All	WAB – 4	55/4Acon

In Hard, Fractured or Soft Rock

Table F.3.13: Selection of windguy cable anchor block in all types of rock

Windguy Cable [mm]	Anchor Type	Drawing No.
26	WAB - 5	56Acon

In Hard Rock

Table F.3.14: Selection of windguy cable drum anchor in hard rock

Windguy Cable [mm]	Anchor Type	Drawing No.	
26	WDR - 1	57Acon	

In Fractured or Soft Rock

Table F.3.15: Selection of windguy cable drum anchor in fractured or soft rock

Windguy Cable [mm]	Anchor Type	Drawing No.	
26	WDR - 2	58Acon	

(2). Retaining structures

Retaining structures are necessary to retain the earth (soil, fractured rock and weathered soft rock) behind the anchorage blocks of the bridge. There are many options for retaining structures. But for trail bridges, the most feasible are retaining walls. Retaining walls can be of gabion boxes, rubble masonry and dry stone masonry. For the short-span trail bridges, dry stone retaining walls or breast walls are preferable since they require only local materials.

The choice between retaining wall and breast wall depends on different factors, such as the available space behind the blocks, the required height of the protection, soil conditions etc.

Retaining walls are used when the earth to be retained is loose soil with a great protection height. For the design of the retaining wall, use the table.

Retaining Walls

Туре	Dry Stone	Banded Dry Stone / Masonry	
Section	W _b	W ₁ W ₂ N N	
Top width, W _t	0.6 - 1.0 m	0.6 - 1.0 m	
Base width, W _b	0.5 - 0.7 H	0.6 - 0.65 H	
Front batter	varies	varies	
Back batter	varies	vertical	
Inward dip of foundation, n	1:3	1:3	
Foundation depth	≥ 0.50 m	≥ 0.50 - 1 m	
Range of height, H	1 - 6 m	6 - 8 m	
Hill slope angle,	< 35°	20°	

Breast walls are used when the earth to be retained is fractured or weathered rock, or compact soil with temporarily unstable nature. For designing breast walls, use the table.

Breast Walls

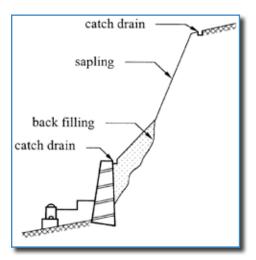
Туре		Dry Stone		Banded Dry Stone / Masonry
Section	Н	w.] >	ďα	W ₁ dry Stone mortar W _b
Top width, Wt	0.50 m			0.5 m
Base width, Wb	0.29H	0.3H	0.33H	> 0.5H
Back batter	3 : 1	4 : 1	5 : 1	3:1
Inward dip of foundation, n	1:3	1 : 4	1:5	1:3
Foundation depth	≥ 0.50 m	≥ 0.50 m	≥ 0.50 m	≥ 0.50 m
Range of height, H	< 6 m	< 4 m	< 3 m	3 - 8 m
Hill stope angle, a	35 - 60°			35 - 60°

(3). Slope Protection Measures

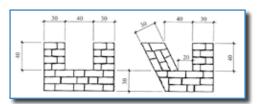
Slope protection measures depend on the factors influencing slope instability. It is recommended that a bridge site be selected, where there are no slope instability features. However, it is often necessary to drain out the surface runoff and seepage water from the slope as a slope protection measure.

Water should be collected as close as possible to its origin and safely channeled to a nearby watercourse. The surface drainage can be catch drain on the slope or drainage around the anchorage foundation or a combination of both.

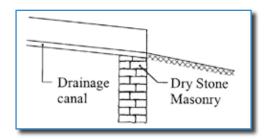
The choice depends on the position of the anchorage foundation and the profile of the natural terrain.



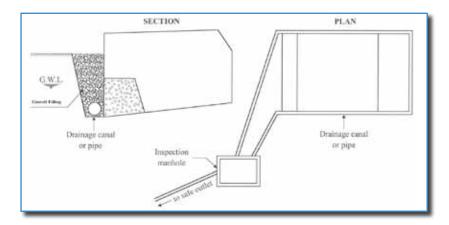
The drain should be open type. The design shows the typical sections of the drain.



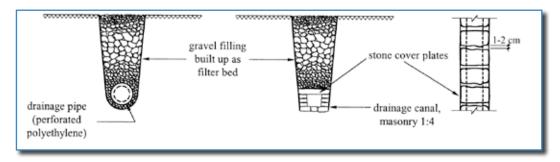
To avoid self-scouring, the drain outlet should be protected.



In seepage area, sub-surface drainage is required around the anchorage foundation. Consider a typical layout design of the sub-surface drain.



A typical design of the sub-surface drain.



(4). Bio-Engineering

Surface drainage alone may not be sufficient to protect unstable slopes. The most effective method for stabilizing such slopes is bio-engineering in combination with light civil structures such as catch drains, check dams, cascades, etc. This is a cheap and easy method. The main concept of this method is to grow trees and plants such as shrubs or grasses. Deep rooted and fast growing trees and plants are most suitable for this purpose. The proper selection of plant types is most important, and it should be based upon local experience. Some of the vegetation measures are:

- Planted grass lines: contour/horizontal or down slope/vertical or random planting;
- Grass seeding;
- Turfing;
- Shrub and tree planting;
- Shrub and tree seeding;
- Fascines (bundles of live branches are laid in shallow trenches).

(5). River Bank Protection

River protection works are of a temporary nature and costly. They require frequent maintenance to keep the structures functional. Therefore, avoid bridge sites which require river protection works as far as possible.

3.6.10 General arrangement drawing

General Arrangement (GA) drawing shows the overall plan and profile of the bridge. The GA should reflect the major components of the bridge and its geometry for dead load case including the elevations of the tower tops, cable anchor points, the foundations and general dimensions. The GA is required for an overall view of the designed bridge and also for layout of the bridge before construction.

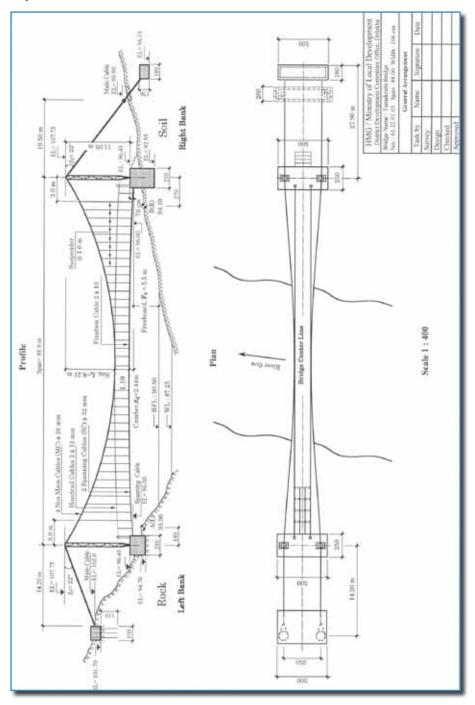
Draw the GA on the same bridge profile as already done in this manual and mention the data on the plan and the profile of the bridge:

- Span l, tower height \mathbf{h}_{t} dead load sag \mathbf{f}_{d} , dead load camber \mathbf{c}_{d} , and backstay angle $\mathbf{\beta}_{t}$
- Backstay distance $\mathbf{D}_{\mathbf{R}}$ and $\mathbf{D}_{\mathbf{L}}$

- Distance from the axis points A and B (which were fixed during the survey) and the center of the towers;
- Main cable elevations at the tower saddles (top of the tower), elevation of the lowest point of the main cable;
- Spanning cable elevation at the anchor point;
- All bridge foundation levels;
- The LWL, HFL and available freeboard $\mathbf{F}_{\mathbf{b}}$;
- Overall dimensions of the bridge structures and their elevations.

The completed GA should be sufficient for the layout of the bridge. An example of the GA drawing of a bridge.

3.7 Design example



3.8 Bridge standard drawing

3.8.1 Introduction & overview of drawings

The Bridge Standard Drawings represent the centerpiece of the Short Trail Bridge Standard. They are composed as a unit component system and are categorized into two groups: **Construction Drawings and Steel Drawings**

Both drawing groups are linked with each other and depending on the bridge design the required drawings are to be selected.

Legend for the Drawing Numbers and Suffixes:

	Drawing No.	Suffix	Bridge or Drawing Type				
S T E E L DRAWINGS	08 07	A N	For All Bridge Types For Suspension Bridge Types				
	56	Ncon	con struction drawings				
z	Anchor Types for Main Cables						
RUCTIO		DA 5 AB 7 DR 3	Deadman Anchor Type 5 Anchor Block Type 7 Drum Rock Type 3				
8 8	Anchor Types for Windguy Cables						
ONST		WAB 2 WDR 1	Windguy Anchor Block Type 2 Windguy Drum Rock Anchor Type 1				
U	Walkway and Tower Foundations						
		TF 11	Tower Foundation Type 11				

3.8.2 Construction drawings

Construction drawings for suspension bridges consist of three different drawing groups.

These are:

- Main Cable Anchor Drawings
- Walkway and Tower Foundation Drawings
- Windguy Cable Anchor Drawings

Table F.3.16: Construction Drawings for Main Cable Anchors

(in Different Soil & Rock Conditions)

	Ground Condition		Anchor	M	ain Cab	les	Turnbuckle or Direct	Drawing		
Grou			Type Nos c/c ₁ Ø [m]		Cable Connection	No.				
			HORS	2	2.50	26	With Turnbuckle Direct Cable Connection	42/1Ncon 42/2Ncon		
	FLAT GROUND	ilty	DEADMAN ANCHORS "DA" TYPES	2	2.50	32	With Turnbuckle Direct Cable Connection	42/3Ncon 42/4Ncon		
	LAT G	All Soil Types: Gravelly, Sandy or Silty	DMAN"	4	3.50	26	With Turnbuckle Direct Cable Connection	44/1Ncon 44/2Ncon		
	_	All Soil Types: avelly, Sandy o	DEA	4	3.30	32	With Turnbuckle Direct Cable Connection	44/3Ncon 44/4Ncon		
SOIL		All		2	2.50	26	With Turnbuckle Direct Cable Connection	42/5Ncon 42/6Ncon		
S	HILL SLOPE		RS	4	3.50	20	With Turnbuckle Direct Cable Connection	44/5Ncon 44/6Ncon		
			NNCHO ES	2	2.50		With Turnbuckle Direct Cable Connection	42/7Ncon 42/8Ncon		
		Gravelly or Sandy Soil	GRAVITY BLOCK ANCHORS "AB" TYPES	4	3.50	32	With Turnbuckle Direct Cable Connection	44/7Ncon 44/8Ncon		
		Silty Soil	WITY I	4	3.50	32	With Turnbuckle Direct Cable Connection	44/9Ncon 44/10Ncon		
	Soft or		GR/	2	2.50	26 or 32	With Turnbuckle	45Ncon		
	Fract	ured Rock		4	3.50	26 or 32	With Turnbuckle	46Ncon		
ROCK		Hard	IORS	2	2.50	26 or 32	Direct Cable Connection	47Ncon		
8		Rock	C ANCH TYPES	4	3.50	26 or 32	Direct Cable Connection	48Ncon		
		oft or	DRUM ROCK ANCHORS "DR" TYPES	2	2.50	26 or 32	Direct Cable Connection	49Ncon		
			Fractured Rock		DRUI	4	3.50	26 or 32	Direct Cable Connection	50Ncon

Table F.3.17: Construction drawings for walkway and tower foundations

(in Different Soil and Rock Conditions)

Ground Condition		Main (Cables	Block	Foundation	Drawing
		Nos	Ø [mm]	Height [m]	Type	No.
	ŗ.	2		1.0	TF 1	92/1Ncon
	es: dy o	2		2.0	TF 2	92/2Ncon
	Typ San	2		3.0	TF 3	92/3Ncon
	All Soil Types: avelly, Sandy Silty	2		4.0	TF 4	92/4Ncon
SOIL	All Soil Types: Gravelly, Sandy or Silty	4	26 or 32 mm	1.0	TF 6	94/1Ncon
SC		4		2.0	TF 7	94/2Ncon
	Gravelly or Sandy	4		3.0	TF 8	94/3Ncon
		4		4.0	TF 10	94/5Ncon
	Silty	4		3.0	TF 9	94/4Ncon
		4		4.0	TF 11	94/6Ncon
	_Soft or	2			TF 1	92/1Ncon
ROCK	Fractured Rock	4		1.0	TF 6	94/1Ncon
&	Hard Rock	2			TF 5	92/5Ncon
	пага коск	4			TF 12	94/7Ncon

Table F.3.17: Construction Drawings for Windguy Cable Anchors

(in Different Soil and Rock Conditions)

