

## VOLUME I : GUIDELINE FOR SURVEY, DESIGN & CONSTRUCTION

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## **VOLUME II FORMS**

**FORM No.1 SURVEY FORM AND CHECKLIST**

**FORM No.2 BRIDGE DESIGN**

**FORM No.3 QUANTITY & COST ESTIMATE FOR COMMUNITY APPROACH**

**FORM No.4 QUANTITY & COST ESTIMATE FOR PUBLIC TENDER & CONTRACTING**

## **VOLUME III STEEL & CONSTRUCTION DRAWINGS**

(IN SEPARATE FOLDER)



**VOLUME I :**

**GUIDELINE FOR SURVEY, DESIGN &  
CONSTRUCTION**



## 1. INTRODUCTION

### 1.1 BACKGROUND

For centuries, people have built simple and inexpensive bridges throughout Nepal. With the advent of modern development, organizations emerged which built suspension bridges where local resources appeared to be over burdened. In this manner, some five hundred sophisticated and costly bridges have been built over the last four decades, which greatly facilitate the movement of goods and people along the major traffic arteries of this country.

At the same time, the intervention of extraneous agencies may have weakened the attitude of self-reliance of many communities. It is also widely understood that external agencies will never be able to meet all the demands for local river crossings. Hence the idea of reactivating and supporting communities' own initiatives for improving their environment and infrastructure in the spirit of decentralization. In view of the absence for technical guidance material, it has become significant for technicians at district level to have a tool for designing economic bridges appropriate for communities in rural areas.

Against this background, the development of the Short-Span Trail Bridge Standard started in 1989, when both HMG and Helvetas concluded that the time has come to initiate a programme with a fresh approach to community trail bridge building in the hill areas of Nepal.

The ultimate objective of this programme, named Bridge Building at the Local Level (BLL) was to help reactivate, promote and support people's problem solving and self-help ability for local bridge building. For achieving this goal the development of appropriate techniques for pedestrian trail bridges was of paramount importance.

The bridge design presented in this manual originates from indigenous local trail bridge types built by Nepali craftsmen for centuries. Recognizing the well-established skills of local trail bridge builders and craftsmen of bridge fabricators, critical and weak components have been improved by an appropriate input of cement and galvanized steel parts.

In the course of the last 12 years, the engineers, overseers, sub-overseers, site supervisors and consultants of the joint Trail Bridge Programs between SDC/Helvetas and HMG's Suspension Bridge Division have developed a standardized, economical and well-tested suspended bridge type design satisfying both engineering requirements and the call for bridge building by local craftsmen.

### 1.2 CONCEPT OF THE HANDBOOK

This Handbook provides technical guidelines for the construction of unstiffened pedestrian suspended type cable bridges (catwalk). It does not apply for suspension bridges, which require higher towers or pylons on both sides of the bridge. For these suspension bridges a separate Handbook will be prepared.

This Handbook comprises three volumes and follows the actual step-by-step process of constructing a bridge.

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 three volumes have been structured as follows:

- Volume I** This volume is the guidebook for site survey, bridge design, cost estimation and construction. It serves as a *Help and Reference* for using the drawings provided in Volume II and the pre-designed formats in Volume III.
- Volume II** Volume two provides all the necessary formats for survey, design and cost estimation.
- Volume III** Volume three contains all the standardized steel and construction drawings and examples of bridge designs.

The above three volumes provide all the necessary information, drawings and formats for the construction of a suspended type cable bridge. The volumes are structured in such a way that well versed practitioners need to work with Volume II and III only, whereby Volume I serves as a reference Volume II + III. For more scientific background information, respective engineering sources need to be consulted.

### 1.3 PRESENTATION OF THE SUSPENDED BRIDGE TYPE

The Suspended Cable Bridge design presented in this Handbook (for details refer to chapter 3.1) has been developed from existing indigenous river crossings built for many generations by Nepali artisans and craftsmen. 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 70 cm walkway is mainly applicable for pedestrian traffic, whereas the 106 cm walkway should be applied for crossings where pack animal traffic is also expected.

Utmost care was taken to make maximum use of local resources, users' capacity, know-how and skills of rural Nepal. The main aim in choosing this approach is to build on existing traditions and thereby promote people's participation, but also make it suitable for local contractors.

### 1.4 TECHNICAL FEATURES AND LIMITATIONS

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 SBD standard design.

All the construction materials conform to international specifications. Exposed steel parts are all 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 Handbook 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 with this standard. It is especially not suitable in unfavorable geological site conditions. At such sites, as mentioned above for longer spans, engineers' input is mandatory.

### 1.5 USERS

This Handbook 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, overseers and sub-overseers.

## 2. SURVEY AND BRIDGE SITE SELECTION

### 2.1 SURVEY AND BRIDGE SITE SELECTION

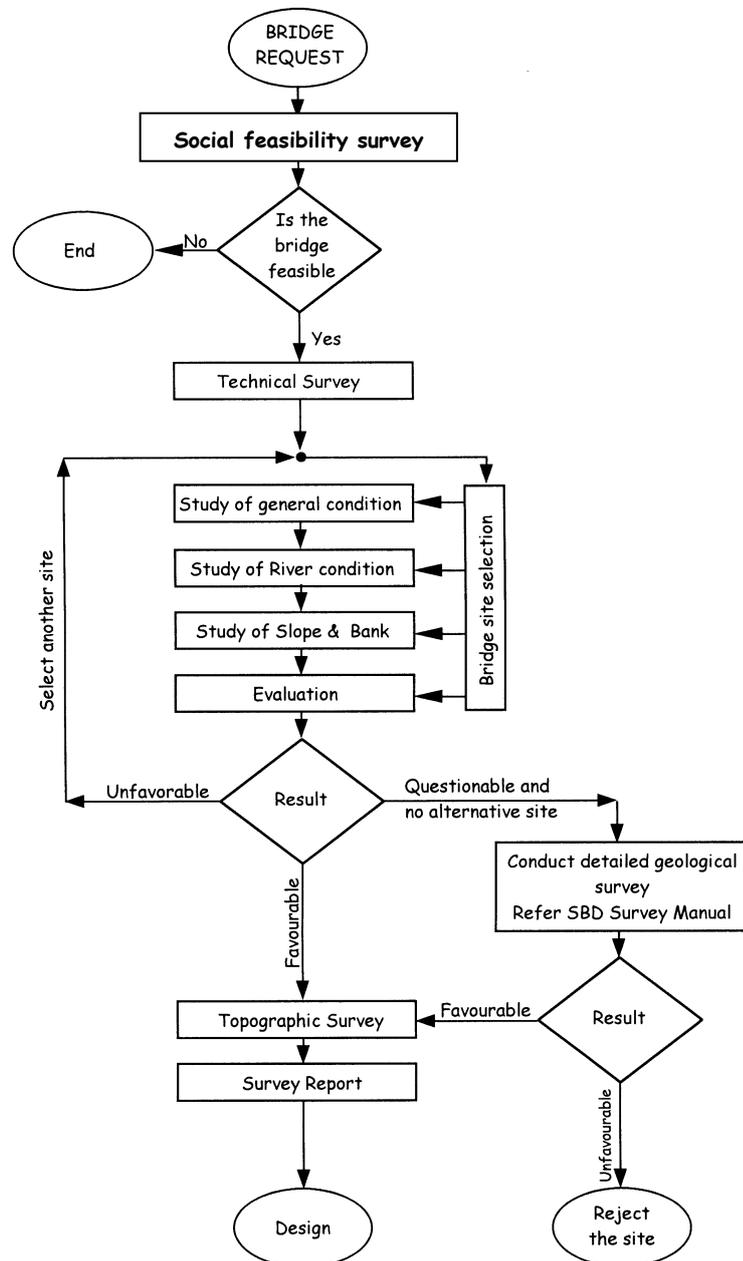
Careful Surveys and Bridge Site Assessments are the basis for proper planning and designing and form the main source for successful bridge construction. The main objective of the Survey and Bridge Site Assessment is to identify the proper bridge site by considering socio-economic as well as technical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

- **Social Feasibility Survey and**
- **Technical Survey**

*\* follow*      **Form No. 1**  
**Survey Form and Checklist**

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.

The Survey process follows as per the flow chart below:



### 2.1.1 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 following socio-economic indicators are of utmost importance:

- 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. The mass meeting should consist of the following agenda:

- 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 (e.g. width of walkway see 2.3.4), costs and situation of local traffic
- Assessment of capacity of the community, 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 Technical Handbook, for further details refer to the Social Organization Support (SOS) Manuals of the BBLP Programme.

### 2.1.2 TECHNICAL SURVEY

The technical survey includes:

- Bridge site selection and Topographic Survey of the selected bridge site

## 2.2 PREPARATION FOR SURVEY

The following preparatory work must 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.

Survey equipment consists of the following materials:

#### For Survey by Abney Level

- 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)
- Calculator, Note Book & Pencil
- Nylon Rope (min. 50m) Masons Thread

#### For Survey by Theodolite

- 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
- Thread and Plumb Bob

### 2.3 GENERAL DATA COLLECTION

General data is required for needs assessment and construction planning of the proposed bridge. Collect the following general data and information:

- 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

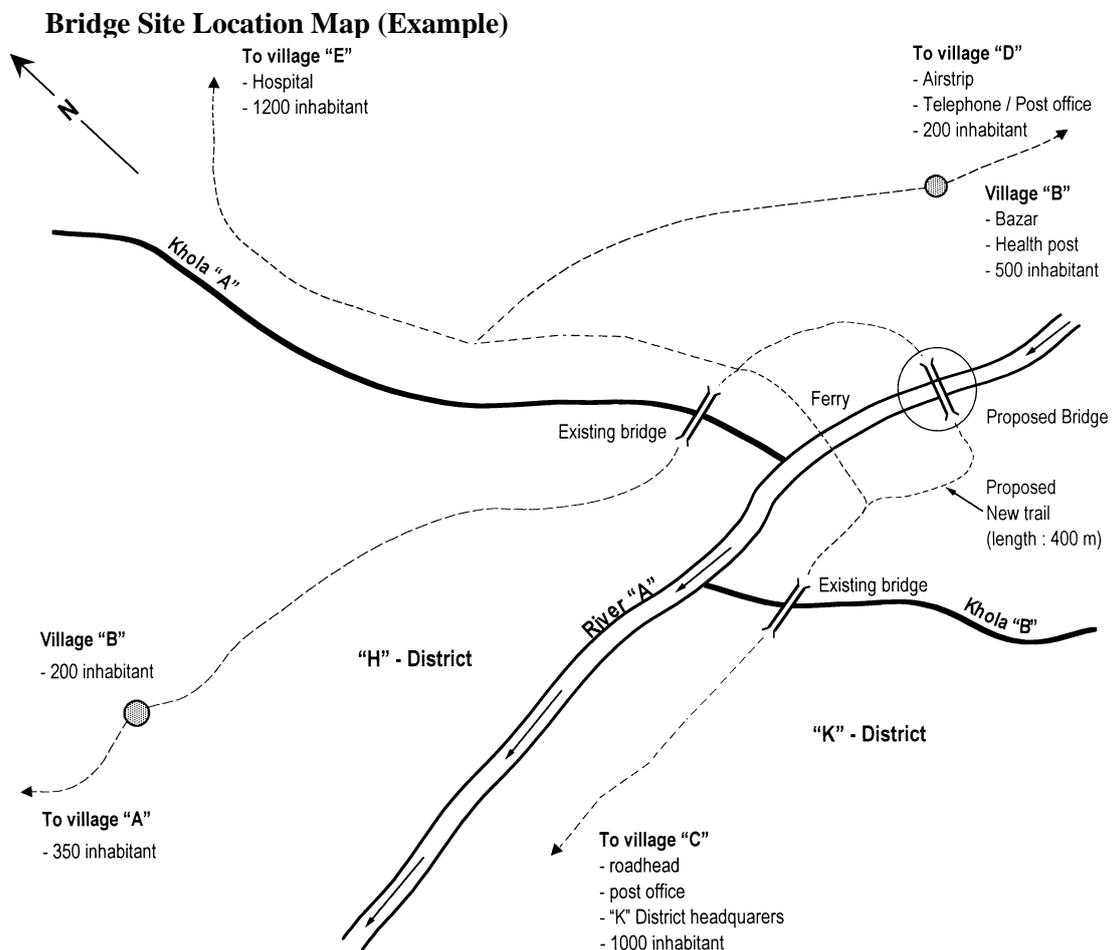
#### 2.3.1 LOCATION OF BRIDGE SITE

Describe the location of the bridge site:

|           | <i>Left Bank</i> | <i>Right Bank</i> |
|-----------|------------------|-------------------|
| VDC       |                  |                   |
| Ward No.  |                  |                   |
| Ilaka No. |                  |                   |
| District. |                  |                   |
| Zone      |                  |                   |

Draw a bridge site location map covering the proposed bridge’s area of influence as shown in the example below. The map should contain the following information:

- 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 approx. distances to the bridge site



### 2.3.2 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.

### 2.3.3 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 2 methods. Count traffic volume at the traditional crossing point for at least one day. And then interview the local people to form a broader impression of the traffic volume throughout the year.

|                          |              | <i>Average Number of Traffic per Day</i> |
|--------------------------|--------------|--|
| <b>Goods Traffic</b>     | Porters      |  |
|                          | Pack Animals |  |
| <b>Non-goods Traffic</b> | Persons      |  |
|                          | Animals      |  |

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

| <i>Access to</i>        | <i>Yes</i> | <i>No</i> |
|-------------------------|------------|-----------|
| Schools                 |            |           |
| Hospital / Health posts |            |           |
| Bazaar/Markets          |            |           |
| Road head               |            |           |
| Post office/Telephone   |            |           |
| Farming                 |            |           |
| Others (specify)        |            |           |

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

### 2.3.4 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

### 2.3.5 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.

For informing the community on how much labor work is overall generally necessary for constructing the bridge, the following formulas can be used to compute the **tentative preliminary number of mandays**:

- 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.

| <i>By Whom</i>   | <i>Type of Participation</i> |
|------------------|------------------------------|
| Local Community  |                              |
| User's Committee |                              |
| VDC              |                              |
| DDC              |                              |
| Local NGO        |                              |
| Individual       |                              |
| Others (specify) |                              |

### 2.3.6 TRANSPORTATION DISTANCE

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

| <i>Type of Transport</i> | <i>Name of nearest Roadhead/Airstrip etc.</i> | <i>Distance from Site up to Roadhead/Airstrip</i> |                    |                      |
|--------------------------|---|---|--------------------|----------------------|
|                          |   | <i>Km/Kosh</i>                                    | <i>Porter Days</i> | <i>By Mule, Days</i> |
| Served by Truck          |   |   |                    |                      |
| Served by Tractor        |   |   |                    |                      |
| Airstrip                 |   |   |                    |                      |
| Helipad                  |   |   |                    |                      |

**2.3.7 AVAILABILITY OF LOCAL MATERIALS**

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

| <i>Description</i> | <i>Haulage Distance, m</i> | <i>Remarks</i> |
|--------------------|----------------------------|----------------|
| Stones             |                            |                |
| Natural Gravel     |                            |                |
| Sand               |                            |                |
| Wood               |                            |                |
| Bamboo             |                            |                |

**2.3.8 AVAILABILITY OF LOCAL BRIDGE BUILDERS**

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

| <i>Names</i> | <i>Skill (Mason, Bridge Fitter)</i> | <i>Village / Address</i> |
|--------------|-------------------------------------|--------------------------|
|              |                                     |                          |
|              |                                     |                          |
|              |                                     |                          |
|              |                                     |                          |

**2.3.9 TEMPORARY CROSSING**

Is a temporary crossing necessary during the construction of the bridge?

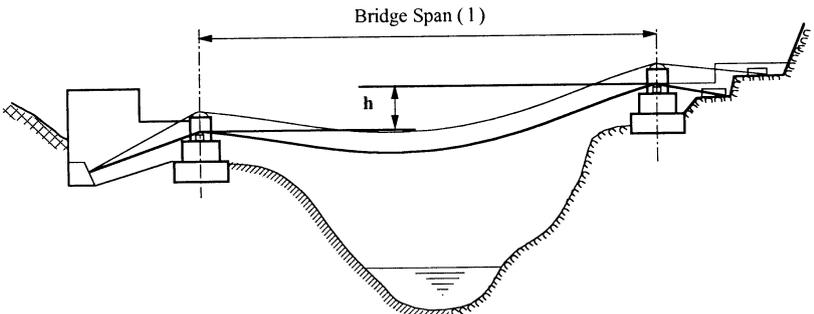
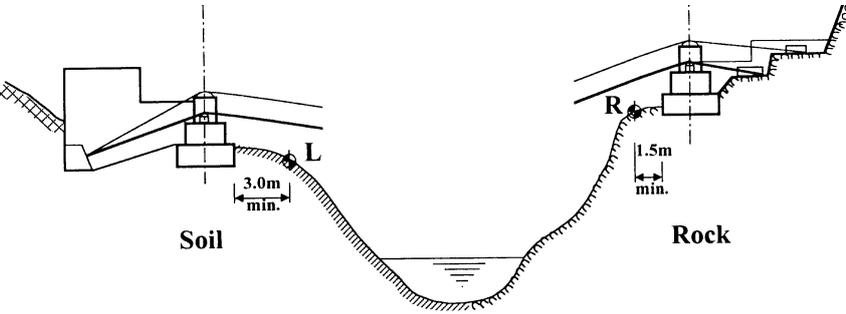
Yes  No

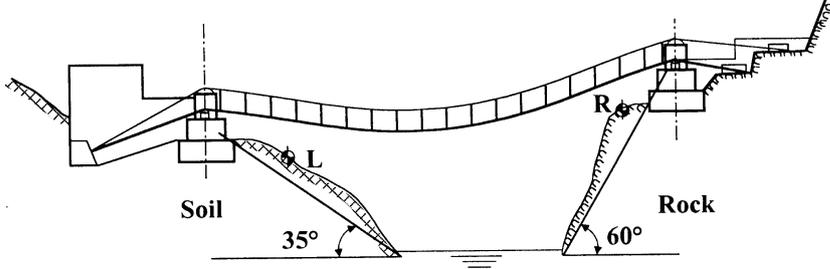
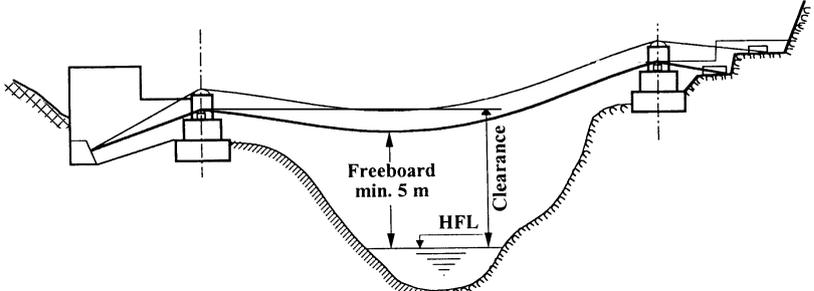
If yes, what kind of temporary crossing do you propose?

Ferry  Cable Car

Temporary Bridge, m Span



| Features  | Condition   |
|---|---|
| <p><b>Level Difference between two Banks</b><br/>                     The level difference <math>h</math> between the two foundation blocks should not be more than <math>l/25</math>.</p>  <ul style="list-style-type: none"> <li>• Locate the tentative position of the bridge foundations at both banks</li> <li>• Measure the level difference <math>h</math> between the foundations of two banks.</li> <li>• Compare with the condition.</li> </ul> <p><b>Space for Foundation</b><br/>                     Foundation should be placed at least 3 m behind the soil slope and 1.5 m behind the rock slope from the front edge of the riverbank.</p>  | <p><b>Favorable:</b><br/> <math>h</math> is equal or less than <math>l/25</math></p> <p><b>Unfavorable:</b><br/> <math>h</math> is bigger than <math>l/25</math></p><br><p><b>Favorable:</b><br/>                     Condition can be fulfilled</p> <p><b>Unfavorable:</b><br/>                     Condition can not be fulfilled</p> |

| Features  | Condition |                   |             |  |  |  |                       |  |                   |      |  |  |            |       |       |           |       |       |           |       |       |            |        |        |             |        |        |   |
|---|-----------|-------------------|-------------|--|--|--|-----------------------|--|-------------------|------|--|--|------------|-------|-------|-----------|-------|-------|-----------|-------|-------|------------|--------|--------|-------------|--------|--------|---|
| <p><b>Slope Profile</b></p> <p>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).</p>  <ul style="list-style-type: none"> <li>• Draw a slope line of 35° (angle of internal friction) in case of a Soil slope and 60° in case of a Rock slope.</li> <li>• Foundation should be placed behind this line.</li> <li>• Check if these conditions can be fulfilled</li> </ul> <p><b>Free Board</b></p> <p>The Freeboard between the lowest point of the bridge and the highest flood level should not be less than 5 m. For this, sufficient <b>clearance</b> between the lower foundation saddle and HFL should be maintained.</p>  <table border="1" data-bbox="1072 1288 1489 1736"> <thead> <tr> <th></th> <th>Favorable</th> <th>Unfavorable</th> </tr> </thead> <tbody> <tr> <td><b>Clearance</b> between lower foundation saddle and HFL is:</td> <td></td> <td></td> </tr> <tr> <td><b>not less than:</b></td> <td></td> <td><b>less than:</b></td> </tr> <tr> <td>span</td> <td></td> <td></td> </tr> <tr> <td>up to 50 m</td> <td>7.5 m</td> <td>7.5 m</td> </tr> <tr> <td>51 - 70 m</td> <td>8.0 m</td> <td>8.0 m</td> </tr> <tr> <td>71 - 90 m</td> <td>9.0 m</td> <td>9.0 m</td> </tr> <tr> <td>91 - 110 m</td> <td>10.0 m</td> <td>10.0 m</td> </tr> <tr> <td>110 - 120 m</td> <td>11.0 m</td> <td>11.0 m</td> </tr> </tbody> </table> <ul style="list-style-type: none"> <li>• Identify HFL by local observation and villagers' information.</li> <li>• Calculate available clearance and compare with the requirement.</li> <li>• <b>Exception:</b> At flat or wide river banks free board may be reduced. At gorges free board may have to be increased.</li> </ul> |           | Favorable         | Unfavorable | <b>Clearance</b> between lower foundation saddle and HFL is: |  |  | <b>not less than:</b> |  | <b>less than:</b> | span |  |  | up to 50 m | 7.5 m | 7.5 m | 51 - 70 m | 8.0 m | 8.0 m | 71 - 90 m | 9.0 m | 9.0 m | 91 - 110 m | 10.0 m | 10.0 m | 110 - 120 m | 11.0 m | 11.0 m | <p><b>Favorable:</b><br/>Condition can be fulfilled</p> <p><b>Unfavorable:</b><br/>Condition can not be fulfilled</p> |
|   | Favorable | Unfavorable       |             |  |  |  |                       |  |                   |      |  |  |            |       |       |           |       |       |           |       |       |            |        |        |             |        |        |   |
| <b>Clearance</b> between lower foundation saddle and HFL is:  |           |                   |             |  |  |  |                       |  |                   |      |  |  |            |       |       |           |       |       |           |       |       |            |        |        |             |        |        |   |
| <b>not less than:</b>   |           | <b>less than:</b> |             |  |  |  |                       |  |                   |      |  |  |            |       |       |           |       |       |           |       |       |            |        |        |             |        |        |   |
| span  |           |                   |             |  |  |  |                       |  |                   |      |  |  |            |       |       |           |       |       |           |       |       |            |        |        |             |        |        |   |
| up to 50 m  | 7.5 m     | 7.5 m             |             |  |  |  |                       |  |                   |      |  |  |            |       |       |           |       |       |           |       |       |            |        |        |             |        |        |   |
| 51 - 70 m   | 8.0 m     | 8.0 m             |             |  |  |  |                       |  |                   |      |  |  |            |       |       |           |       |       |           |       |       |            |        |        |             |        |        |   |
| 71 - 90 m   | 9.0 m     | 9.0 m             |             |  |  |  |                       |  |                   |      |  |  |            |       |       |           |       |       |           |       |       |            |        |        |             |        |        |   |
| 91 - 110 m  | 10.0 m    | 10.0 m            |             |  |  |  |                       |  |                   |      |  |  |            |       |       |           |       |       |           |       |       |            |        |        |             |        |        |   |
| 110 - 120 m   | 11.0 m    | 11.0 m            |             |  |  |  |                       |  |                   |      |  |  |            |       |       |           |       |       |           |       |       |            |        |        |             |        |        |   |