Gro	und Condition	Windguy Cable Block Height Ø [mm]		Foundation Type	Drawing No.	
	pes: iandy y		1.0	WAB 1	55/1Ncon	
I⊒	.>\o\+'.	E	2.0	WAB 2	55/2Ncon	
80	Soil Typ		3.0	WAB 3	55/3Ncon	
	All Soil T Gravelly, or Sil	Ø 26	4.0	WAB 4	55/4Ncon	
	All Rock Types		<u>•</u>	1.0	WAB 5	56Ncon
×	Hard Rock	Cable		WDR 1	57Ncon	
ROCK	Fractured or Soft Rock	One (Drum Type	WDR 2	58Ncon	

Table F.3.19: Summary of All Construction Drawings

		Drawing Titles	Drawing Nos.
	TING TAILS	Walkway Fitting for Suspension Bridge for 106 cm Walkway Width	19Ncon
35	DEADMAN ANCHORS IN FLAT GROUND	2 Cables Ø 26mm, c/c ₁ = 2.50m, with Turn Buckle, all Soil Types 2 Cables Ø 32mm, c/c ₁ = 2.50m, with Turn Buckle, all Soil Types 4 Cables Ø 26mm, c/c ₁ = 3.50m, with Turn Buckle, all Soil Types 4 Cables Ø 32mm, c/c ₁ = 3.50m, with Turn Buckle, all Soil Types 2 Cables Ø 26mm, c/c ₁ = 2.50m, Direct Cable Connection, all Soil Types 2 Cables Ø 32mm, c/c ₁ = 2.50m, Direct Cable Connection, all Soil Types 4 Cables Ø 26mm, c/c ₁ = 3.50m, Direct Cable Connection, all Soil Types 4 Cables Ø 32mm, c/c ₁ = 3.50m, Direct Cable Connection, all Soil Types	42/1Ncon 42/3Ncon 44/1Ncon 44/3Ncon 42/2Ncon 42/4Ncon 44/2Ncon 44/4Ncon
MAIN CABLE ANCHORS	GRAVITY BLOCK ANCHORS IN HILL SLOPES	2 Cables Ø 26mm, $c/c_1 = 2.50m$, with Turn Buckle, all Soil Types 2 Cables Ø 2mm, $c/c_1 = 2.50m$, with Turn Buckle, all Soil Types 4 Cables Ø 26mm, $c/c_1 = 3.50m$, with Turn Buckle, all Soil Types 4 Cables Ø 32mm, $c/c_1 = 3.50m$, with Turn Buckle, gravelly or sandy Soil 4 Cables Ø 32mm, $c/c_1 = 3.50m$, with Turn Buckle, silty Soil 2 Cables Ø 26mm, $c/c_1 = 2.50m$, Direct Connection, all Soil Types 2 Cables Ø 32mm, $c/c_1 = 2.50m$, Direct Connection, all Soil Types 4 Cables Ø 26mm, $c/c_1 = 3.50m$, Direct Connection, all Soil Types 4 Cables Ø 32mm, $c/c_1 = 3.50m$, Direct Connection, gravelly or sandy Soil 4 Cables Ø 32mm, $c/c_1 = 3.50m$, Direct Cable Connection, silty Soil 2 Cables Ø 26 or 32mm, $c/c_1 = 3.50m$, with Turn Buckle, all Rock Types 4 Cables Ø 26 or 32mm, $c/c_1 = 3.50m$, with Turn Buckle, all Rock Types	42/5Ncon 42/7Ncon 44/5Ncon 44/7Ncon 44/9Ncon 42/6Ncon 42/8Ncon 44/6Ncon 44/10Ncon 45Ncon 46Ncon
	DRUM ROCK ANCHORS	2 Cables Ø 26 or 32mm, c/c ₁ = 2.50m, Direct Connection, in hard Rock 4 Cables Ø 26 or 32mm, c/c ₁ = 3.50m, Direct Connection, in hard Rock 2 Cables Ø 26 or 32mm, c/c ₁ = 2.50m, Direct Connection, fractured/soft Rock 4 Cables Ø 26 or 32mm, c/c ₁ = 3.50m, Direct Connection, fractured/soft Rock	47Ncon 48Ncon 49Ncon 50Ncon
	WWALKWAY AND IOWER FOUNDATIONS	2 Main Cables $c/c_1 = 2.50m$, Block Height 1.0m, all Soil Types & soft Rock 2 Main Cables $c/c_1 = 2.50m$, Block Height 2.0m, all Soil Types 2 Main Cables $c/c_1 = 2.50m$, Block Height 3.0m, all Soil Types 2 Main Cables $c/c_1 = 2.50m$, Block Height 4.0m, all Soil Types 2 Main Cables $c/c_1 = 2.50m$, Block Height 1.0m, in hard Rock 4 Main Cables $c/c_1 = 3.50m$, Block Height 1.0m, all Soil Types & soft Rock 4 Main Cables $c/c_1 = 3.50m$, Block Height 2.0m, all Soil Types 4 Main Cables $c/c_1 = 3.50m$, Block Height 3.0m, in gravelly or sandy Soil 4 Main Cables $c/c_1 = 3.50m$, Block Height 3.0m, in silty Soil 4 Main Cables $c/c_1 = 3.50m$, Block Height 4.0m, in gravelly or sandy Soil 4 Main Cables $c/c_1 = 3.50m$, Block Height 4.0m, in silty Soil 4 Main Cables $c/c_1 = 3.50m$, Block Height 4.0m, in hard Rock	92/1Ncon 92/2Ncon 92/3Ncon 92/4Ncon 92/5Ncon 94/1Ncon 94/2Ncon 94/3Ncon 94/4Ncon 94/6Ncon 94/6Ncon
WINDGUY	CABLE ANCHORS OPTIONAL	1 Cable Ø 26mm, Block Height 1.0m, for all Soil Types 1 Cable Ø 26mm, Block Height 2.0m, for all Soil Types 1 Cable Ø 26mm, Block Height 3.0m, for all Soil Types 1 Cable Ø 26mm, Block Height 4.0m, for all Soil Types 1 Cable Ø 26mm, Block Height 1.0m, for all Rock Types 1 Cable Ø 26mm, Drum Type in hard Rock 1 Cable Ø 26mm, Drum Type in fractured or soft Rock	55/1Acon 55/2Acon 55/3Acon 55/4Acon 56Acon 57Acon 58Acon

IV. Steel Drawings

Table F.3.20: Summary of All Steel Drawings

	Drawing Titles	Drawing Nos.
WALKWAY CROSS BEAM	Crossbeam for Walkway Width = 106 cm	07N
STEEL DECK	Steel deck Standard Panel, length = 198 cm / width = 34 cm Steel deck Special Panel, length = 223 cm / width = 34 cm	08A 10A
WINDGUY PARTS	Windties Cable Clamps for Windguys Cable ø 26 or 32 mm Windguys Cable Anchorage for one Cable End ø 26 or 32 mm	11A 50A
SUSPENDERS	Suspenders for 2 Main Cables ø 26 or 32mm Suspenders for 4 Main Cables ø 26 or 32mm	31N 32N
MAIN CABLE ANCHORS	Main Cable Anchorage for 2 Main Cables ø 26 or 32mm Main Cable Anchorage for 4 Main Cables ø 26 or 32mm	42N 44N
WALKWAY & TOWER FOUNDATION	Walkway and Tower Foundation, $c/c_1 = 2.50$ m, $c/c_2 = 383$ mm Walkway and Tower Foundation, $c/c_1 = 3.50$ m, $c/c_2 = 383$ mm	92N 94N
TOWERS	Guide for selecting Towers, Main Cables and Spanning Cables Assembly and Layout for Tower No. 1, Height 5.50 m Assembly and Layout for Tower No. 2, Height 7.35 m Assembly and Layout for Tower No. 3, Height 9.20 m Assembly and Layout for Tower No. 4, Height 11.05 m Base Element for Tower Nos. 1, 2, 3 or 4 Intermediate Element for Tower Nos. 1, 2 or 3 Intermediate Element for Tower No. 4 Top Element for Tower Nos. 1, 2 or 3 Top Element for Tower No 4 Saddle for Tower Nos. 1, 2, 3 or 4	99N 141N 142N 143N 144N 100N 109N 110N 119N 121N 135N

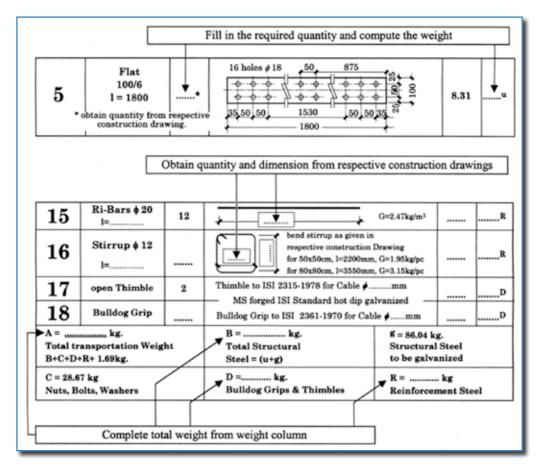
3.8.3 Concept of the standard drawings

Steel Drawings

Each drawing provides the necessary information and specifications for manufacturing the desired steel parts. The required quantity of steel parts has to be filled in the space provided in the title of the drawing.

Specific items such as reinforcement rods and flats for Main Cable Anchorages have to be filled in the empty spaces in the material lists.

Example:



From the total weights of each drawing, the grand total for each steel category has to be added up as follows:

- **A:** Means the entire weight of the steel including galvanization to be transported to the site.
- **B:** This is the total structural steel, raw or untreated (u+g). This includes steel profiles, plates and flats but not reinforcement bars and other steel items.
- **C:** This is the weight of the Nuts, Bolts and Washers (galvanized weight).
- **D:** This is the weight of the Bulldog Grips or Thimbles and other items, if required (galvanized weight).
- R: This is the raw weight of the Reinforcement Steel or Plain Rods. They are never galvanized.

The Total Transportation Weight A = B + C + D + R

g: The small g indicates the weight of the structural steel to be galvanized. This weight is part or can be the sum of the total structural steel (B), but it is not an additional weight.

The above distinctions have been made for quotation purposes because the price per kg (or piece) of the different items varies greatly. Reinforcement steel is usually much cheaper than structural steel; and nuts and bolts are much more expensive than structural steel, etc. The weight of the steel to be galvanized is necessary to obtain the price for galvanization **separately**, excluding the cost of the steel itself.

The steel drawings are usually not necessary at the construction site, but for assembly and identification of the steel parts, a copy of each steel drawing should be available. Also for maintenance at a later stage, copies of the steel drawings are useful.

Construction Drawings

The construction drawings are the actual site drawings. A complete set is absolutely necessary at the site.

- Walkway fitting drawing for 106cm walkway width
- Main cable anchorages

For the Main Cable Anchorages, there are three main categories of drawings

- Deadman Anchors for Flat Ground of up to 15° slope
- Gravity Block Anchors for Hill Slopes of more than 15°
- Drum Rock Anchors for Fractured or Soft Rock or Hard Rock

With these three groups of Main Cable Anchorages, the optimal kind of anchor can be applied. The selection depends upon the prevailing Soil/Rock condition on the respective river banks and the number and diameter of the Main Cables.

- Walkway and Tower Foundations
 - Depending on the Soil/Rock conditions the number of Main Cables and the required Block Height, Walkway and Tower Foundations are to be selected. There are five options for the two Main Cables with c/c1 = 2.50m, and seven options for the four Main Cables with c/c1 = 3.50m.
- Windguy Cable Anchors

There are two categories of anchor types for anchoring the windguy cables.

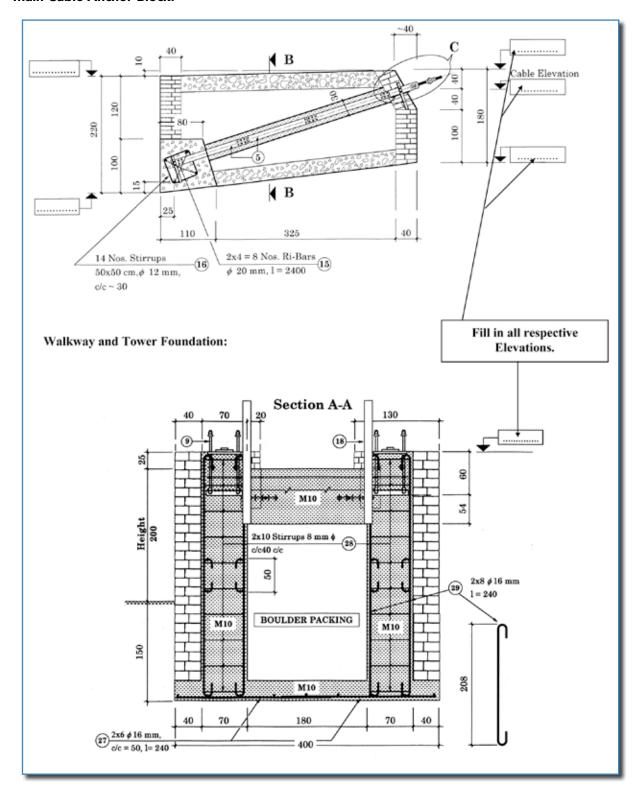
- Gravity Block Anchors for different Soil/Rock conditions with variable Block Heights (five types)
- rum Rock Anchors for fractured or soft Rock or for hard Rock (two types)

All drawing types are complete designs and fulfill their respective parameters selected in the design form. Also, in all drawings, the necessary quantities of construction materials have already been calculated as far as possible. They have to be filled in their respective tables given in the cost estimate Form No. 3 or 4.