**2.4.3 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.

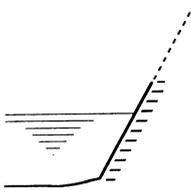
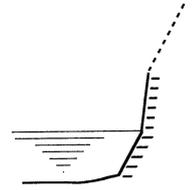
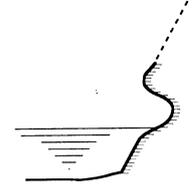
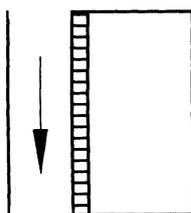
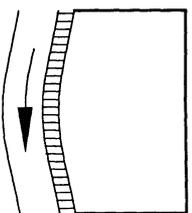
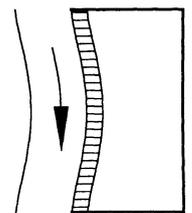
**If the slope and bank is soil, potential instability features and failure modes are:**

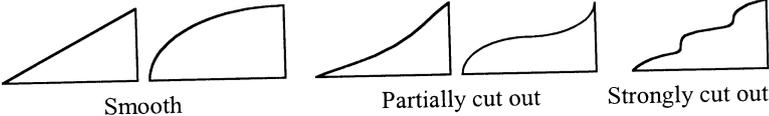
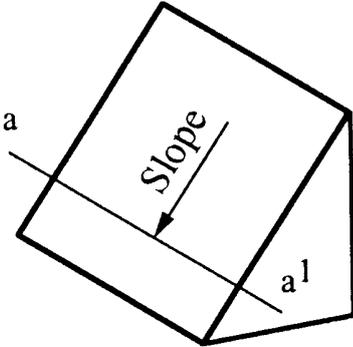
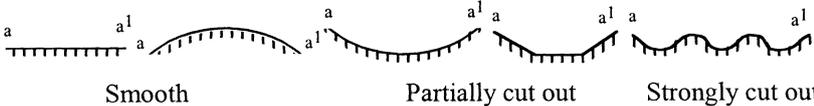
- bank erosion
- toppling instability of the bank
- erosion of the slope
- land slide

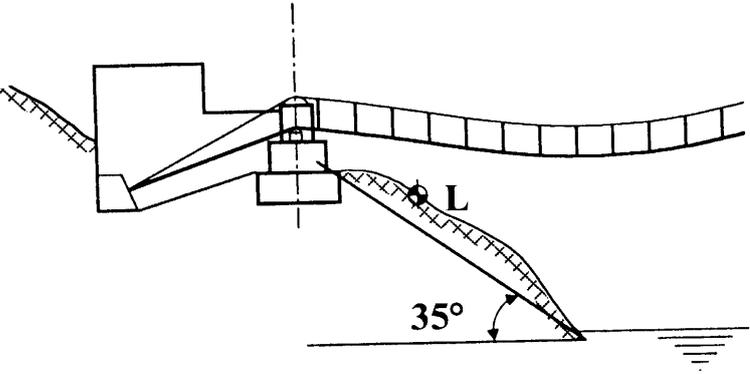
**If the slope and bank is rock, potential instability features and failure modes are:**

- 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.

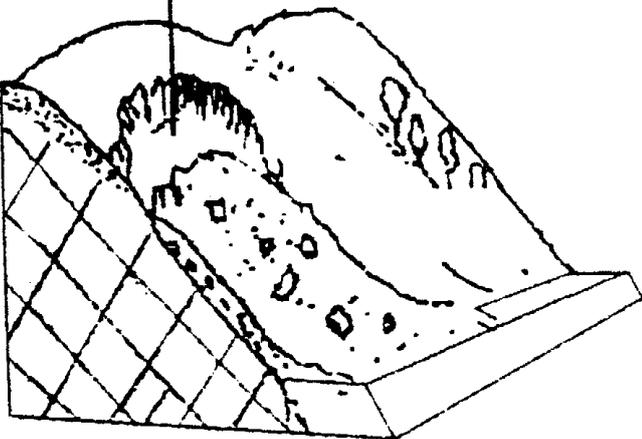
To avoid the above instability features, use the following checklist to evaluate the slope and bank of the selected site:

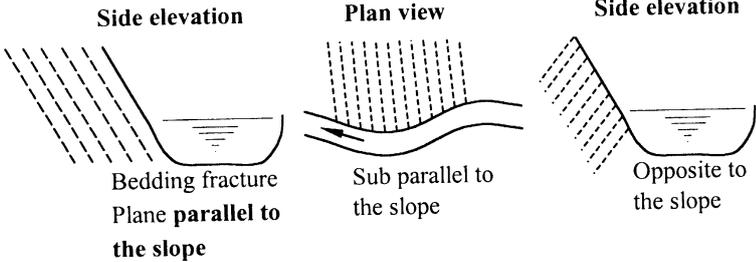
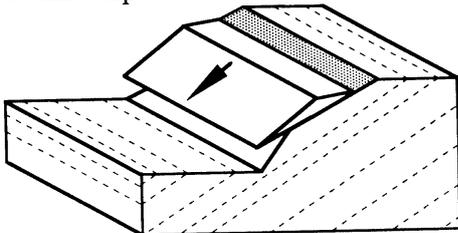
| <i>Features</i>  | <i>Condition</i>   |
|--|--|
| <p><b>If the River Bank or Slope is SOIL</b></p> <p><b>Bank Profile</b><br/>The bank profile should be smooth.</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>Smooth</p> </div> <div style="text-align: center;">  <p>Partially cut out</p> </div> <div style="text-align: center;">  <p>Strongly cut out</p> </div> </div> <p><b>River Bank Contour</b><br/>The bridge site should be located at the straight reach of the river to avoid the river from undercutting or bank erosion.</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>Straight</p> </div> <div style="text-align: center;">  <p>Convex</p> </div> <div style="text-align: center;">  <p>Concave</p> </div> </div> | <p><b>Favorable:</b><br/>Bank profile is smooth to partially cut out</p> <p><b>Unfavorable:</b><br/>Bank profile is strongly cut out</p><br><p><b>Favorable:</b><br/>River contour is straight or convex</p> <p><b>Unfavorable:</b><br/>River contour is concave</p> |

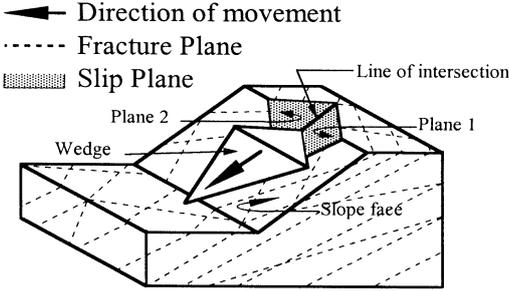
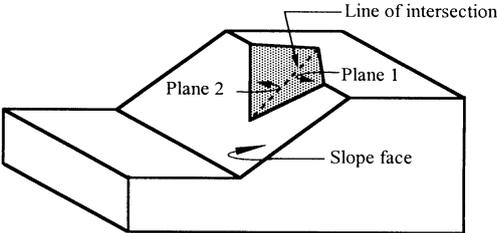
| <i>Features</i>   | <i>Condition</i>   |
|---|--|
| <p><b>Bank Erosion</b><br/>The River bank should not show any sign of erosion.</p> <p style="text-align: center;">Photo: Damsadi Ghat</p> <p style="text-align: center;">Bank erosion due to high river current</p> <p><b>Slope Profile</b><br/>The slope profile should be smooth.</p>  <p style="text-align: center;">Smooth                      Partially cut out                      Strongly cut out</p> <p><b>Transverse Slope</b><br/>The transverse slope should be smooth.</p>  <p style="text-align: center;">Transverse slope strongly cut out</p>  <p style="text-align: center;">Smooth                      Partially cut out                      Strongly cut out</p> | <p><b>Favorable:</b><br/>No sign of fresh erosion</p> <p><b>Unfavorable:</b><br/>Presence of fresh erosion</p> <p><b>Favorable:</b><br/>Slope profile is smooth to partially cut out</p> <p><b>Unfavorable:</b><br/>Slope profile is strongly cut out</p> <p><b>Favorable:</b><br/>Transverse slope is smooth to partially cut out</p> <p><b>Unfavorable:</b><br/>Transverse slope is strongly cut out</p> |

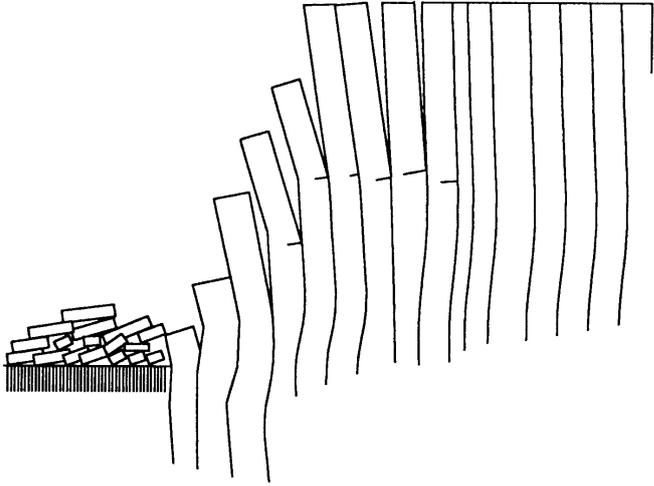
| <i>Features</i>  | <i>Condition</i>   |
|--|--|
| <p><b>Slope Inclination (Soil Slope)</b><br/>                     The slope inclination should be less than 35°.</p>  <p>Estimate the slope inclination and compare it with the condition. If the site has an unfavorable slope inclination, it can still be selected provided the general condition of slope profile is fulfilled.</p> <p><b>River Undercutting</b><br/>                     The bridge site should be free from river undercutting which may lead to landslide.</p> <p>Photo: From MRE ICIMOD, Page 20</p> <p>Landslide caused by river undercutting</p> | <p><b>Favorable:</b> Slope inclination is equal or smaller than 35°</p> <p><b>Unfavorable:</b> Slope inclination is bigger than 35°</p> <p><b>Favorable:</b><br/>                     There is no river undercutting</p> <p><b>Unfavorable:</b><br/>                     River undercutting is active or there is potential for river undercutting</p> |