It is absolutely necessary to fill in the Elevations and Cable diameters as indicated in the drawings. The levels are to be determined in the topographic profile of the survey, whereas the cable diameter can be taken from the design form.

Examples of Construction Drawings:

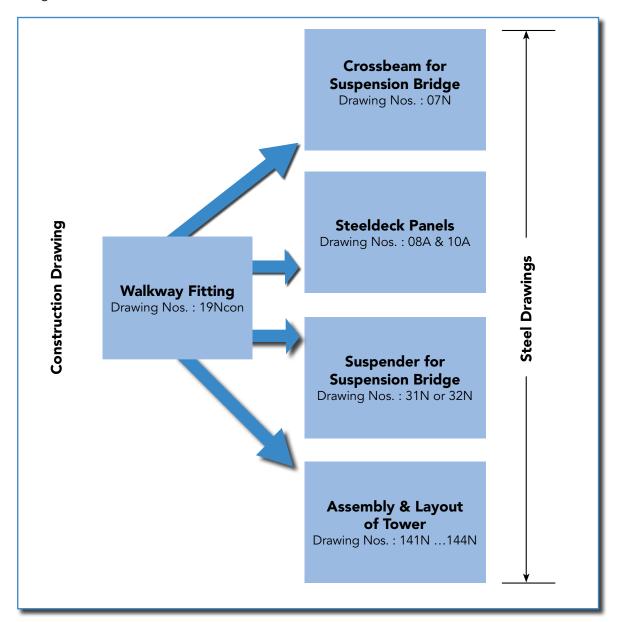
Main Cable Anchor Block:



3.8.4 Relationship between construction and steel drawings

Each Construction Drawing has related Steel Drawings. Their respective related drawing numbers are mentioned on the drawing itself, and also the respective steel parts numbers are indicated on the construction drawing for easy reference.

The Construction Drawings "Walkway Fitting", Nos. 19Ncon show the elements of the superstructure of the bridge. The related Steel Drawings are the Steel Crossbeam, Steel deck, Suspender and Tower Drawings.



The Steel Drawings for the cable anchorages Nos. 42N, 44N and 50A are related to the corresponding Construction Drawings Nos. 42/1Ncon...44/1Ncon...and 55/1Acon.

The Steel Drawings for the walkway and tower foundations Nos. 92N, and 94N are related to the corresponding Construction Drawings Nos. 92/1Ncon...and 94/1Ncon.

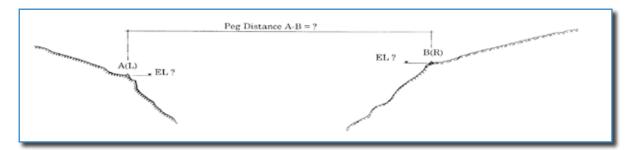
3.9 Construction

3.9.1 Bridge layout

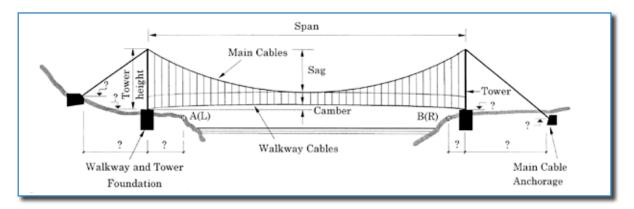
The Bridge Layout is to fix the bridge position and foundations at the site as per the design.

Procedure for General Bridge Layout (refer to General Arrangement 'GA' Drawing):

- Find the existing pegs and Bench Marks.
- Measure the horizontal distance between the axis pegs A (L) and B(R), and compare with the measurement given in the General Arrangement.
- Check the elevations of the axis pegs A (L) and B(R), and compare with the elevations given in the GA.

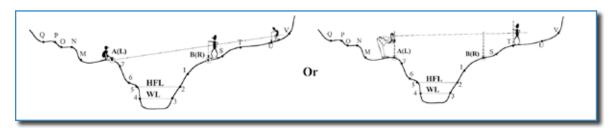


- If the horizontal distance between the axis pegs A (L) and B(R) and their elevations are not similar to the measurements given in the GA, readjust the design according to the actual measurements.
- If the horizontal distance between the axis pegs A (L) and B(R) and their elevations are identical to the measurements given in the GA, fix the position of all the foundation blocks.



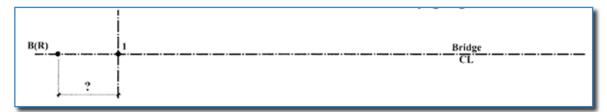
Procedure for Detailed Foundation Layout:

Align the centerline of the bridge by joining the permanent points with mason threads or by ranging between the axis pegs 'A' and 'B'.





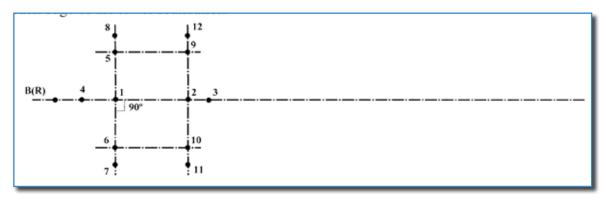
Mark the front of the tower foundation on the bridge centerline (peg 1) with reference to the axis peg. The distance between the front of the tower foundation and the axis peg is given in the GA.



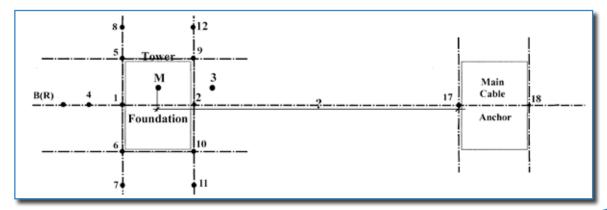
- Check the location of the front of the tower to ensure that it is at a sufficient distance (minimum 3m for soil slope and 1.5m for rock slope) from the bank edge.
- Measure the length of the foundation from peg 1 and fix peg 2. Set up two additional centerline pegs at a safe distance for the excavation works (pegs 3 and 4).



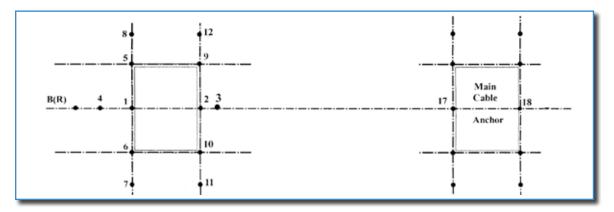
Draw an offset line (right angle) through pegs 1 and 2 by the 3-4-5 method. Starting from peg 1, set out pegs 5, 6, 7 and 8 for the reference line of the front edge, and from peg 2 for pegs 9, 10, 11 and 12 for the back edge of the tower foundation.



Determine the center point of the tower foundation and measure the distance between the tower axis and the front of the main cable anchor and fix peg 17. Draw an offset line through peg 17 as a reference line of the front edge. Set up one additional centerline peg at a safe distance behind and proceed as above.



• Determine the reference line at the downstream edge with the help of pegs 5 and 9. For the upstream edge, use pegs 6 and 10.



• Fix the elevation line (datum level), and indicate the depth of the excavation work for the tower foundation and the main cable anchor as per the elevations indicated in the GA and Anchorage Drawings.

Setting out Windguy Cable Anchorages

In the General Arrangement, the location of the wind guy cable anchorages is usually given in reference to the tower and bridge centerline: D1, d1, D2, d2. The correct direction is given by the angles 1, 2.

Plan:

 D_1, D_2

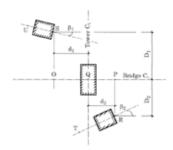
 Distances measured from the bridge axis to the front (centerline) of the windguy cable anchorage block.

 $d_1 d_2$

Distances measured from the tower centerline to the front of the windguy cable anchorage block.

 β_1, β_2

Angle between the windguy cable and the direction of the bridge centerline.



Procedure:

- Measures the distances d1 and d2 from point Q along the bridge centerline, peg out points Q, P.
- Set up the theodolite at O and P and measure the distances D1 and D2 perpendicular to the centerline of the bridge, peg out points R and S.
- Set up the theodolite at R and S and set out reference lines R T, S U.

PRT = $\beta 2 + 90^{\circ} (\beta 2 + 1009)$

OSU = $\beta 1 + 90^{\circ} (\beta 1 + 1009)$

Peg out points T and U. The reference lines R - T and S - U are the centerlines of the windguy cable anchorages.

• Check if the ground levels at points S, U, R and T correspond approximately to the layout given in the General Arrangement.

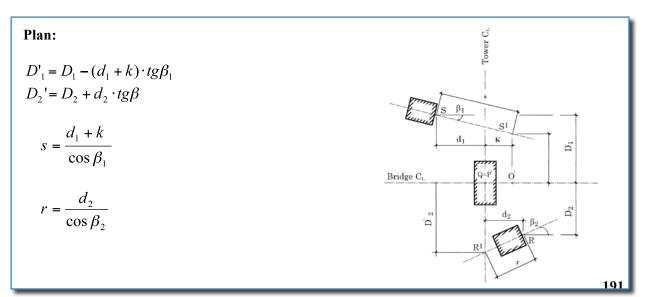
If the ground levels are correct:

Set out the windguy cable anchorage blocks in the same way as for the Main Anchor Foundation.

Setting out Windguy Cable Anchorages in Case of Obstacles

If it is not possible to set out the windguy cable anchorages, according to the above procedure due to obstacles (rock, trees, etc.), it can also be done by using other points like R' and S'.

Plan:



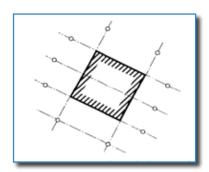
Procedure:

- Choose points P' and O' and measure the distance k from the tower centerline to P' and O'.
- Set up the theodolite at O', and measure the distance D'1 and D'2 perpendicular to the centerline of the bridge and determine R' and S'.
- Set up the theodolite at R' and S' and set out reference lines R' R and S' S. Measure the distances r, s and peg out points R, S.

Notes:

- The points O', P' can also be at the river bed if it will facilitate setting out the reference lines.
- Reference lines for the windguy anchorages are to be set out in the same way as employed for the main anchorages.

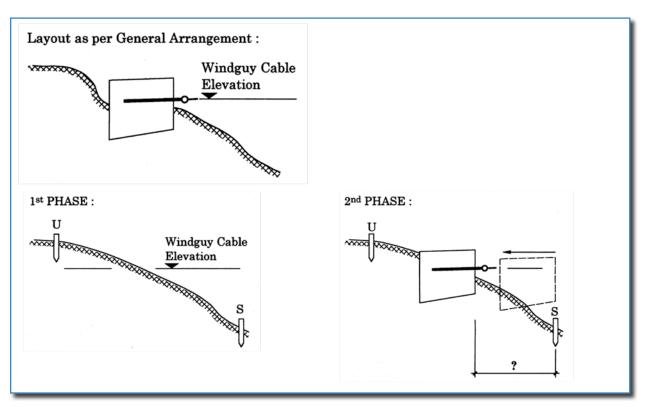
A bench mark should be set up for checking the elevation.



Setting out Windguy Cable Anchorages in Case of Incorrect Survey

In some instances, the elevation of the ground near the windguy anchorages may not coincide with the General Arrangement. In such cases, the layout of the anchorage block position can be revised at the site.

- 1. Prepare a new profile drawing along the reference lines R T and S U and indicate the windguy cable elevation according to the General Arrangement (first phase).
- 2. Relocate the windguy cable anchorage block in such a way that its position in relation to the ground is similar to the layout given in the General Arrangement (second phase).
- 3. Draw the new location of the anchorage block in the profile drawing and transmit the data to the design office which will prepare a revised design.
- Make sure that the windguy cable is still long enough.



3.9.2 Foundation excavation

In Soil:

The foundations should be excavated with slopes to provide stability in the cut slope. The cut slope in soil should generally not exceed 3:1 (V:H). The foundations should be excavated stagewise. Trenches should be excavated vertically with sheeting, or must be banked with slopes which afford the necessary stability.

All safety requirements for the protection of personnel during excavation must be met.

Slope Pitch

- In well consolidated stable ground, maximum slope pitch 3:1 (3m vertical, 1m horizontal);
- In moderately consolidated but stable soil, maximum slope pitch 2:1 (2m vertical, 1m horizontal);
- In non-cohesive ground, maximum slope pitch 1:1 (1m vertical, 1m horizontal).

If slope stability is impaired by unfavourable strata morphology, artesian water, intermediate friction layers, vibration, etc. the slope pitch must be reduced.

The most important point to be borne in mind during excavation is the fact that almost every bridge foundation bed is inclined. It is not allowed to excavate horizontally and form the incline with fill material!

To ensure that the foundation bed is clean and undisturbed, the bottom 10cm should be excavated only shortly before the concrete is poured.

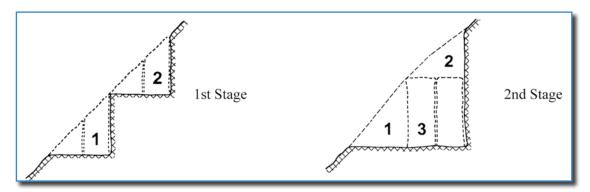
During all excavation stages, the excavation depth should be accurately maintained. For this, establish an elevation line (datum level) and measure the foundation depths with fixed sticks.

All the excavated soil should be safely disposed of without damaging the existing vegetation down hill, thus not affecting the environment.

In Rock:

Rock excavation is necessary to prepare the platform for a drum anchorage or for a rock block anchorage. The rock should be excavated manually without blasting.

Excavation in rock is done by first drilling holes to weaken the rock, and then using crowbars to break it up and dig out the pieces. The cutting can be carried out by forming steps.



3.9.3 Cement works

(a). Composition and Mixtures

Cement concrete is a mixture of the four components:

- Cement:
 - Ordinary Portland Cement commonly used for general construction works.
- Sand;
- Gravel;
- Water.

Cement is very sensitive to humidity and moisture; therefore it should never be stored for a long time. In the rainy season, cement bags have to be packed in additional sealed plastic bags plus additional nylon bags for protecting the cement against water and damage.

Sand should be clean, sharp, angular, hard and durable. Sand must be well washed and cleaned of mud or any organic material before use. A well-graded sand should be used for cement works. All or most of the sand should pass through a 3 mm sieve or mesh wire. However, it should not be too fine, only 15% of the sand at the most can be smaller than 150 microns, which is like dust.

Gravel should be clean, hard, angular and non-porous. Usually riverside gravel makes the best aggregate for preparing concrete. The corn size of gravel should be smaller than 40 mm (1½ inches) but bigger than 5 mm.

Water from rivers or lakes is usually suitable for making cement mixtures. Do not use water from ponds or swamps, it may contain a lot of organic materials.

The main characteristic of any cement work is given by the mix proportions of their components:

- Cement Mortar = A mix of Cement and Sand
- Cement Concrete = A mix of Cement, Sand and Gravel

Of course, Water is added in both cases, but the mix proportions of cement, sand and gravel give the main characteristics of any cemented work.

Mixing the above components thoroughly is of utmost importance. Hand mixing should be done on a clean watertight platform. Cement and sand should first be mixed dry, and then gravel added. Now the whole mixture should be turned over three times dry. Then mixing should take place for at least five minutes by slowly sprinkling water until the concrete is of a uniform color.

Table F.3.21: Quantities for Various Types of Cement Works

-	Mixed proportions					Dry required quantities for one cubic meter wet:				
Type of Cement Work	Cement	:	Sand	:	Gravel	Cement bags @ 50 kg	kg	Sand [m3]	Gravel [m3]	Stones or Boulders [m3]
Cement Mortars	1 1 1 1	: : : : : : : : : : : : : : : : : : : :	1 2 3 4 6		- - - -	20.4 13.6 10.2 7.6 5.0	1020 680 510 380 250	0.71 0.95 1.05 1.05 1.05	- - -	- - - -
Cement Plaster (20 mm includes 12% waste)	1 1	:	4 6		- -	0.18 0.12	9 6	0.024 0.024	- -	- -
Cement Stone	1 1	:	4 6		uncoursed stone masonry	2.66 1.75	133 87.5	0.37 0.37	- -	1.1
Masonries Masonries	1 1	:	4 6		coursed stone masonry	2.28 1.50	114 75	0.32	-	1.1 1.1
Cement Concretes (plain or reinforced)	1 1 1 1	: : :	4 3 2 1½		: 8 : 6 (M10) : 4 (M15) : 3 (M20)	3.4 4.4 6.4 8	170 220 320 400	0.47 0.47 0.45 0.42	0.94 0.89 0.85 0.84	- - -
"Plum" Concrete	1	: with	3 50% bc	ulde	: 6 ers	2.64	132	0.28	0.54	0.50

Source: Indian Practical Civil Engineers' Handbook, Section 20

The amount of **Water** should be about half the volume of cement. One 50-kg bag of cement has a volume of approximately 35 liters, which is equal to approximately two kerosene tins.

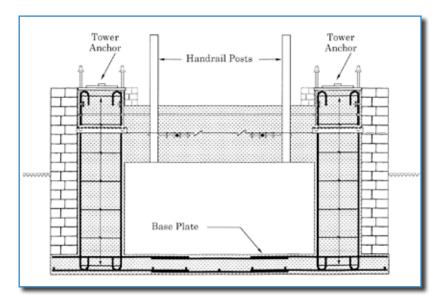
Concrete and **Mortar** should be placed in its final position within one hour. After placing, it should be well compacted with the help of rods in order to remove any air pockets. For concrete of high quality, good compaction is essential. This may mean extra work during placing, but on no account should more water be added for reducing the compacting work. Concreting should never be done if it is raining.

Curing means keeping completed cement works wet until the setting process is completed. If concrete works are not kept continuously wet during the setting process, cement mortar, cement stone masonry work and especially concrete do not develop their full strength. Curing should be done for at least 28 days.

For increasing the strength of concrete, ribbed Tor-Steel bars are added which makes Reinforced Cement Concrete or RCC.

(b). Tower and Walkway Foundations

The tower and walkway foundations are built for providing a safe base for the towers and for the firm anchoring of the spanning cables, fixation cables and handrail cables. This structure also stands for the bridge entrance.



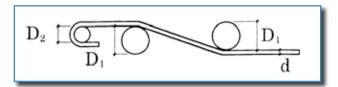
For this structure, the proper and precise placing of the reinforcement bars is very important. The bars usually come pre-bent from the workshop, but can also be bent at the site if required.

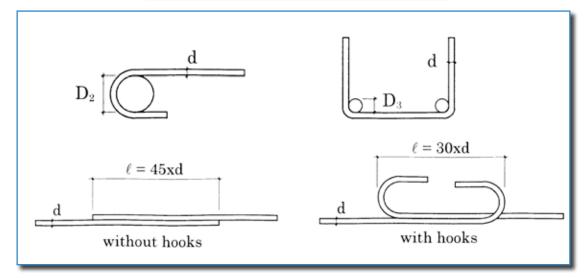
 $D_1 = 15 x d$

 $D_2' = 6 x d$, for rod $\emptyset \le 20 mm$

 $8 \times d$, for rod $\emptyset > 20$ mm

 $D_3 = 4 \times d$, for rod $\emptyset \le 16$ mm





Reinforcement steel is fixed with binding wire, so that no displacement can happen during concreting.

(c). Cable Anchors in Soil

Cable Anchors in Soil or Soil Anchors are constructed either as:

- Deadman Anchor or;
- Gravity Block Anchor.

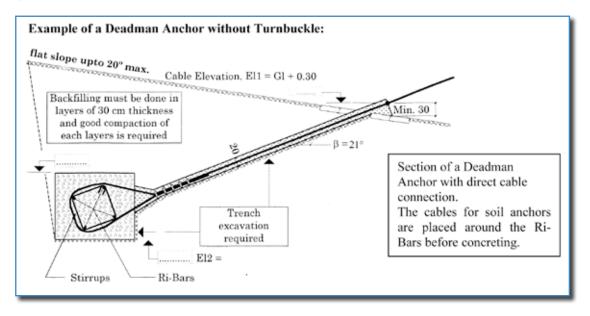
For both Soil Anchor Types (Deadman and Block Anchors), ready-made design drawings are provided for Anchors with *Turnbuckles* or Anchors with *Direct Cable Connection*. One Cable Anchor should always have a Turnbuckle which allows fine adjustment of the cables during erection time. For economic reasons, the cable anchor on the other bank should always have a direct cable connection.

Always choose the more convenient bank for the Main Cable Anchor with Turnbuckle.

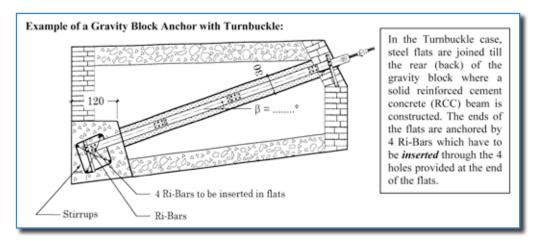
For the Main Cable Anchor with Direct Cable Connection the Main Cables have to be fixed during the construction of the particular Anchor Type. The Main Cables, therefore have to be ready during the time of construction. Make sure that the Main Cables are deposited at a safe distance from the bank of the river during construction time.

For both the Soil - Anchor Types (Deadman and Block Anchor), ready-made design drawings are provided for Anchor with Turnbuckles or Anchors with direct cable connections. These drawings contain all the information about assembly and location of each steel part.

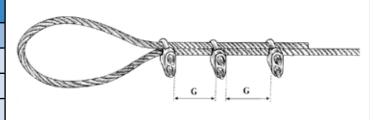
Example of a Deadman Anchor without Turnbuckle:



Example of a Gravity Block Anchor with Turnbuckle:



Nos. & Spacing of Bulldog Grips								
Cable φ mm	Nos.	G						
13	3	10cm						
26	5	15m						
32	6	20m						



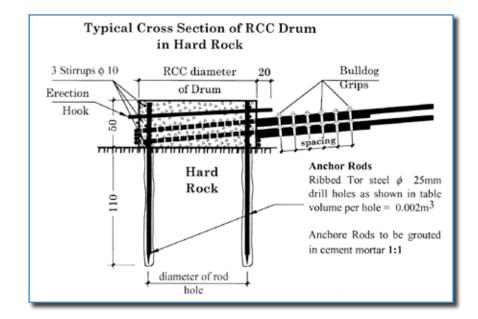
(d). Constructing Drum Anchorages in Rock

There are two types of Drum Anchorages in Rock:

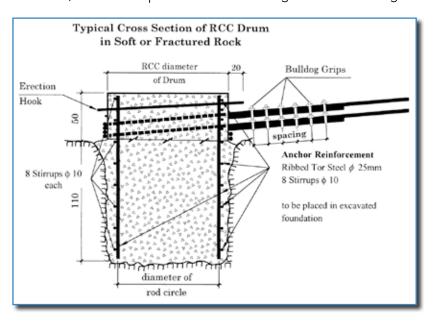
- Drum Anchor in Hard Rock
- Drum Anchor in Soft or Highly Fractured Rock

Drum Anchorages in Hard Rock are made by drilling holes of 32mm diameter (= diameter of crowbar) into the rock. Clean the boreholes of dust and debris by flushing them with water.

Fill the holes with cement mortar 1:1 before the anchor rods are inserted.



Drum Anchorages in Soft or Fractured Rock are not done by drilling holes, but by excavating a round pit. The Anchor Reinforcement has to be placed into the pit and is fixed with the help of stirrups. The excavated pit is then filled and well compacted with concrete 1 : 2 : 4 up to the ground level. At this stage, the anchor rods should protrude (stick out) approx. 50 cm. The formwork for the drum is made using a chitra (bamboo mat) lined with a plastic sheet bound together with binding wire.



(e). Water Management and Backfilling

The life expectancy of a bridge largely depends on proper water management.

Any **water seepage** encountered during excavation should be intercepted as close as possible to its origin, and channeled safely to a nearby watercourse. Especially vulnerable is the place behind the Deadman Beam! If in doubt, or in case of unusual humidity or water seepage, provide a drain behind the Deadman Beam with a side outlet. Sometimes, water seepage occurs during the rainy season only. Inquire with the local people.

Divert surface water and provide drainage channels as necessary. Do not hamper existing irrigation channels, rather improve and adjust them with some cement works. Discuss solutions with the local people and decide on the spot.

As a general rule divert water as far away from the bridge foundations as possible.

For managing surface water well, also fill in the gaps around completed anchor blocks well above the existing surface. Back filling prevents surface water from flushing out the excavations.

(f). Finishing Work

Provide finishing structures like retaining walls, staircases, small trail improvements, adjustments to nearby houses, etc. if they add functional value to the bridge. Never do cement pointing or other non-functional works. Also check the vegetation and plant life in the vicinity of the bridge. Plant some new trees if possible, especially if some had to be cut down in order to build the bridge.

3.9.4 Bridge erection

As soon as the anchor blocks and tower foundations are completed, the bridge erection works can be started. Bridge erection and fitting works are somewhat difficult and dangerous, and require especially skilled laborers who will not suffer from giddiness. Because of this somewhat risky work, the necessary

safety precautions should strictly be followed and the respective responsibilities should be clarified before starting the work.

(a). Erection of Towers

The towers must be temporarily fixed during erection, because they rest as a line load on the base plate which acts like a hinge. In order to avoid serious accidents during erection, the towers must be temporarily fixed at their base. For this purpose, temporary side struts have been provided at the tower and walkway foundation with an additional 8 angles for each tower (see position B-5 of Base Element Drawing No. 100N). The angles are supplied with holes at one end only, the exact position of the required hole at the other end must be marked at the site when erecting the base element.