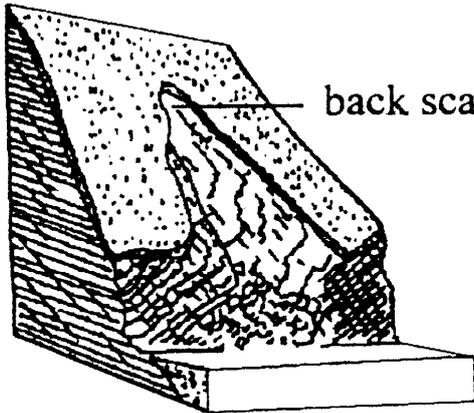
| <i>Features</i>   | <i>Condition</i>  |
|---|---|
| <p><b>Inclined Trees</b><br/>The selected site should not have inclined trees, which indicate an active landslide.</p> <p style="text-align: center;">Inclined trees on landslide mass</p> <p><b>Seepage or Swampy Area</b><br/>The bank slope should not have any seepage or swampy area, which may lead to slope instability.</p> <p><b>Gully Erosion</b><br/>No signs of gully erosion should exist within the vicinity of the selected site.</p> <p style="text-align: center;">Photo</p> <p style="text-align: center;">Active gully erosion</p> <ul style="list-style-type: none"> <li>• Observe if any rivulets are within the vicinity of the selected site.</li> <li>• If rivulet exists, examine the dimension of the gully cutting.</li> </ul> | <p><b>Favorable:</b><br/>Inclined trees are not present</p> <p><b>Unfavorable:</b><br/>Inclined trees are present</p> <p><b>Favorable:</b><br/>No Seepage or swampy area is absent</p> <p><b>Unfavorable:</b><br/>Seepage or swampy area is present</p> <p><b>Favorable:</b><br/>No sign of gully erosion or only light gully erosion</p> <p><b>Unfavorable:</b><br/>Heavy gully erosion exists</p> |

| <i>Features</i>  | <i>Condition</i>   |
|--|--|
| <p><b>Slipped (Slump) Soil Mass</b><br/>                     The bridge should not be located on already slipped soil masses.</p> <p style="text-align: center;">Photo</p> <p style="text-align: center;">Slope with slipped soil mass</p> <p style="text-align: center;"><b>back scar</b></p>  <p style="text-align: center;"><b>Slope Failure Model</b></p> <ul style="list-style-type: none"> <li>• Examine and identify any indication of soil mass movement. This can be done by observing traces of back scars on the slope.</li> </ul> | <p><b>Favorable:</b><br/>                     There are no back scars or signs of soil mass movement</p> <p><b>Unfavorable:</b><br/>                     There are back scars or signs of soil mass movement</p> |

| <i>Features</i>   | <i>Condition</i>   |
|---|--|
| <p><b>If the River Bank is ROCK</b></p> <p><b>Plain Failure</b><br/>                     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 plain failure.</p> <p>Bedding plain is <b>parallel to the slope</b> and plain failure is active.<br/> <b>Site is extremely unfavorable!</b></p>  <p>Side elevation: Bedding fracture Plane <b>parallel to the slope</b></p> <p>Plan view: Sub parallel to the slope</p> <p>Side elevation: Opposite to the slope</p> <p>← Direction of movement<br/>                     ..... Bedding / Fracture Plane<br/>                     ▨ Slip Plane</p> <p><b>Plain Failure Model</b></p>  <ul style="list-style-type: none"> <li>• Identify bedding/fracture plain (layers of rock)</li> <li>• Check its direction and inclination</li> <li>• Compare with the condition</li> </ul> | <p><b>Favorable:</b></p> <p><b>Plain failure will not take place, if:</b></p> <ul style="list-style-type: none"> <li>• Bedding/fracture plain is sub-parallel to opposite to the slope</li> <li>• Bedding/fracture plain is parallel to the slope, but inclination is less than 35°</li> </ul> <p><b>Unfavorable:</b></p> <p><b>Plain failure will take place, if:</b></p> <ul style="list-style-type: none"> <li>• Bedding/fracture plain is parallel to the slope and inclination is greater than 35°</li> <li>• Presence of old slided rocks</li> </ul> |

| <i>Features</i>   | <i>Condition</i>   |
|---|--|
| <p><b>Wedge Failure</b><br/>Any form of wedge failure leads to sliding of rock masses. The rock bank/slope should not have wedge failures or potential wedge failures.</p> <p style="text-align: center;">Photo</p> <p style="text-align: center;">Traces of wedge failure</p>  <p style="text-align: center;"><b>Wedge Failure Model</b></p>  <p style="text-align: center;"><b>Wedge Failure</b></p> <ul style="list-style-type: none"> <li>• Identify if there are fracture plains facing each other (intersecting)</li> <li>• Check the inclination of the intersection line</li> <li>• Compare with the condition</li> </ul> | <p><b>Favorable:</b></p> <p><b>Wedge failure will not take place, if</b></p> <ul style="list-style-type: none"> <li>• There are no fracture plains facing each other</li> <li>• There are two or more intersecting fracture plains but the inclination of its line of intersection is less than 35°</li> <li>• There are two or more intersecting fracture plains but the inclination of its line of intersection is opposite to the slope</li> </ul> <p><b>Unfavorable:</b></p> <p><b>Wedge failure will take place, if</b></p> <ul style="list-style-type: none"> <li>• There are two or more intersecting fracture plains and the inclination of its intersection line is more than 35° to the slope</li> <li>• Presence of old slided wedge</li> </ul> |

| <i>Features</i>  | <i>Condition</i>   |
|--|--|
| <p><b>Toppling Failure</b><br/>The rock bank/slope should not have any features of toppling failure.</p> <p style="text-align: center;">Photo</p> <p style="text-align: center;">Potential toppling failure</p>  <p style="text-align: center;"><b>Toppling Failure Model</b></p> <ul style="list-style-type: none"> <li>• Identify if there is formation of vertically elongated rock blocks (cubes) due to vertical and horizontal fracture planes/joints</li> <li>• Estimate inclination of the slope</li> <li>• Estimate inclination and orientation of the rock block and compare with the conditions</li> </ul> | <p><b>Favorable:</b></p> <p><b>Toppling will not take place, if</b></p> <ul style="list-style-type: none"> <li>• the Rock slope is less than 60°</li> <li>• there is no formation of rock blocks</li> <li>• there is a formation of rock block but b/h (width of the block/height of the block) is bigger than 1</li> </ul> <p><b>Unfavorable:</b></p> <p><b>Toppling will take place, if</b></p> <ul style="list-style-type: none"> <li>• there is a formation of vertically elongated rock blocks in a steep slope bigger than 60° and the blocks are tilted towards the slope</li> <li>• old toppled rock blocks are present</li> </ul> |

| <i>Features</i>  | <i>Condition</i>  |
|--|---|
| <p><b>Translational Failure (Slide)</b><br/>The rock slope should not have any potential of rotational failure.</p> <p style="text-align: center;">Photo</p> <p style="text-align: center;"><b>Translational failure (sliding) of soft rock slope</b></p>  <p style="text-align: center;"><b>failure (slide) model</b></p> <ul style="list-style-type: none"> <li>• Identify type of rock and its weathering grade</li> <li>• Estimate inclination of the slope</li> <li>• Compare with the conditions</li> </ul> | <p><b>Favorable:</b></p> <p><b>Sliding will not take place, if the</b></p> <ul style="list-style-type: none"> <li>• slope is hard rock</li> <li>• slope is soft rock but not weathered</li> <li>• slope is soft rock and weathered but not steeper than 40°</li> </ul> <p><b>Unfavorable:</b></p> <p><b>Sliding will take place, if</b></p> <ul style="list-style-type: none"> <li>• the slope is highly weathered soft rock and steep than 40°</li> <li>• back scars or old slide are present</li> </ul> |

### 2.4.4 EVALUATION OF THE BRIDGE SITE

After completing investigation of the site as per chapter 2.4.1 to 2.4.3, categories the bridge site as

- Good** All or most of the features are favorable and if the surveyor is confident about the stability of the slopes. Proceed with further survey work.
- Bad** Most of the features are unfavorable. Reject site.
- Questionable** Most of the features are favorable and some are unfavorable. The site is questionable. In this case, further detailed investigation by an experienced geotechnical engineer is necessary. For detail refer to the SBD Survey Manual.

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.**

### 2.4.5 CLASSIFICATION OF SOIL AND ROCK

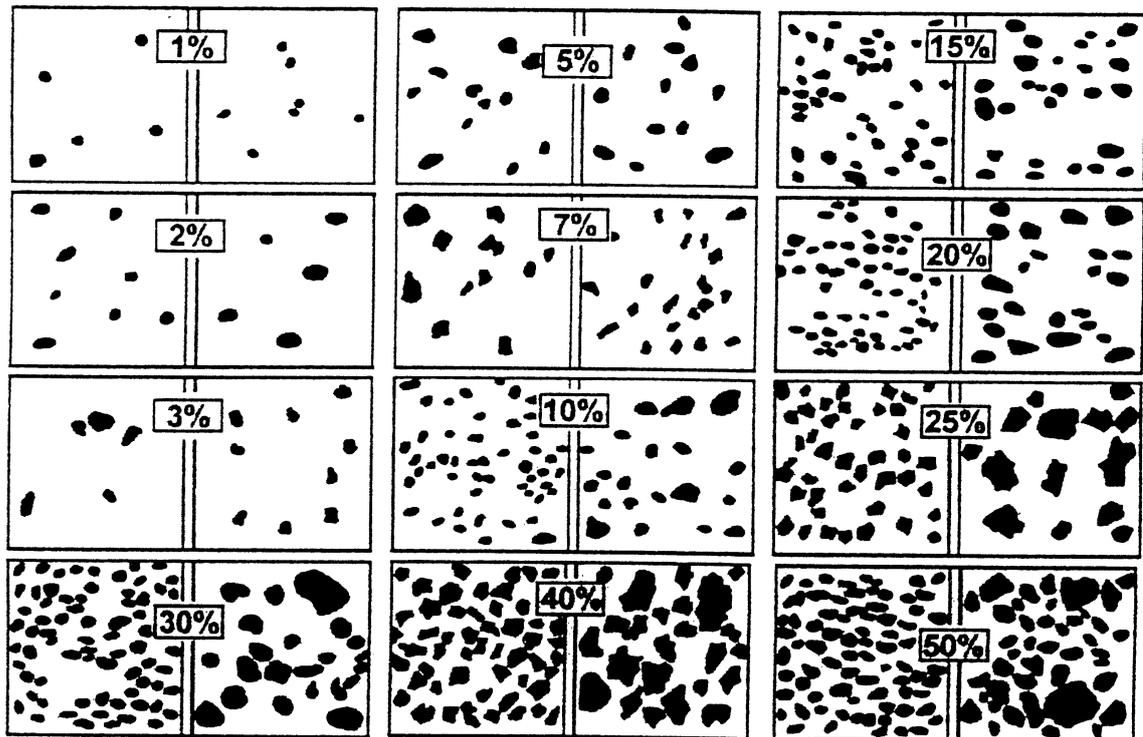
Identification of Soil and Rock types is required for appropriate foundation design. Soil and Rocks can broadly be classified as per the following tables.

#### Soil Classification

| Soil Type   |  | How to Identify         | Soil Parameters                        |  |  | Applicable Foundation Design |
|---|--|-------------------------|--|--|--|------------------------------|
|   |  |                         | Bearing Capacity, [kN/m <sup>2</sup> ] | Angle of Internal Friction, $\phi^\circ$ | Unit Weight, $\gamma$ [kN/m <sup>3</sup> ] |                              |
| <b>Coarse Grained Soils</b><br>More than half of the materials are of individual grains visible to the naked eye (grain size bigger than 0.06 mm)       | <b>Gravelly Soils</b><br>Estimate the percentage (%) of coarse grains larger than 6 mm. If, more than half of the coarse fraction is larger than 6 mm, the soil is Gravelly Soil | 400-600<br><b>(400)</b> | 32-38<br><b>(35)</b>                   | <b>19</b>                                | <b>Deadman Anchor</b>                      |                              |
|   | <b>Sandy Soils</b><br>If, more than half of the coarse fraction is smaller than 0.06 mm grain size, the soil is Sandy Soil   | 200-300<br><b>(200)</b> | 31-37<br><b>(33)</b>                   | <b>18</b>                                |  |                              |
| <b>Fine Grained Soils</b><br>More than half of the materials are individual grains <b>not</b> visible to the naked eye (grain size smaller than 0.06mm) | <b>Silty Soils</b><br>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                     | 150-200<br><b>(150)</b> | 30-32<br><b>(30)</b>                   | <b>17</b>                                |  |                              |
|   | <b>Clay</b><br>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<br><b>(100)</b> | 9-25<br><b>(22)</b>                    | <b>16</b>                                |  |                              |

For estimating the percentage (%) of coarse grains use the following figure:

**Ratio of coarse grains**



**Rock Classification**

| Rock Type | Examples  | How to Identify                        | Degree of Fractures or Weathering                   | How to Identify   | Rock Parameters                        |                               | Applicable Foundation Design  |
|-----------|---|--|---|---|--|-------------------------------|-------------------------------|
|           |   |  |   |   | Bearing Capacity, [kN/m <sup>2</sup> ] | Angle of Sliding Friction, φ° |                               |
| Hard Rock | Quartzite<br>Limestone<br>Granite,<br>Dolomite<br>etc.        | Gives metallic sound after hammer blow | 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<br>(1500)                    | 35-50<br>(40)                 | Drum Anchor in Hard Rock      |
|           |   |  | Highly fractured rock and fresh to fairly weathered | In the rock exists widely open cracks, fractures and bedding                            | 1500                                   | 35-50<br>(40)                 | Drum Anchor in Fractured Rock |
| Soft Rock | Phyllite<br>Slate<br>Siltstone<br>Claystone<br>Schist<br>etc. | Gives dull sound after hammer blow     | Fresh   | No sign of weathering   | 1300                                   | 25-40<br>(30)                 | Drum Anchor in Fractured Rock |
|           |   |  | Fairly to highly weathered                          | Most of the original rock has been seriously altered<br>Rock can be broken by hand      | 600-750<br>(650)                       | 25-40<br>(30)                 | Deadman Anchor                |

### 2.4.6 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 as per the following example.

#### Example for Soil

Location: Main Anchorage Foundation at Right Bank

| Sketch  | Depth from Surface, [m] | Soil Type     | Soil Parameter                         |                                    | Remarks                     |
|---|-------------------------|---------------|--|------------------------------------|-----------------------------|
|   |                         |               | Bearing Capacity, [kN/m <sup>2</sup> ] | Angle of Internal Friction, $\phi$ |                             |
|    | 0.0                     | Top soil      |  |                                    |                             |
|    | 0.3                     | Sandy Soil    |  |                                    |                             |
|  | 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 following example.

#### Example for Rock

Location: Main Anchorage Foundation at Left Bank

| Rock Type | Degree of Fracture/Weathering         | Rock Parameter                         |                                   | Applicable Foundation Design                | Remarks |
|-----------|---------------------------------------|--|-----------------------------------|---|---------|
|           |                                       | Bearing Capacity, [kN/m <sup>2</sup> ] | Angle of Sliding Friction, $\phi$ |   |         |
| Hard Rock | Highly fractured and fairly weathered | 1500                                   | 40                                | Drum anchorage foundation in fractured rock |         |

## 2.5 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

### 2.5.1 SURVEY AREA

Area to be covered by the topographic survey:

For bridges **without windguy** arrangement,

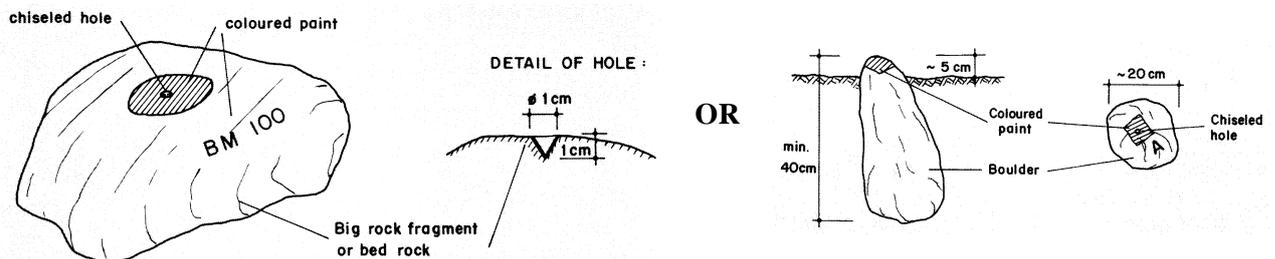
- A profile along the bridge axis covering up to 25m behind the main anchorage blocks.

For bridges **with windguy** arrangement,

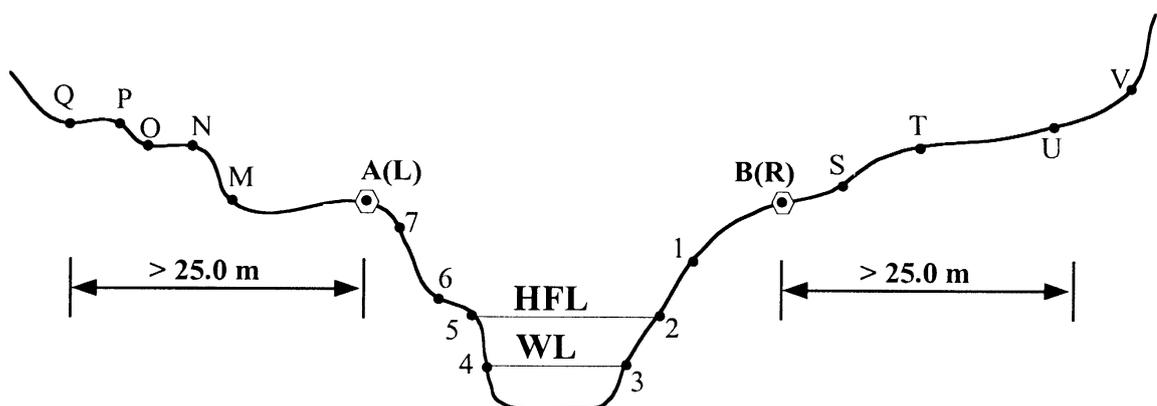
- A profile along the bridge axis covering up to 25m behind the main anchorage blocks **and** a topographic plan covering the area of 10m upstream and 10m downstream from the tentative location of the windguy foundations.

### 2.5.2 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 as per the sketch below:

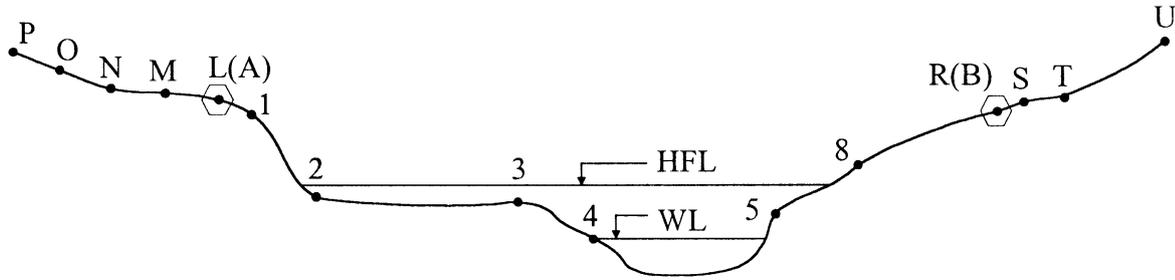


Additional survey points along the centerline should be fixed to survey the bridge axis profile as shown in the sketch below. These survey points should be fixed at breaking points of slope and terraces, which will accurately indicate the topography of the bridge axis. The profile should cover 25m behind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



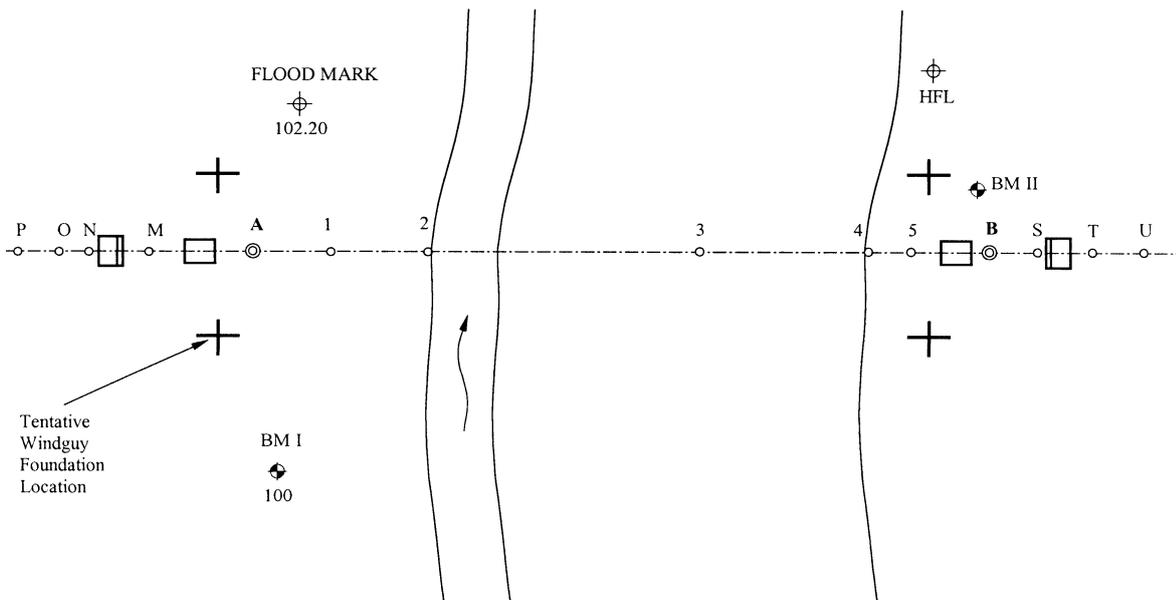
Draw a sketch of the profile/cross section of the bridge axis (centerline) with axis points **A** and **B**, with all the survey points and topographic features, including tentative position of the bridge foundations, low water level and high flood level.

**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)**



### 2.5.3 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 120 m.

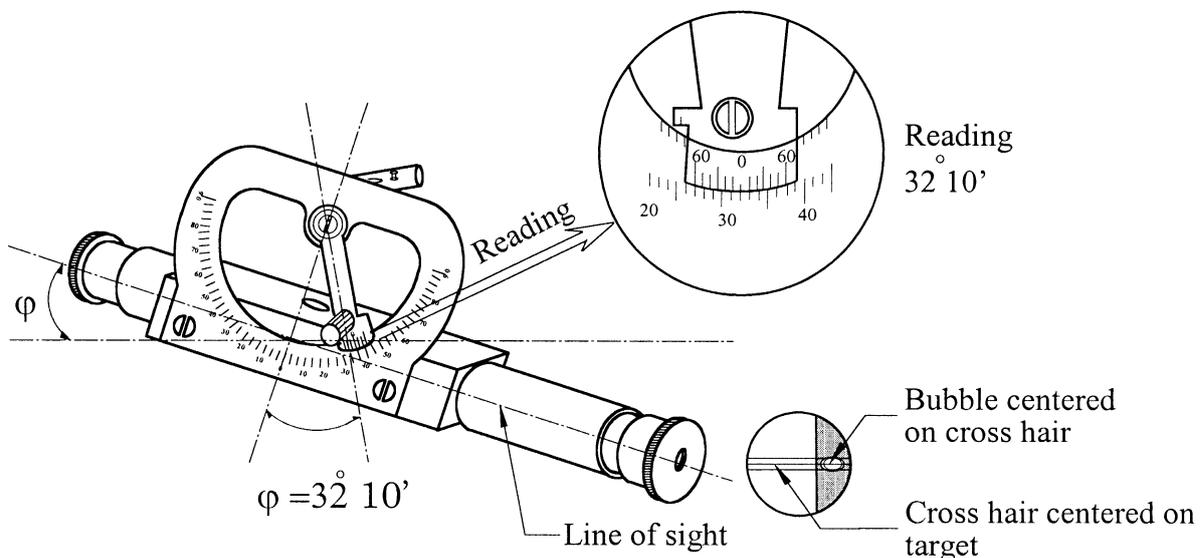
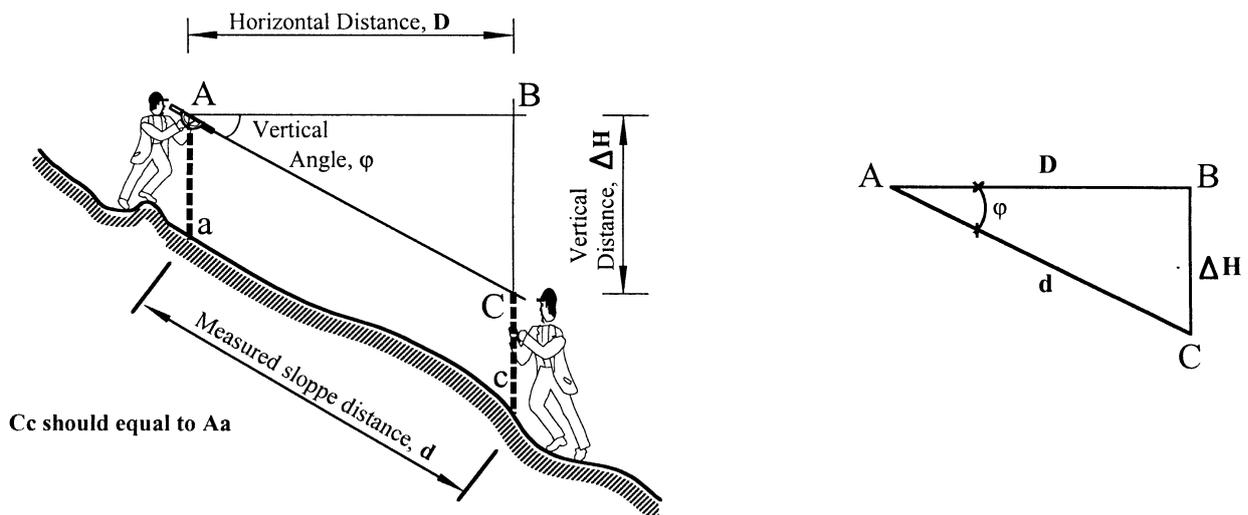
- A detailed **profile** along the selected bridge axis is sufficient for bridges without windguy arrangement. A topographic profile can be made by the Abney level, however for fixing precise levels a Level Instrument is necessary.
- For bridges requiring a windguy arrangement a more detailed topographic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