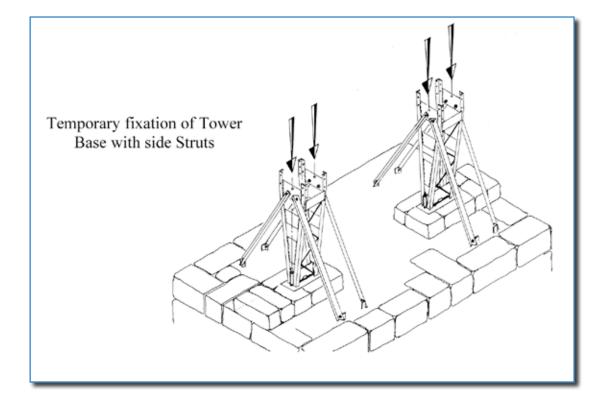
First fix both the Base Elements at the bottom and put them in an exactly vertical position. Fix the temporary angles at the bottom of each side, then mark the required position of the hole at the other end of the angle. Also give a position number to each angle so that they won't get mixed up. Have one hole of diameter 17 mm drilled at the site or at the nearest workshop. For tower erection, refer to the respective Assembly and Layout Drawings.

- Check Steel parts for labels and numbers put by the manufacturer.
- Use steel-cones for easy fitting works and tighten the nuts and bolts fully only after the next diagonal bracing has been put in place. Each tower consists of the parts:

Type of element	Part Nos. in Steel Drawing
Base Element	В
Intermediate Element	I
Top Element	T
Saddle	S

Retighten all Nuts and Bolts firmly after fixing the Elements.

After the bridge has been erected, the cable clamps on the top of the pylon must be firmly tightened, and then all the side struts (angles) must be removed.



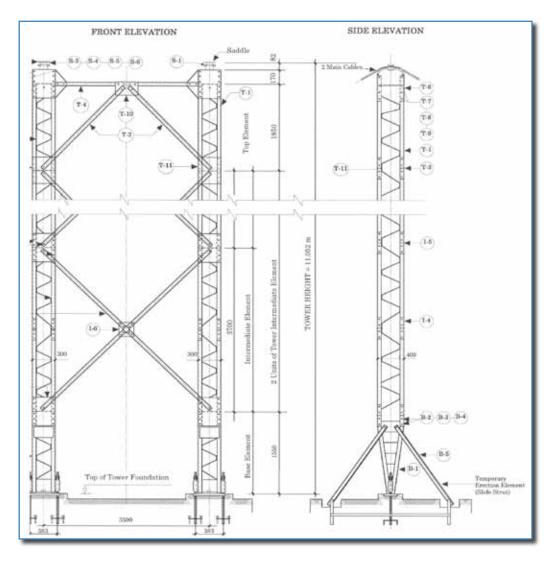
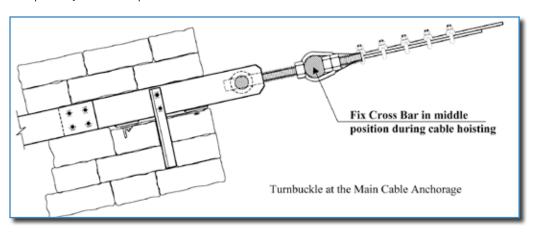


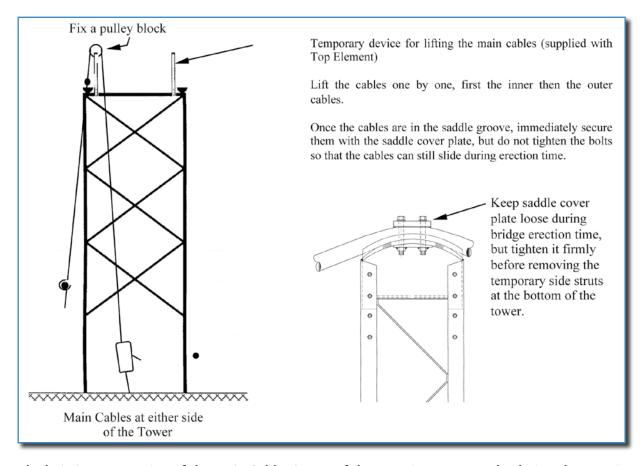
Figure F.3.16: Assembly & Layout of Tower No. 4

(b). Hoisting of Main Cables and Sag Setting

Usually, the main cables are pulled across the river with the help of nylon ropes. In case of a deep or turbulent river, attach an empty airtight plastic can (jerry can) at the end of the cable. This will prevent the cable-end from getting stuck between stones and rocks lying on the riverbed.

Make sure that the respective Main Cables are pulled on either side of the Tower and Walkway Foundations. Fix them temporarily at the respective Turnbuckle at the Main Cable Anchor.



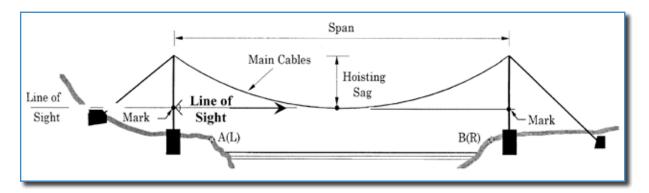


The hoisting sag setting of the Main Cables is one of the most important tasks during the erection of the bridge.

The towers should stand exactly vertical, the saddle cover plates are loose, and the temporary side struts are fixed. With this arrangement, the main cables can slide over the saddles when the bridge is being erected and the cables become longer; and the towers remain in vertical position in dead load.

With a leveling instrument, the exact hoisting sag is fixed in the way:

- Mark the elevation of the hoisting sag on both the towers with permanent paint.
- Now set up the leveling instrument on the tower foundation so that its line of sight matches with the mark on the tower across the river. Setting up the leveling instrument at the prescribed hoisting sag elevation has to be done by trial and error, and may require several attempts. Make use of the three adjustment wheels of the leveling instrument when the eyesight is close to the mark.
- Pull the Main Cables until they reach a level of about 20 cm higher than the hoisting sag.
- Clamp the cables around the thimbles at the cross bar of the Turnbuckle of the main cable
 anchorage. Make sure that the crossbar is in the middle position of the threaded anchor bars when
 clamping the main cables, secured with two nuts in the front and one in the back
- The Main Cables should be left in this "over pulled" position for at least 12 hours so that some relaxation can take place.
- Now move the Turnbuckles to achieve the exact sag setting. For compensating elongations due to change in air temperature, recheck the hoisting sag at different times of the day and make the necessary adjustments. It is recommended to adjust the final sag setting during the hot day after noon, when the cables have accumulated maximum heat, i.e., during maximum elongation condition.
- The hoisting sags of all the Main Cables must be identical at any point of time.



Also check the sags from time to time when the fitting works are going on. Different elongations may take place due to dissimilar hidden cable relaxations when the tension increases. Adjust possible sag differences with the help of the turnbuckles at the main cable anchor so that the Main Cables are always parallel and compare the dead load sag with the pre-calculated values.

(c). Hoisting of Spanning Cables

Fix the Spanning Cables at the Turnbuckles of the Tower and Walkway Anchorage on one river bank. Make sure that the crossbar of the turnbuckles are at the outermost position secured with two nuts each so that more tension can be applied when all the fitting work is completed.

Pull the cables across the river and secure them at the corresponding turnbuckles on the other bank (crossbar at the outermost position).

It is not necessary to achieve the sag corresponding to the required dead load camber, since this requires very high pulling forces. Just make sure that both the Spanning Cables are hanging approximately parallel and are high enough over the highest water-level of the river.

It is much easier to adjust the spanning cables when the suspender is being fitted .

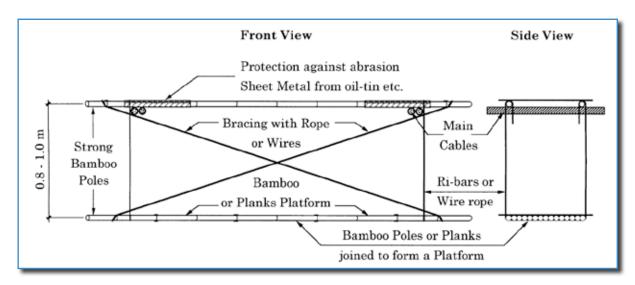
(d). Fitting Suspenders and Center Row of Steel Deck

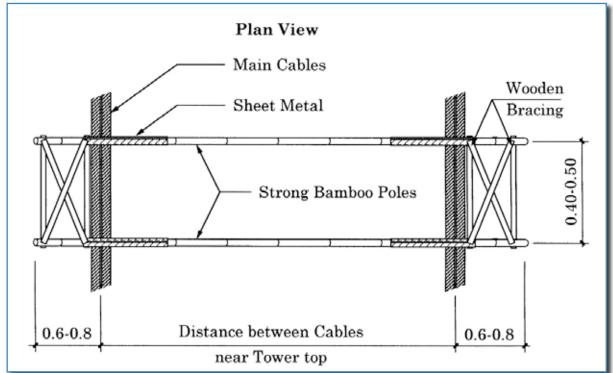
Fitting the suspenders and walkway elements are the most difficult and daring job. Adequate safety precautions should be strictly followed and the respective responsibilities should be clarified.

The suspender fitting work should start from both the towers and proceed towards the center of the bridge. This procedure is easier and has more advantages than starting the fitting work from the center. However, in order to achieve a proper symmetry of the suspenders, the central suspender must be fitted first. The only disadvantage will arise when finishing the fitting works at the middle of the bridge. Due to inaccuracies, the remaining spacing at the center of the bridge might be either too long or too short. For minimizing this imprecision, the required distances to the towers and the center have to be rechecked after fitting 10 suspenders.

Preparation for Suspender Fitting Works:

- Lay out all the suspenders in sequence on the ground.
- Prepare all crossbeams, J-hooks and steel deck.
- Prepare two fitter platforms, one for the main cables and one for the spanning cables, and two gauged sticks of exactly 1.00m length.





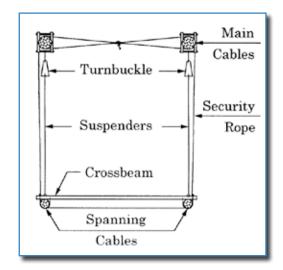
Assembly:

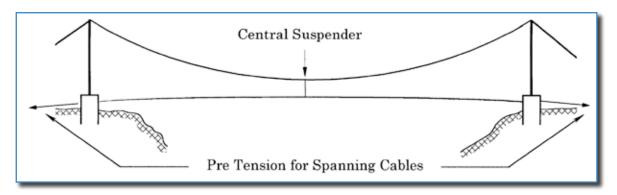
First fit the top portion on the main cables, then hang the platform under this by using either steel bars or cables.

Fitting the central suspender:

With the help of the fitting platform, the suspender in the center has to fitted first. Determine and reconfirm the center with a tape and level instrument, then fit the first suspender-pair at the center of the bridge. To avoid excessive load on the center suspender during erection time, bind all cables (spanning and main cables) together a security rope.

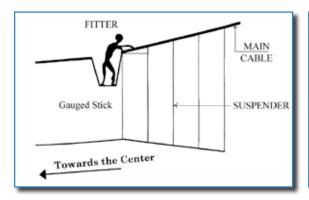
The **security rope** supports the suspender in the middle during erection work.

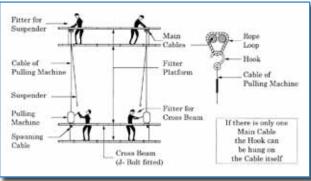




Tighten the spanning cable to some extent; now the cables are ready to be fixed to the suspenders.

Sketches and Procedures for Fitting Operations:





- Start the fitting work from both sides of the bridge and work towards the center of the bridge;
- Fix one cable car on top of the main cables and one on top of the spanning cables;
- Fix the first two suspenders to the main cables at the prescribed distance from the tower;
- Lift the spanning cable until the suspenders can be connected with the threaded rod of the walkway crossbeam. Note: The first crossbeam at the bridge entrance is fitted without a suspender (see Drw. No. 19Ncon).
- In order that the suspenders are fixed exactly 1m apart, use gauged sticks for exact fitting;
- Re-adjust the spanning cables from both the banks as the suspenders are being fitted;

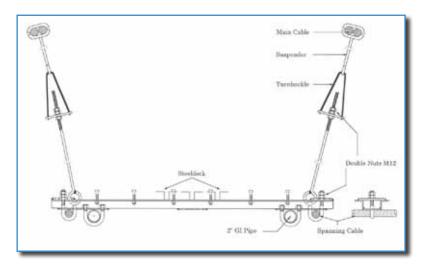
- After fitting ten pairs of suspenders, check the distances to the tower and to the center;
- Adjust only inaccuracies by moving the crossbeams;
- Gradually start fitting the center row only with standard steel deck panels (refer Drawing No. 19 Ncon).