### 2.5.4 SURVEY BY ABNEY LEVEL

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

#### Measurement of Vertical Angle:

The principal of measuring the vertical angle by the Abney Level is illustrated in the sketch and procedure described below:



The Procedure of measurement is as follows:

1. The Surveyor stands at point **A** with the Abney level.
2. 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.
3. The Surveyor holds the Abney Level to the eye and sights towards the target at point **C**, centering the cross hair against the target.
4. The index arm is then adjusted until the bubble is centered against the target and cross hair.
5. 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  $\Delta H$  between **a** and **c**

$$\Delta H = d \times \sin \phi$$

Elevation of **c**

$$H = \text{Elevation of } a \pm \Delta H$$

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

**d** = slope distance from **a** to **c**

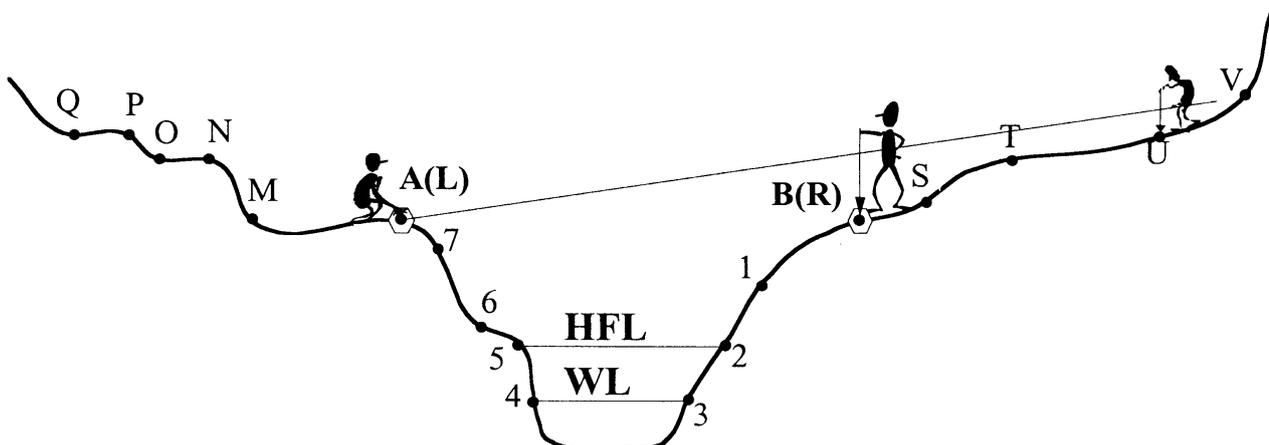
$\phi$  = vertical angle from **a** to **c**

To take the profile along the bridge axis, the Surveyor should first set the exact centerline as described in chapter 3.5.2. There are two methods of setting the centerline.

- **By Nylon Rope and Plumb Bob:**

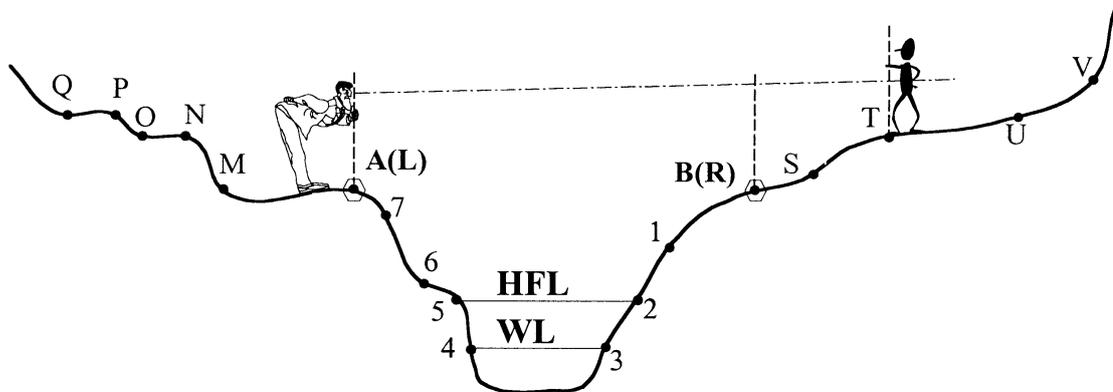
This method is accurate only for spans up to 50m. Survey points along the bridge centerline are fixed with the help of a nylon rope and plumb bob.

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 bob as per the procedures shown in the sketch below:



- **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 as per the procedures shown in the sketch below:



### Bridge Axis Profile:

Proceed with the survey of the bridge axis profile after having fixed the centerline as per following steps (refer to example on page 31).

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 below)
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 following formula:

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

#### Example: Error Correction of Measured Vertical Angles

|                                     |  |
|-------------------------------------|--|
| measured vertical angle from A to B | $\varphi_{AB} = 0^{\circ}50'$ (Downhill sighted)     |
| measured vertical angle from B to A | $\varphi_{BA} = 1^{\circ}30'$ (Uphill sighted)       |
| error factor                        | $E = (1^{\circ}30' - 0^{\circ}50')/2 = 0^{\circ}20'$ |
| corrected angle                     | $\varphi'_{AB} = 0^{\circ}50' + 20' = 1^{\circ}10'$  |
| corrected angle                     | $\varphi'_{BA} = 1^{\circ}30' - 20' = 1^{\circ}10'$  |

All measured vertical angles should be corrected as:

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

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

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

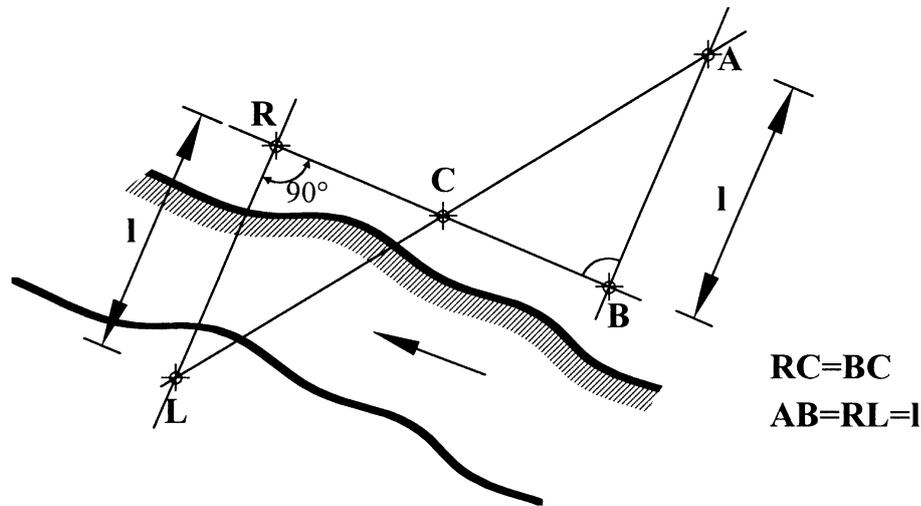
| <b>Example: Calculation of Horizontal Distance D and Elevation H of Survey Points:</b> |         |              |   |                   |
|--|---------|--------------|---|-------------------|
| Elevation of   | A       | =            | 100.00 m  |                   |
| measured vertical angle from   | A to M, | $\phi_{AM}$  | = +7°0' (upward sighting)                               |                   |
| corrected vertical angle from  | A to M  | $\phi'_{AM}$ | = +7°0' - 0°20' = +6°40'                                |                   |
| measured slope distance  | A to M  | d            | = 13.35 m   |                   |
| horizontal distance between  | A and M | D            | = $d \times \cos \phi' = 13.35 \times \cos 6^\circ 40'$ | = 13.26 m         |
| vertical distance between  | A and M | $\Delta H$   | = $d \times \sin \phi' = 13.35 \times \sin 6^\circ 40'$ | = +1.55 m         |
| Elevation of   | M       | H            | = Elevation of 'A' + $\Delta H$                         | = 100.0 + 1.55    |
|  |         |              |   | = <b>101.55 m</b> |

Enter the measurements and calculations into the **Abney Level** survey sheet as per given example on page 32.

**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 following example.

How much is the width of the river  $l = \text{Distance from L to R}$  ?

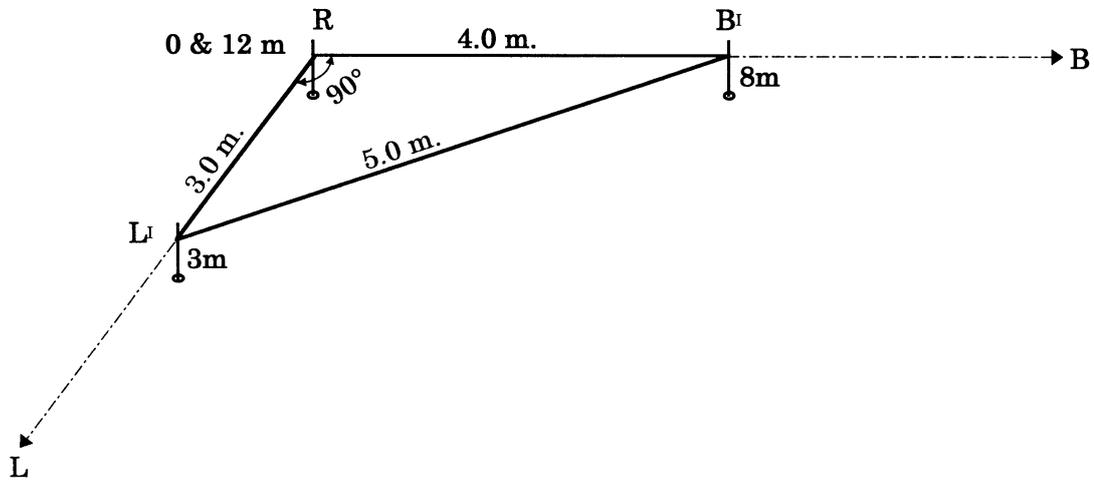


The procedure of the measurement is as follows:

1. 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 below: **Setting of a Right Angle**).
2. On this base line **R - B**, mark the mid point **C** so that **RC** is equal to **CB**.
3. Set again a base line **B - A** perpendicular to the line **R - B** similarly to step 1.
4. Mark exactly point **A** by ranging through point **L - C**, so that all these three points lie in the same line of sight.
5. Measure length **B - A**. This length will be equivalent to the river width **L - R = l**.