When the center is reached, there will be some extra length of spanning cable. For adjusting this, pull the spanning cables from both the banks with the tirefor machine through the loose J-hooks. Make sure that the middle row of the steel deck is fitted when doing this work.

- When all the suspenders have been fixed, tighten the spanning cables with the cable pulling machine as much as possible before fitting the 2" G.I. pipes, the crossbeams and before fitting the rest of the steel deck panels.
- Fix the handrail cables by pulling them through the suspender-rings just above the suspender turnbuckle, and secure them to the handrail posts by winding the cable end twice around the post.

Fitting the 2" G.I. Pipes:

Two 2" G.I. pipes have to be mounted from below to the steel deck cross beams. This provides additional vertical but also lateral stability to the entire walkway. These pipes can also be used for transferring water across the river as per local requirement.



The G.I. pipes have to be fitted before the outer rows of the steel decks are mounted in the way:

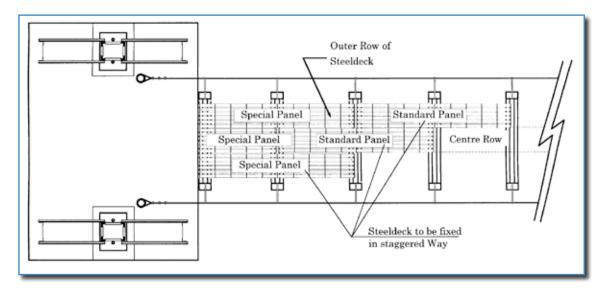
- Lay two pipes of 6m length end to end on the ground and join them together firmly. Use a 2" die set and jute threads to make the joint water tight.
- In the same way, also fix half of the "union" at each end of the 12m piece.
- Now carry the 12m pipe to the bridge, pass it through the suspenders by securing it with nylon ropes until the entire 12m piece is on the outside of the suspenders.
- Now bring the pipe into proper position underneath the walkway, and secure it immediately with the U-clamps and join it with the "union".
- In case a union coincides with a crossbeam, cut the pipe and make a new thread with the die set.

This work requires special attention. While passing the pipe outside the suspenders, several workers are necessary and sufficient ropes are required to secure the pipe at all times.

(e). Finishing the Walkway Steel Deck

Now the remaining steel deck panels can be fitted. Fit them in a staggered way. Adjust the end of the walkway with "Special Panels"; and cut off any extra length with a hacksaw as required.

• If wood is used for the bridge deck, the planks should be 2 meters long and at least 4 cm thick. They should also be fitted in a staggered way. Use washers below the Bolt Heads. The distance between the Crossbeams is 1 meter.



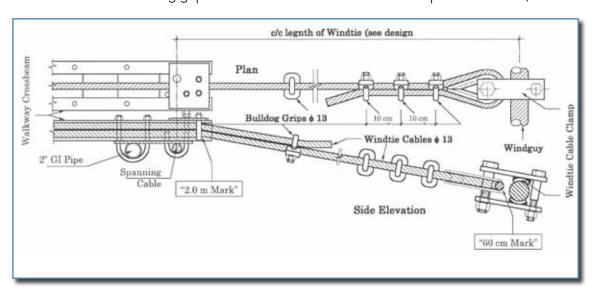
Note:

1. Make sure that all U-clamps which hold the G.I. pipes have been tightened firmly before fitting the steel deck.

(f). Fitting Wind Bracings

Wind bracings might be required to protect the superstructure from excessive wind forces.

- Cut the windtie cable according to the calculations resulting from the design form;
- Mark each cable at 60 cm from the end;
- Fit a thimble and bulldog grips so that the "60 cm mark" is at the top of the thimble;



Now mark each windtie cable at 2.0 meter from the other cable end.

The windtie cables are now ready to be fixed to the windguy cable. For this, fix the cut windtie cables at intervals of 5.0 m to the windguy cable; take starting measurements from the design form or the general arrangement.

Make sure that the windtie cable clamps and bulldog grips are firmly tight, and that the nuts are locked against the threaded plates of the windtie cable clamp, because these connections are no more accessible after hoisting.

Hoisting Windguy Cables:

Place the wind guy cable in position along the bridge deck outside the suspenders;

Pass the respective windties through the walkway beam and clamp them loosely at the "2.0m Mark";

Note: The steel deck in the center row at this location must be removed for this purpose.

- Fix one bulldog grip with the windtie from the other side just outside the crossbeam;
- After fixing all the windties, attach both cable-ends of the windguy cable to the respective windguy anchors (crossbar at the outermost position). Simultaneously apply tension to both the windguy cables to avoid any unsymmetrical lateral load to the bridge, then tighten all clamps at the "2.0m Mark".

Adjusting the Windguy / Tie - Cables :

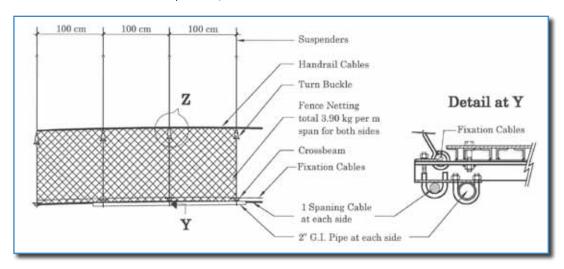
- The windties can be adjusted by loosening the bulldog grips at both sides of the crossbeam;
- Loosen also one bulldog grip outside the crossbeam, but make sure that the grip on the other side is tight!
- Now allow the first windtie pair to balance off any unsystematic forces;
- Then grasp the cable under tension (only one cable) from the middle of the crossbeam and lift it as required;
- Use a crowbar and wooden logs to hold this position.
- Now push the loose cable-end of the second windtie through the loose bulldog grip outside the crossbeam and clamp it to the cable under tension;
- Now do the same with the other end, and finally again clamp both the cables to the crossbeam.

This procedure should be repeated until all the windties are tight. The adjustment length is not limited and can also be done again at a later stage.

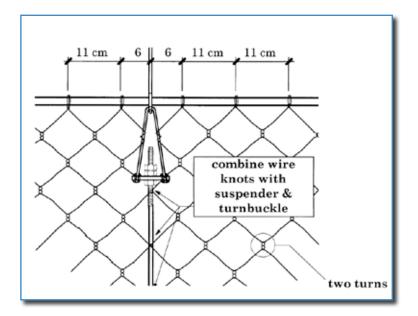
(g). Finishing Erection Works

Now there remains the fitting of the fixation cable, the wire mesh and some final adjustments.

Like the handrail cable, the fixation cable is to be passed through the rings at the bottom of the suspenders. Anchor the fixation cables to the spanning cable anchor.



The fencing is woven on the spot between the handrail and the fixation cables with gabion wire (12 SWG \triangleq Ø 2.64 mm)



Finally the whole bridge should be aligned with the help of the turnbuckles at the suspenders so that the walkway forms a smooth parabola. If a wind bracing system (windguys and windties) is in place, recheck whether all the cables are tight and align the walkway so that it is perfectly straight.

Suspension Trail Bridge Design Form

Bridge Design

- 1. Cables and Standard Tower Selection
- 2. Main Cable Anchor Blocks
- 3. Walkway & Tower Foundations
- 4. Windguy Cable Anchor Blocks
- 5. Suspender List
- 6. Windguy Arrangement
- 7. Bridge Standard Drawings

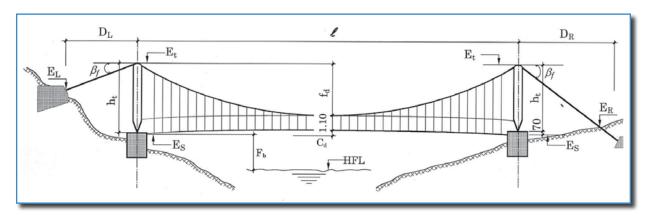
Bridge No. & Name:
River Name:
District Name:
Designed by:
Approved by:
Date:

Bridge No: Woreda: Woreda:

Span: Walkway Width:

1. Cables and Standard Tower Selection for Suspension Bridge Type

A. Survey Data & Calculation of Freeboard



Bridge Geometry

1. Span of the Bridge (should be rounded off to the nearest meter) l =

2. Elevation of the Spanning Cable Anchor Point $E_s =$ _____

3. Highest Flood Level HFL = _____

4. Freeboard (min. 3.00m) $F_b = E_s - HFL = F_b =$

(If the freeboard is less than 5.00m, try either to raise the elevation of the spanning cable anchor point by increasing the height of the Walkway and Tower Foundation, or to adjust the span to gain the required elevation.)

B. Selection of Cables and Standard Tower (Pylon)

Select the Main and Spanning Cable combinations, standard tower type and tower height h_t and the Bridge Geometry according to the span from the table. The Bridge Geometry refers to main cable dead load sag f_d , dead load camber c_d of spanning cable and the main cable inclination at tower saddle βf in full load case.

Table F.3.22: Selection of Cables & Standard Towers

Span	Tower Height/		Cables Nos. & diam		Dead Load	Hoisting Sag	Camber	Full load Backstay
m	(Type) h _t m	Main mm	Spanning mm	Windguy mm	Sag f _d m	f _h m	c _ժ m	Angle ß _f deg.
30.0					4.20	4.13	0.90	29.83
31.0					4.15	4.07	0.95	28.83
32.0					4.10	4.02	1.00	27.88
33.0					4.10	4.01	1.00	27.24
34.0					4.08	3.99	1.02	26.55
35.0					4.05	3.95	1.05	25.84
36.0					4.22	4.12	0.88	26.14
37.0		26	ø 26		4.19	4.09	0.91	25.49
38.0		, Ø	2 ø		4.16	4.05	0.94	24.88
39.0					4.13	4.01	0.97	24.31
40.0					4.10	3.97	1.00	23.77
41.0					4.10	3.96	1.00	23.39
42.0	5.50				4.10	3.96	1.00	23.03
43.0	بن <u>ب</u>				4.30	4.16	0.80	23.48
44.0					4.40	4.26	0.70	23.53
45.0					4.40	4.25	0.70	23.20
46.0				red	3.92	3.77	1.18	20.45
47.0				Not Required	3.90	3.74	1.20	20.10
48.0					4.05	3.89	1.05	20.39
49.0				N N	4.05	3.88	1.05	20.13
50.0					4.10	3.93	1.00	20.07
51.0					4.10	3.92	1.00	19.83
52.0					4.10	3.91	1.00	19.61
53.0					4.10	3.90	1.00	19.40
54.0					4.10	3.88	1.00	19.20
55.0		32	, 32		4.25	4.04	0.85	19.46
56.0		8	2 8		5.47	5.30	1.48	22.82
57.0					5.44	5.26	1.51	22.46
58.0					5.41	5.22	1.54	22.12
59.0	7.35				5.38	5.18	1.57	21.79
60.0					5.35	5.13	1.60	21.48
61.0					5.35	5.12	1.60	21.26
62.0					5.45	5.22	1.50	21.32
63.0					5.65	5.42	1.30	21.65
64.0					5.85	5.63	1.10	21.97
65.0					5.95	5.72	1.00	22.01

Span	Tower Height/		Cables Nos. & diam	otor	Dead Load	Hoisting	Camber	Full load Backstay
l m	(Type) h _t m	Main mm	Spanning mm	Windguy mm	Sag f _d m	Sag f _h m	c _d m	Angle β_f deg.
66.0					7.02	6.81	1.78	24.48
67.0					6.99	6.77	1.81	24.15
68.0					6.96	6.73	1.84	23.83
69.0					6.93	6.69	1.87	23.54
70.0	9.20	ø 32			7.20	6.97	1.60	23.97
71.0	% (J)	0 0		rec	7.40	7.17	1.40	24.22
72.0				<u> </u>	7.60	7.37	1.20	24.47
73.0				le d	7.70	7.46	1.10	24.47
74.0				r R	7.65	7.40	1.15	24.14
75.0				Not Required	7.65	7.40	1.15	23.93
76.0				_	8.57	8.36	2.08	25.38
77.0					8.54	8.33	2.11	25.07
78.0			25		8.51	8.29	2.14	24.77
79.0					8.48	8.25	2.17	24.48
80.0					8.45	8.22	2.20	24.20
81.0					8.42	8.18	2.23	23.93
82.0					8.39	8.14	2.26	23.67
83.0			2Ø 32		8.36	8.10	2.29	23.41
84.0					8.33	8.06	2.32	23.16
85.0		ø 26			8.30	8.02	2.35	22.92
86.0		4 Ø			8.27	7.98	2.38	22.68
87.0	ıo			only)	8.24	7.94	2.41	22.46
88.0	1.05			O	8.21	7.90	2.44	22.24
89.0	~			lal	8.35	8.04	2.30	22.34
90.0				io	8.55	8.24	2.10	22.56
91.0				pti	8.85	8.54	1.80	22.96
92.0				26 (Optiona	9.05	8.74	1.60	23.16
93.0				97	9.25	8.95	1.40	23.36
94.0				Ø 5	9.25	8.94	1.40	23.20
95.0				G.	9.20	8.87	1.45	22.96
96.0					7.98	7.68	2.67	20.00
97.0		7			8.05	7.75	2.60	20.00
98.0		ø 32			8.13	7.82	2.52	20.00
99.0		4			8.20	7.89	2.45	20.00
100.0					8.28	7.96	2.37	20.00