### Setting of a Right Angle:

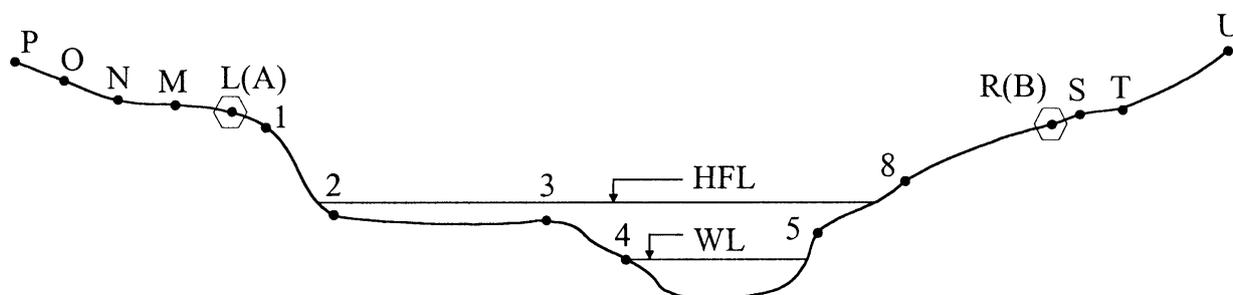
One simple method to set a right angle from a point of a base line is the 3-4-5 method. One measuring tape and 3 wooden pegs are needed, as shown in the sketch below:



The procedure of the measurement is as follows

1. The first person should hold '0' and '12' m mark of the measuring tape at point **R**.
2. 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 as shown in the sketch above. A right angle triangle will be formed with sides of 3, 4, and 5m.
3. Line **R – B'** is now perpendicular to the line **R – L'**.

**Example : BRIDGE AXIS PROFILE BY ABNEY LEVEL**



Bridge Name : Tokre Ghat    District : Nawalparasi    Surveyed by : Chuda Mani    Date : 27.11.2055

| STATION | POINTS | SLOPE<br>DISTANCE<br>d<br>m | VERTICAL<br>ANGLE<br>[Observed]<br>φ | VERTICAL<br>ANGLE<br>[Corrected]<br>φ' | HORIZONTAL<br>DISTANCE<br>D<br>m | VERTICAL<br>DISTANCE |       | REDUCED LEVEL<br>(ELEVATION)<br>H<br>m | REMARKS<br>(Description of Points)                 |
|---------|--------|-----------------------------|--------------------------------------|--|----------------------------------|----------------------|-------|--|--|
|         |        |                             |                                      |  |                                  | ±                    | ΔH    |  |  |
| A       | B      |                             | -0°50'                               | -1°10'                                 |                                  |                      |       |  | Observation for vertical<br>angle error correction |
| B       | A      |                             | +1°30'                               | +1°10'                                 |                                  |                      |       |  |  |
| A       |        |                             |                                      |  |                                  |                      |       | 100.00                                 | Datum Level (Assumed)                              |
|         | M      | 3.35                        | +7°20'                               | +7°0'                                  | 3.32                             | +                    | 0.40  | 100.41                                 |  |
|         | N      | 8.00                        | +6°20'                               | +6°0'                                  | 7.95                             | +                    | 0.84  | 100.84                                 |  |
|         | O      | 13.00                       | +11°0'                               | +10°40'                                | 12.77                            | +                    | 2.40  | 102.40                                 |  |
|         | P      | 17.25                       | +13°0'                               | +12°40'                                | 16.83                            | +                    | 3.78  | 103.78                                 |  |
|         | 1      | 4.20                        | -23°40'                              | -24°0'                                 | 3.84                             | -                    | 1.70  | 98.30                                  |  |
|         | 3      | 27.50                       | -18°40'                              | -19°0'                                 | 26.00                            | -                    | 8.95  | 91.05                                  | HFL= El <sub>3</sub> +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)                                   |
| B       |        |                             |                                      |  |                                  |                      |       | 98.67                                  |  |
|         | 3      | 41.80                       | -10°10'                              | -10°30'                                | 41.10                            | -                    | 7.62  | 91.05                                  |  |
|         | 8      | 12.40                       | -19°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                                  |  |
|         | B      | 41.80                       | +10°50'                              | +10°30'                                | 41.10                            | +                    | 7.62  | 98.67                                  |  |

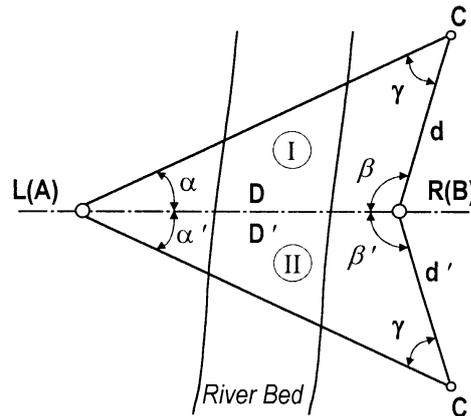
### 2.5.5 SURVEY BY THEODOLITE

When the span of the bridge is more than 120 m 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 and to the SBD Survey Manual.

#### Profile Along Bridge Axis:

Fix the bridge centerline as described in chapter 2.5.2. 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, as illustrated in the sketch below and in the example given on page 33.



For accuracy double triangulation is necessary. The procedure is:

#### I<sup>st</sup> 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 **B - C = 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  $\angle ABC = \beta$  from face left and face right
4. Set up theodolite at **C** and measure the horizontal angle  $\angle ACB = \gamma$  from face left and face right
5. Set up theodolite at **A** and measure the horizontal angle  $\angle BAC = \alpha$  from face left and face right
6. Sum up these angles ( $\delta = \beta + \gamma + \alpha$ ), which should be theoretically equal to  $180^\circ$  or  $200^\circ$ . If the sum is not equal to  $180^\circ$  or  $200^\circ$ , the difference  $\Delta$  should be equally distributed to all the three angles so that the sum becomes  $180^\circ$  or  $200^\circ$
7. Calculate distance **A - B = D** with the trigonometric formula,  $D = \frac{d \times \sin \gamma}{\sin \beta}$

#### II<sup>nd</sup> Triangulation

1. Repeat the same procedure as above and calculate distance **A - B = D'**
2. Calculate final distance  $D = \frac{D + D'}{2}$

Use the standard form "Triangulation" for recording the readings and calculation given in the example on page 34.

**Example:**

# TRIANGULATION

Bridge Name: Kolimara District: Achham Surveyed by: L.N. Tripathi Date: March 1997

## 1<sup>st</sup> Triangulation

Sketch:

$$d_1 = \frac{10.836}{\dots}$$

$$d_2 = \frac{10.840}{\dots}$$

$$d_3 = \frac{10.838}{\dots}$$

$$d_{\text{mean}} = \frac{10.838}{\dots} \quad D = d_{\text{mean}} \times \frac{\sin \gamma}{\sin \beta} = \frac{127.034 \text{ m}}{\dots}$$

| INSTRUMENT STATION                                     | HORIZONTAL CIRCLE |             | ANGLE       |                        | MEAN                     |
|--|-------------------|-------------|-------------|------------------------|--------------------------|
|  | FACE RIGHT        | FACE LEFT   | FACE RIGHT  | FACE LEFT              |                          |
| A  | 0 0 0 0 0 0       | 1 9 9 9 9 4 | 1 6 1 5 5 8 | 1 6 1 5 5 8            | 1 6 1 5 5 8 = $\alpha_0$ |
|  | 1 6 1 5 5 9       | 3 6 1 5 5 2 |             |                        |                          |
|  | 0 0 0 0 0 0       | 1 9 9 9 9 8 | 2 8 8 3     | 2 8 8 3                |                          |
| 3 9 7 1 7  | 1 9 7 1 5         |             |             |                        |                          |
| 0 0 0 0 0 0  | 1 9 9 9 9 2       | 3 5 5 7 0   | 3 5 5 7 0   | 3 5 5 7 0 = $\gamma_0$ |                          |
| 3 5 5 7 0  | 2 3 5 5 6 2       |             |             |                        |                          |
| $\delta = \alpha_0 + \beta_0 + \gamma_0 = 2 0 0 0 1 1$ |                   |             |             |                        |                          |

$$\Delta = (200^\circ \text{ or } 180^\circ) - \delta = \underline{200.011}$$

$$\alpha = \alpha_0 \pm \Delta/3 = \underline{161.553}$$

$$\beta = \beta_0 \pm \Delta/3 = \underline{2.880}$$

$$\gamma = \gamma_0 \pm \Delta/3 = \underline{35.567}$$

If  $\delta > \pm 0.02^\circ$  or  $0.018''$  repeat the angle readings

## 2<sup>nd</sup> Triangulation

Sketch:

$$d_1 = \frac{12.163}{\dots}$$

$$d_2 = \frac{12.161}{\dots}$$

$$d_3 = \frac{12.165}{\dots}$$

$$d_{\text{mean}} = \frac{12.163 \text{ m}}{\dots} \quad D = d_{\text{mean}} \times \frac{\sin \gamma}{\sin \beta} = \frac{127.113 \text{ m}}{\dots}$$

| INSTRUMENT STATION                                     | HORIZONTAL CIRCLE |             | ANGLE       |                        | MEAN                 |
|--|-------------------|-------------|-------------|------------------------|----------------------|
|  | FACE RIGHT        | FACE LEFT   | FACE RIGHT  | FACE LEFT              |                      |
| A  | 0 0 0 0 0 0       | 1 9 9 9 9 4 | 5 9 1 8     |                        | 5 9 1 8 = $\alpha_0$ |
|  | 3 9 4 0 8 2       | 1 9 4 0 7 8 |             |                        |                      |
|  | 0 0 0 0 0 0       | 1 9 9 9 9 8 | 1 0 9 7 3 0 | 1 0 9 7 3 0            |                      |
| 1 0 9 7 3 0  | 3 0 9 7 2 8       |             |             |                        |                      |
| 8 4 3 5 3 2  | 8 4 3 5 1         | 8 4 3 5 3   | 8 4 3 5 1   | 8 4 3 5 2 = $\gamma_0$ |                      |
| 0 0 0 0 0 0  | 2 0 0 0 0 0       |             |             |                        |                      |
| $\delta = \alpha_0 + \beta_0 + \gamma_0 = 1 9 9 9 9 9$ |                   |             |             |                        |                      |

$$\Delta = (200^\circ \text{ or } 180^\circ) - \delta = \underline{200.001}$$

$$\alpha = \alpha_0 \pm \Delta/3 = \underline{5.917}$$

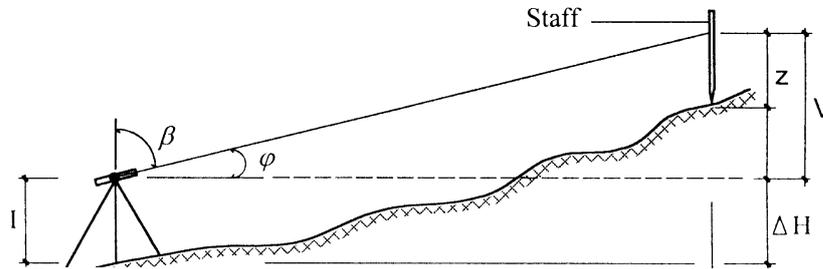
$$\beta = \beta_0 \pm \Delta/3 = \underline{109.731}$$

$$\gamma = \gamma_0 \pm \Delta/3 = \underline{84.352}$$

If  $\delta > \pm 0.02^\circ$  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 as shown in the sketch below and as per example given on page 36.