Span	Tower Height/	Cables Nos. & diameter			Dead Load	Hoisting Sag	Camber	Full load Backstay
m m	(Type) h _t m	Main mm	Spanning mm	Windguy mm	Sag f _d m	f _h m	c _ս m	Angle ß _r deg.
101.0		4 ø 32	2 ø 32	ø 26 (Optional only)	8.35	8.03	2.30	20.00
102.0					8.40	8.07	2.25	20.00
103.0					8.50	8.17	2.15	20.00
104.0					8.57	8.23	2.08	20.00
105.0					8.65	8.31	2.00	20.00
106.0	11.05				8.71	8.36	1.94	20.00
107.0					8.80	8.45	1.85	20.00
108.0					8.85	8.49	1.80	20.00
109.0					8.94	8.58	1.71	20.00
110.0					9.00	8.63	1.65	20.00
111.0					9.00	8.62	1.65	19.88
112.0	·				8.95	8.55	1.70	19.70
113.0					8.95	8.54	1.70	19.60
114.0					8.95	8.53	1.70	19.50
115.0					8.90	8.46	1.75	19.34
116.0					8.90	8.45	1.75	19.24
117.0					8.85	8.38	1.80	19.09
118.0					8.85	8.37	1.80	19.00
119.0					8.85	8.36	1.80	18.92
120.0					8.85	8.34	1.80	18.83

The above Cable Combinations and Towers have been calculated for the specifications and bridge geometry.

```
Cables: construction 7 x 19, wire strand core, 160 kg/mm<sup>2</sup> (1.57 kN/mm<sup>2</sup>) tensile strength of wire
                    minimum 3
Safety Factor:
                       p = (300 + \frac{5000}{span}) \text{ kg/m}^2 or (3 + \frac{50}{span}) \text{ kN/m}^2
Live load
p = 400 \text{ kg/m}^2 (4 \text{ kN/m}^2) if the span is 50.0 m or less
                              \beta_f \cong _____
       Backstay Angle
       Camber
                   c_d =
       Safety factor for Tower = ____
       Example:
                         Span = 115m
                                                                               : nos. 4Ø 32mm
                    ⇒ selected cable combination:
                                                            Main Cables
                                                            Spanning Cables : nos. 2Ø 32mm
                                                            Windguy Cable : not applicable
Dead Load Sag, fd = 8.9m
                                                            Dead Load Camber, Cd = 1.75m
                                                            Backstay Angle, \beta_f = 19.34^{\circ}
                     ⇒ selected Tower:
                                                  Standard Tower Height, h_t = 11.05m / Type 4
```

Selected Cable combination, Bridge Geometry and Standard Towers from Table 3.17

MC	Main Cables:	nos
SC	Spanning Cables:	nos
HRC	Handrail Cables:	nos
FC	Fixation Cables:	nos
WGC	Windguy Cables (optional):	
Dead Load Sag,		$f_d = \underline{\hspace{1cm}}$
Dead Load Camber,		c _d =
Standard Tower Type:		
Tower Height,		h _t =

C. Fixing the backstay lengths (dl and dr) and main cable anchorage elevations (E, and E,)

- Fix the position of the Main Anchorage Foundation Blocks and their Cable Anchorage Elevations
 on the right bank and the left bank in the bridge profile considering the topography and geological
 condition of the ground
- Measure the backstay length DL and DR with a scale in the bridge profile.
- Calculate the Main Cable Anchorage Elevation.

Calculated Backstay Length (D_L and D_R) and Main Cable Anchorage Elevations, (E_L and E_R):

$$\begin{array}{lll} \textbf{E}_{t} & = \textbf{Es} + \textbf{0.70} + \textbf{ht} & = \underline{} \\ \boldsymbol{\beta}_{f} & \text{(from Table 1.1)} & = \underline{} \\ \textbf{D}_{L} & \text{(measured from the bridge profile)} & = \underline{} \\ \textbf{D}_{R} & \text{(measured from the bridge profile)} & = \underline{} \\ \textbf{E}_{L} & = \textbf{Et} - (\textbf{DL} \times \textbf{Tan} \ \boldsymbol{\beta}_{f}) & = \underline{} \\ \textbf{E}_{R} & = \textbf{E}_{t} - (\textbf{D}_{R} \times \textbf{Tan} \ \boldsymbol{\beta}_{f}) & = \underline{} \\ \end{array}$$

D. Calculation of Cable Lengths

Type of Cable	dia (mm)	Nos		y Length m]	Cutting Length*
			D _L	D _R	[m/pc]
Main Cable					
Spanning Cable					
Handrail Cable					
Fixation Cable					
Windguy Cable**		1 (U/S)			
(Optional)		1 (D/S)			
Windties** (Optional)					

*	Cutting	Lenath:
	Ou centry	_0,,9,0,,,

Main Cable = $1.08 \times \text{Span} + 1.15 (D_L + D_R) + \text{Anchorage Length on the Right Bank} +$

Anchorage Length on the Left Bank.

Calculate the Anchorage Lengths only after selection of the Main Cable Anchor Blocks.

Spanning Cable = $1.025 \times \text{Span} + 3.5 \text{m}$.

Handrail Cable = Span Fixation Cable = Span

** Windguy Cable = Refer to Design of Windguy Arrangement ** Windties = Refer to Design of Windguy Arrangement

E. Calculation of Hoisting Sag

This calculation has to be made after the tower erection work has been completed.

1.	Actual Span measured in the field	l	= m
2.	Hoisting Sag (from Table No 1.1 as per actual span)	f_h	= m
3.	Tower Height	h_t	= m
4.	Marking Point on Tower (from steel tower base) at hoisting sag elevation =	$h_t - f_h$	= m

2. Main Cable Anchor Design

A. Design Data

Main Cables:						
	Right Ba	nk Cor	ndition			
Geology:	Soil					
If Soil, how is the Ground Surface?	Flat (up to 15° slope)		or		Hill Slope (more than 15°	slope)
What is the Soil Type?	Gravelly		Sandy		Silty	
If Rock , what is the Rock	Hard Rock		Hard Rock		Soft Rock	
Type?	(only a few fractu	ıres)	(highly frac	tured)		
	Left Ban	k Con	dition			
Geology:	Soil					
If Soil, how is the Ground Surface?	Flat (up to 15° slope)		or		Hill Slope (more than 15°	slope)
What is the Soil Type?	Gravelly		Sandy		Silty	
If Rock , what is the Rock	Hard Rock		Hard Rock		Soft Rock	
Type?	(only a few fractu	ıres)	(highly frac	tured)		

B. Selection of Anchor Types

Select the appropriate Anchor Types for the Right and Left Banks according to the above design data. s are the rules for selecting the anchor blocks:

- One Main Cable Anchor should always have turnbuckle for fine adjustment during sag setting, whereas for economic reasons, the main cable anchor on the other bank should always have a direct cable connection.
- Always select an Anchor Block with turnbuckle for one bank and an Anchor Block with direct cable connection for the other bank.
- If one bank is soil and the other bank is rock, always select a Drum Anchor for the rocky bank.
- If both banks are rocky, select an Anchor Block for one bank and a Drum Anchor for the other bank.

Procedure for selection:

 According to the Soil type and Slope of ground or the Rock type, refer to the respective tables for the selection of the Anchor Types.

In Soil and Flat Ground (Cable Connection with Turnbuckle)

In Soil and Flat Ground (Direct Cable Connection)

In Soil and Hill Slope (Cable Connection with Turnbuckle)

In Soil and Hill Slope (Direct Cable Connection)

In Hard, Soft or Fractured Rock (Cable Connection with Turnbuckle)

In Hard Rock (Direct Cable Connection)

In Fractured Hard Rock or Soft Rock (Direct Cable Connection)

In Table F.3.23

In Table F.3.25

In Hard Rock (Direct Cable Connection)

In Table F.3.28

In Table F.3.29

In the table match the design data: Number and Diameter of Main Cables → if Soil, Soil type → select Anchor type and corresponding Drawing No. for right bank and left bank respectively.

Anchorage Type Selection Tables

In Soil and Flat Ground (Ground slope up to 15°)

Table F.3.23: Selection of Main Cable Deadman Anchor in Soil & Flat Ground (Cable Connection with Turnbuckle)

Main Cable	Foundation Soil Type	Anchor Type	Drawing No
2x26	All	DA 1	42/1Ncon
2x32	All	DA 2	42/3Ncon
4x26	All	DA 3	44/1Ncon
4x32	All	DA 4	44/3Ncon

Table F.3.24: Selection of Main Cable Deadman Anchor in Soil & Flat Ground (Direct Cable Connection)

Main Cable	Foundation Soil Type	Anchor Type	Drawing No
2x26	All	DA 5	42/2Ncon
2x32	All	DA 6	42/4Ncon
4x26	All	DA 7	44/2Ncon
4x32	All	DA 8	44/4Ncon

In Soil and Hill Slope

Table F.3.25: Selection of Main Cable Deadman Anchor in Soil & Hill Slope (Cable Connection with Turnbuckle)

Main Cable	Foundation Soil Type	Anchor Type	Drawing No
2x26	All	AB 1	42/5Ncon
2x32	All	AB 2	42/7Ncon
4x26	All	AB 3	44/5Ncon
4.22	Gravelly or Sandy	AB 4	44/7Ncon
4x32	Silty	AB 5	44/9Ncon

Table F.3.26: Selection of Main Cable Anchor Block in Soil & Hill Slope (Direct Cable Connection)

Main Cable	Foundation Soil Type	Anchor Type	Drawing No
2x26	All	AB 6	42/6Ncon
2x32	All	AB 7	42/8Ncon
4x26	All	AB 8	44/6Ncon
422	Gravelly or Sandy	AB 9	44/8Ncon
4x32	Silty	AB 10	44/10Ncon

In Hard, Soft or Fractured Rock

Table F.3.27: Selection of Main Cable Anchor Block in Hard, Soft or Fractured Rock (Cable Connection with Turnbbuckle)

Main Cable, mm	Anchor Type	Drawing No
2x26 or 2x32	AB - 11	45Ncon
4x26 or 4x32	AB - 12	46Ncon

In Hard Rock

Table F.3.28: Selection of Main Cable Drum Anchor in Hard Rock

Main Cable, mm	Anchor Type	Drawing No
2x26 or 2x32	DR-1	47Ncon
4x26 or 4x32	DR-2	48Ncon

In Fractured Hard Rock or Soft Rock

Table F.3.29: Selection of Main Cable Drum Anchor in Fractured Hard/Soft Rock

Main Cable, mm	Anchor Type	Drawing No
2x26 or 2x32	DR-3	49Ncon
4x26 or 4x32	DR-4	50Ncon

==> Selected Main Cable Anchor type and corresponding Drawings from the Table above:

Left Bank: Anchor Type	_ Drawing No
Right Bank: Anchor Type	_ Drawing No

2. Walkway and Tower Foundation Design

A. Design Data

Fill in the Design Data from Survey Form and Checklist

Main Cable: No	S		
Spanning Cable: No	os		
	Right Bank / Condition		
Geology:	Soil		
If Soil , what is the Soil Type?	Gravelly Sandy Silty		
Foundation Block Height (H) from the Ground (data from bridge profile):	1.0m 2.0m 3.0m 4.0m		
If Rock , what is the Rock Type?	Hard Rock Soft Rock		
Foundation Block Height (H) from the	(only a few fractures) (highly fractures)		
Ground (data from bridge profile):	1.0m in case of Rock		
	Left Bank / Condition		
Geology:	Soil		
If Soil, what is the Soil Type?	Gravelly Sandy Silty		
Foundation Block Height (H) from the Ground (data from bridge profile):	1.0m 2.0m 3.0m 4.0m		
If Rock , what is the Rock Type?	Hard Rock Soft Rock		
Foundation Block Height (H) from the	(only a few fractures) (highly fractures)		
Ground (data from bridge profile):	1.0m in case of Rock		

B. Selection of Walkway and Tower Foundations

Select the appropriate Walkway and Tower Foundations for the Right and the Left Banks according to the above design data.

Procedure for selection:

 According to the Soil or Rock type, refer to the respective tables for the selection of the Walkway and Tower Foundations.

In Soil : **Table F.3.30**In Hard Rock : **Table F.3.31**In Fractured Hard Rock or Soft Rock : **Table F.3.32**

If the bank is rock, always take the foundation block height **H** as 1.0m, If the bank is soil on a hill slope, always take the foundation block height H as 1.0m.

If the bank is soil on flat ground but the foundation block height H needs to be raised, always take the foundation block height as 1.0, or 2.0, or 3.0, or 4.0m (maximum).

In the table, match the design data: Number and Diameter of Main Cables → Foundation Block Height, H → if Soil, Soil type → select Foundation type and corresponding Drawing No. for right bank and left bank respectively.

Walkway and Tower Foundations Selection Tables

In Soil

Table F.3.30: Selection of Walkway & Tower Foundation in Soil

Main Cable	Foundation Block Height (H) m	Soil Type	Foundation Type	Drawing No
	1.0	All	TF-1	92/1Ncon
2x26 and 2x32mm	2.0	All	TF-2	92/2Ncon
ZXZO and ZX3Zmm	3.0	All	TF-3	92/3Ncon
	4.0	All	TF-4	92/4Ncon
	1.0	All	TF-6	94/1Ncon
	2.0	All	TF-7	94/2Ncon
4x26mm	2.0	Gravelly/Sandy	TF-8	94/3Ncon
4x2omm	3.0	Silty	TF-9	94/4Ncon
	4.0	Gravelly/Sandy	TF-10	94/5Ncon
	4.0	Silty	TF-11	94/6Ncon
	1.0	All	TF-6	94/1Ncon
	2.0	All	TF-7	94/2Ncon
4x32mm	3.0	Gravelly/Sandy	TF-8	94/3Ncon
4x3∠mm	3.0	Silty	TF-9	94/4Ncon
	4.0	Gravelly/Sandy	TF-10	94/5Ncon
	4.0	Silty	TF-11	94/6Ncon

In Hard Rock

Table F.3.31: Selection of Walkway & Tower Foundation in Hard Rock

Main Cable	Foundation Block Height (H) M	Foundation Type	Drawing No
2x26 or 2x32mm	1.0	TF-5	92/5Ncon
4x26 or 4x32mm	1.0	TF-12	94/7Ncon

In Fractured Hard Rock or Soft Rock

Table F.3.32: Selection of Walkway & Tower Foundation in Fractured Hard Rock or Soft Rock

Main Cable	Foundation Block Height (H) M	Foundation Type	Drawing No
2x26 or 2x32mm	1.0	TF-1	92/1Ncon
4x26 or 4x32mm	1.0	TF-6	94/1Ncon

 Selected Walkway and Tower 	Foundations and corres	ponding drawings	from the table above:
--	------------------------	------------------	-----------------------

Right Bank:	Foundation Type	Drawing No	
Left Bank:	Foundation Type	_Drawing No	

4. Windguy Anchorage Foundation Blocks Design (Optional)

A. Design Data

Fill in the Design Data from Survey Form and Checklist.

Windguy Cable:nos Ømm			
Right Bank / Upstream			
Geology:	Soil		
If Soil , what is the Soil Type?	Gravelly Sandy Silty		
Anchor Block Height from Ground (data from bridge profile):	1.0m 2.0m 3.0m 4.0m		
If Rock , what is the Rock Type?	Hard Rock Soft Rock		
Anchor Block Height from Ground	(only a few fractures) (highly fractures)		
(data from bridge profile):	1.0m in case of Rock		
	Right Bank / Upstream		
Geology:	Soil		
If Soil, what is the Soil Type?	Gravelly Sandy Silty		
Anchor Block Height from Ground (data from bridge profile):	1.0m 2.0m 3.0m 4.0m		
If Rock, what is the Rock Type?	Hard Rock Soft Rock		
Anchor Block Height from Ground	(only a few fractures) (highly fractures)		
(data from bridge profile):	1.0m in case of Rock		

	Left Bank / Upstream		
Geology:	Soil		
If Soil , what is the Soil Type?	Gravelly	Sandy	Silty
Anchor Block Height from Ground (data from bridge profile):	1.0m 2.0m	3.0m	4.0m
If Rock , what is the Rock Type?	Hard Rock	Hard Rock	Soft Rock
Anchor Block Height from Ground	(only a few fractures)	(highly fractures)	
(data from bridge profile):	1.0m in case of	f Rock	
	Left Bank / Upstream		
Geology:	Soil Upstream		
Geology: If Soil, what is the Soil Type?	·	Sandy	Silty
	Soil	Sandy 3.0m	Silty
If Soil, what is the Soil Type? Anchor Block Height from Ground	Soil Gravelly	<u>: </u>	,
If Soil, what is the Soil Type? Anchor Block Height from Ground (data from bridge profile):	Soil Gravelly 1.0m 2.0m	3.0m	4.0m

B. Selection of Windguy Cable Anchor Blocks (Optional only)

Provision of a windguy cable arrangement is optional.

Select appropriate Windguy Cable Anchor Blocks for the Right and Left Banks according to the above design data. s are the rules for selection of the anchor blocks.

- If the bank is rock, always take block height as 1.0m.
- If the bank is soil in hill slope, always take block height as 1.0m.
- If one bank is soil and the other bank is rock, always select a Drum Anchor for the rocky bank.
- If both banks are rocky, select an Anchor Block for one bank and a Drum Anchor for the other bank.
- If the bank is soil but on flat ground and the Anchor Block Height needs to be raised, always take the foundation block height as 1.0, or 2.0, or 3.0, or 4.0m (maximum).

Procedure for selection:

According to the Soil or Rock type, refer to the respective tables for selection of the Windguy Cable Anchor Blocks:

In Soil : Table F.3.33
In all types of Rock (Anchor Block) : Table F.3.34
In Hard Rock (Drum Anchor) : Table F.3.35
In Fractured Hard Rock or Soft Rock (Drum Anchor) : Table F.3.36

In the table, match the design data: Diameter of Windguy Cable → Soil or Rock type → if soil → Anchorage Block Height → select Anchor Block type and corresponding Drawing No. for right bank upstream and downstream and for left bank upstream and downstream respectively.

Select the appropriate Windguy Cable Anchor blocks from the table.

In Soil

Table F.3.33: Selection of Windguy Cable Anchor Block in Soil

Windguy Cable [mm]	Anchor Block Height	Soil Type	Anchor Type	Drawing No
	1	All	WAB - 1	55/1Acon
27	2	All	WAB – 2	55/2Acon
26	3	All	WAB – 3	55/3Acon
	4	All	WAB – 4	55/4Acon

In Hard, Fractured or Soft Rock

Table F.3.34: Selection of Windguy Cable Anchor Block in All Types of Rocks

Windguy Cable [mm]	Anchor Type	Drawing No
26	WAB - 5	56Acon

In Hard Rock

Table F.3.35: Selection of Windguy Cable Drum Anchor in Hard Rock

Windguy Cable [mm]	Anchor Type	Drawing No
26	WDR - 1	57Acon

In Fractured or Soft Rock

Table F.3.36: Selection of Windguy Cable Drum Anchor in Fractured or Soft Rock

Windguy Cable [mm]	Anchor Type	Drawing No
26	WDR - 2	58Acon

• Selected Windguy Cable Anchor and corresponding Drawings from the table above:

Right Bank, Upstream:	Anchor Type,	Drawing No
Downstream:	Anchor Type,	Drawing No
Left Bank, Upstream:	Anchor Type,	Drawing No
Downstream:	Anchor Type,	Drawing No

5. Suspender List

Calculate the Suspender List using the computer program **"Suspender Design"** which is included in the CD-ROM (available in separate form).

The calculation is based on the fixed geometry of the bridge and the design of the suspender.

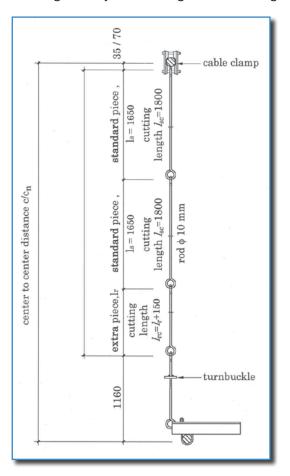


Figure F.3.17: Typical Design of Suspender

The only input data required for the calculation is the span, I. The procedure for the Suspender List calculation is as follows:

- Open the computer program SSTB Design > "Suspender Design".
- Enter the input data: Bridge Name, Bridge Span and width "B" of the Walkway and Tower Foundation.
- Print result.

Attach the printout of the Suspender List with the drawing of the suspenders (Drawing No 31N or 32N).

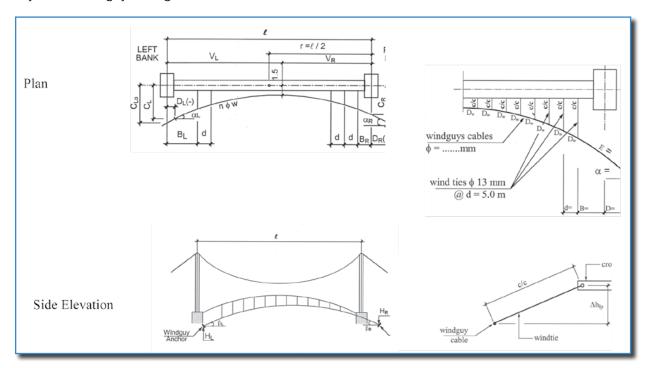
6. Design of Wind guy Arrangement

For special cases, i.e., when the bridge span is more than 120m or in extremely windy areas with wind speeds in excess of 160 km/hr and unfavourable nature of the wind flow, a windguy system is mandatory.

For calculation of the Windguy Arrangement use the computer program "Windguy Design" which is included in the CD-ROM which is available in separate form.

The calculation is based on the fixed geometry of the bridge.

Layout of Windguy Arrangement



The calculation procedure is as:

- Open the computer program SSTB Design > "Windguy Design".
- Enter the general input data: Bridge Name, Bridge Span and elevation of Steel Tower Base.
- Enter the tentative position of the first windtie $\mathbf{B}_{\mathbf{L}}$ and $\mathbf{B}_{\mathbf{R}}$ as per the topography. The program will adjust to the nearest actual values.
- Give the level of the windguy anchorage on the right bank $\mathbf{H_L}$ and the left bank $\mathbf{H_R}$. $\mathbf{H_L}$ and $\mathbf{H_R}$ should be at or below the level of the spanning cable at the anchorage point (Es).
- Give (select) the windguy anchor position on the right bank (or the left bank), i.e. C_R and D_R or (C_L and D_I). Accordingly, the windties listing will be from right bank to left bank or vise versa.
- Input the value V_R (distance up to the vertex of the windguy cable) if the selected windguy anchor position is on the right bank or V_L if the selected windguy anchor position is on the left bank.
- Check the span and sag ratio of the wind guy cable, I/b. It should be not less than 8 and not more than 10. If this condition is not met, input new **V** till I/b is within the recommended limit.
- Check the lowest point of the windguy cable $\Delta \mathbf{h}_{lp}$. It should not be negative (-). If $\Delta \mathbf{h}_{lp}$ is negative, input new \mathbf{H}_{l} and \mathbf{H}_{R} with a lower value.
- Input the value of $\mathbf{D_{Lo}}$ (or $\mathbf{D_{Ro}}$) = 0. The result will show $\mathbf{C_{Lo}}$ (or $\mathbf{C_{Ro}}$), and the horizontal angle α_{L} (or α_{R}).
- Draw a straight line with the given C_{Lo} (or C_{Ro}), and horizontal angle α_L (or α_R). Fix the windguy anchor position on the left bank (or the right bank) along this line. The anchorage block should be placed on safe ground and at the optimum foundation location so that it has sufficient embedded depth and also so that deep excavation can be avoided.
- After fixing the anchorage position, measure the actual C_1 (or C_2). The result will give D_1 (or D_2)
- Draw longitudinal sections along the windguy cables at the foundations and determine the exact position of the front of the foundations (\mathbf{D}_{R} , \mathbf{C}_{R} and \mathbf{D}_{L} , \mathbf{C}_{L}) and the windguy cable elevations (\mathbf{H}_{R} , \mathbf{H}_{L}).
- If the final position of the foundations does not match the design as above, repeat the calculation process from the second bullet till all the foundations are located at the optimum positions.
- Calculate the Windguy Arrangement for both upstream and downstream.
- Attach the printout of the results (Windguy Arrangement) with the drawing of the Windtie cable Clamps (Drawing No. 11A) and also transfer it to the General Arrangement Drawing.

7. Bridge Standard Drawings
Select the required Steel Drawings and Construction Drawings from the design as above and the drawing

Steel Drawings

Drawing Title		Drawing No.	Required Drawing
Walkway and Anchors			
Steel Crossbeams			
Suspenders			
Main Cable Anchor With Turn Buckle			
Main Cable Anchor With Direct Cable Connection			
Walkway and tower Foundation			
Steel Deck			

Towers		
Assembly and Layout		
Base Element		
Intermediate Element		
Top Element		
Saddle		

Optional		
Windguy Parts	Windtie Cable Clamps for One Cable Ø 26 or 32mm	
	Windguy Cable Anchorage for one Cable Ø 26 or 32mm	

Construction Drawings

Drawing Title	Drawing No	Required Drawing
Walkway Fitting		
Main Calala Anahaya		LB:
Main Cable Anchors		RB:
Mallaura and Taura Faundations		RB
Walkway and Tower Foundations		LB

Designed by:	Date:	
Cable hoisted by:	Date:	