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 100.00 m
2. Select bench mark **BMII** 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 **BMII** accurately with a tape
5. Take the distance **D** between axis points **A** and **B** from the triangulation (refer to previous chapter)
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 hair 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 followings for all readings:

$$\text{Vertical Distance} \quad V = D \times \tan \varphi \quad \text{or} \quad V = \frac{D}{\tan \beta}$$

$$\begin{aligned} \text{Elevation difference} \quad \Delta H &= V - Z + I \text{ for upward vertical angle reading} \\ \Delta H &= V + Z - I \text{ for downward vertical angle reading} \end{aligned}$$

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

$$\begin{aligned} \text{Elevation of} \quad \mathbf{A} &= \text{El. of BM I} \pm \Delta H \\ \text{Elevation of} \quad \mathbf{B} &= \text{El. of A} \pm \Delta H \\ \text{Elevation of} \quad \mathbf{BMII} &= \text{El. of B} \pm \Delta H \end{aligned}$$

Insert the readings and the calculations in the Survey form of “**Summary of Triangulation and Elevations of Pegs and Benchmarks**” as per example given on page 36.

Example:

# SUMMARY OF TRIANGULATION and ELEVATIONS of PEGS and BENCHMARKS

Bridge Name : *Kolimora* District : *Achham* Surveyed by : *L. N. Tripathi* Date : *March 1997*

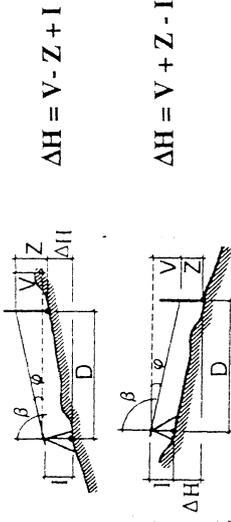
## 1. Summary of Triangulation

1<sup>st</sup> Triangulation  $D_1 = 127.034 \text{ m}$   
 2<sup>nd</sup> Triangulation  $D_2 = 127.113 \text{ m}$   
 Difference  $\Delta D = 0.079 \text{ m}$   
 Mean Distance  $D = \frac{D_1 + D_2}{2} = 127.07 \text{ m}$   
 $\Delta D/D = 0.0006$

If  $\Delta D/D > 0.0025$  repeat the triangulation

REDUCED LEVELS: BMI = 100.00  
 BMI A = 102.91  
 B = 100.770  
 = 102.150

## 2. Elevation



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

| INSTRUMENT STATION | STAFF STATION | INSTRUMENT HEIGHT |     | MIDDLE HAIR |     | HORIZONTAL DISTANCE |     | VERTICAL ANGLE          |       | VERTICAL DISTANCE |      | DIFFERENCE IN ELEVATION |  |
|--------------------|---------------|-------------------|-----|-------------|-----|---------------------|-----|-------------------------|-------|-------------------|------|-------------------------|--|
|                    |               | m                 | cm  | m           | cm  | m                   | cm  | MEAN (Left + Right) / 2 | m     | cm                | m    | cm                      |  |
| A                  | B             | 1                 | 250 | 2           | 020 | 1                   | 270 | 99839                   | 0166  | 1033              | 1138 |                         |  |
| B                  | A             | 1                 | 170 | 1           | 010 | 1                   | 270 | 101231                  | 1230  | 246               | -139 |                         |  |
| A                  | BMI           | 1                 | 250 | 0           | 30  | 4                   | 87  | 121635                  | 21631 | 172               | -077 |                         |  |
| BMI                | A             | 1                 | 200 | 0           | 40  | 4                   | 87  | 100317                  | 0317  | 002               | +078 |                         |  |
| B                  | BMI           | 1                 | 170 | 5           | 0   | 9                   | 02  | 99310                   | 0694  | 010               | +077 |                         |  |
| BMI                | B             | 1                 | 180 | 2           | 0   | 9                   | 02  | 112130                  | 12126 | 174               | -076 |                         |  |

**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 tacheometric method. Tacheometric 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 tacheometry. For this, measure a distance of about 40 m 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 following Formula.

$$D = (100 l \pm \Delta) \times \cos^2 \phi$$

$$V = (50 l \pm \Delta) \times \sin 2\phi$$

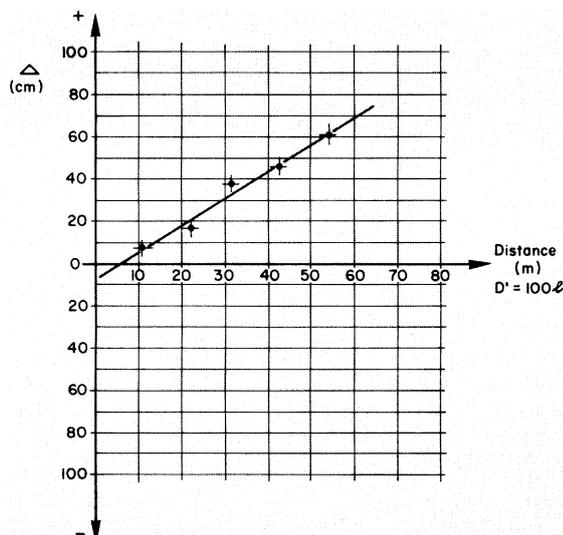
Δ is calculated before the survey as per following procedure:

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 tacheometric calculation
7. Determine the difference (error) between the tape measurement and the tacheometric measurement for each peg
8. Plot the graph for **Δ correction**

**Example: Δ - Corrections**

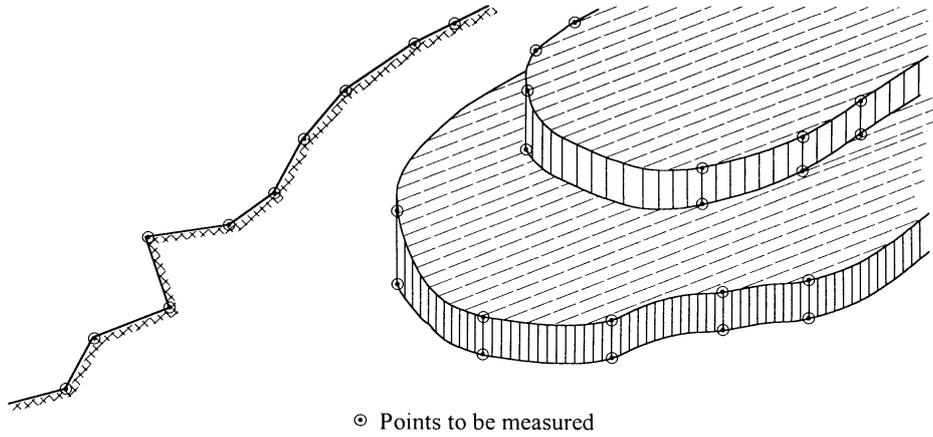
| Top hair<br>l <sub>1</sub><br>(cm) | Bottom hair<br>l <sub>2</sub><br>(cm) | Difference<br>l = l <sub>1</sub> - l <sub>2</sub><br>(cm) | Distance<br>D' = l x 100<br>(m) | Tape Measurement<br>Distance, D<br>(m) | Correction<br>Δ = D - D'<br>(cm) |
|------------------------------------|---------------------------------------|---|---------------------------------|--|----------------------------------|
| 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



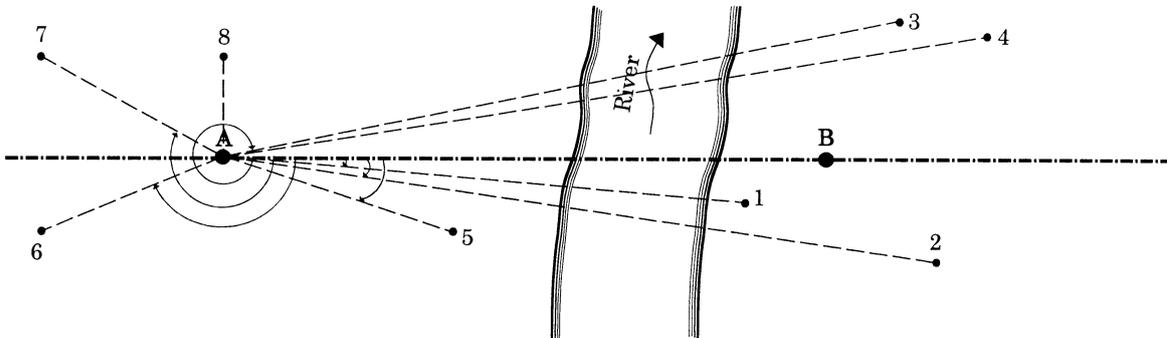
**Tachometric Survey:**

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 as shown in the sketch below. 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.

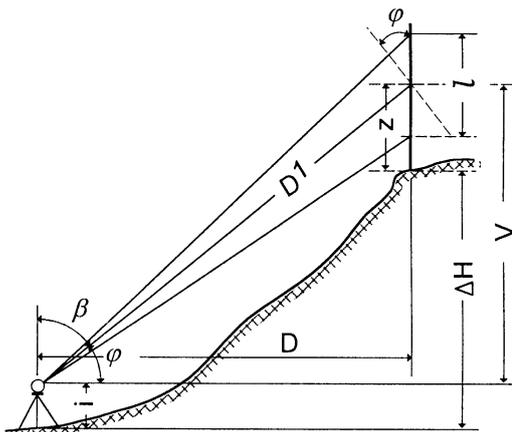


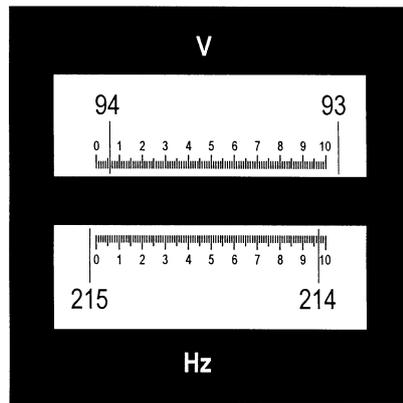
The procedure of survey is:

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 following sketch

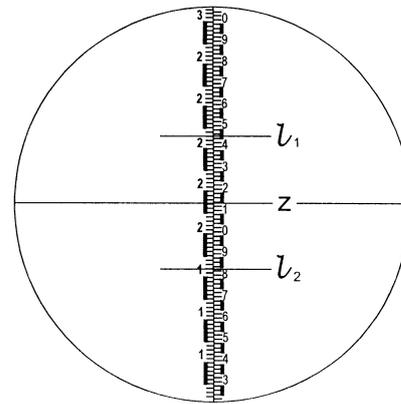


3. Take for every survey point (staff point) the readings of the horizontal circle, the vertical circle, the top hair, the middle hair and the bottom hair, after proper sighting to the respective survey points, as illustrated in the sketch of step 2 above and the sketch below.





Vertical Angle,  $\beta = 94^{\circ} 06'$   
 Horizontal Angle  $\alpha = 214^{\circ} 97'$



Top Hair,  $U_1 = 2.455$   
 Bottom Hair,  $U_2 = 1.844$   
 Middle Hair,  $Z = 2.15$

4. Record the readings into the “Tacheometry” survey sheet as shown in the example on page 40.
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**, following the procedure from step 3-4.
8. Calculate the horizontal and vertical distances and elevations of the survey points with the help of the tacheometric formulas given in the “Tacheometry” survey sheet as shown in the example on page 40.

### 2.5.6 TOPOGRAPHIC MAPS

As per the field survey data, it is necessary to prepare the following 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 following steps (refer the example of the plotted bridge axis profile given on page 41).

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 farthest 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 “Tacheometry” 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 windguy arrangement is to be considered in the bridge design. In most of the cases of short span trail bridges, windguy arrangement will not be necessary, and a contour plan is not required for bridge design.

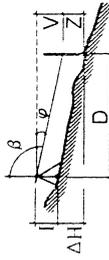
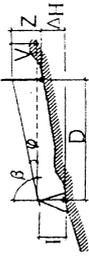
The method of plotting a detailed contour plan is not discussed here. For further information, refer to topographic survey books or the SBD Survey Manual. A sample of a contour plan is presented on page 42.

**TACHEOMETRY**

Bridge Name : *Kolimora* District : *Achham* Surveyed by : *L. N. Tripathi* Date : *March 1997*

$$\Delta H = V - Z + I$$

$$\Delta H = V + Z - I$$



$$V = 50 \times \ell \times \sin^2 \phi = 50 \times \ell \times \sin 2\beta$$

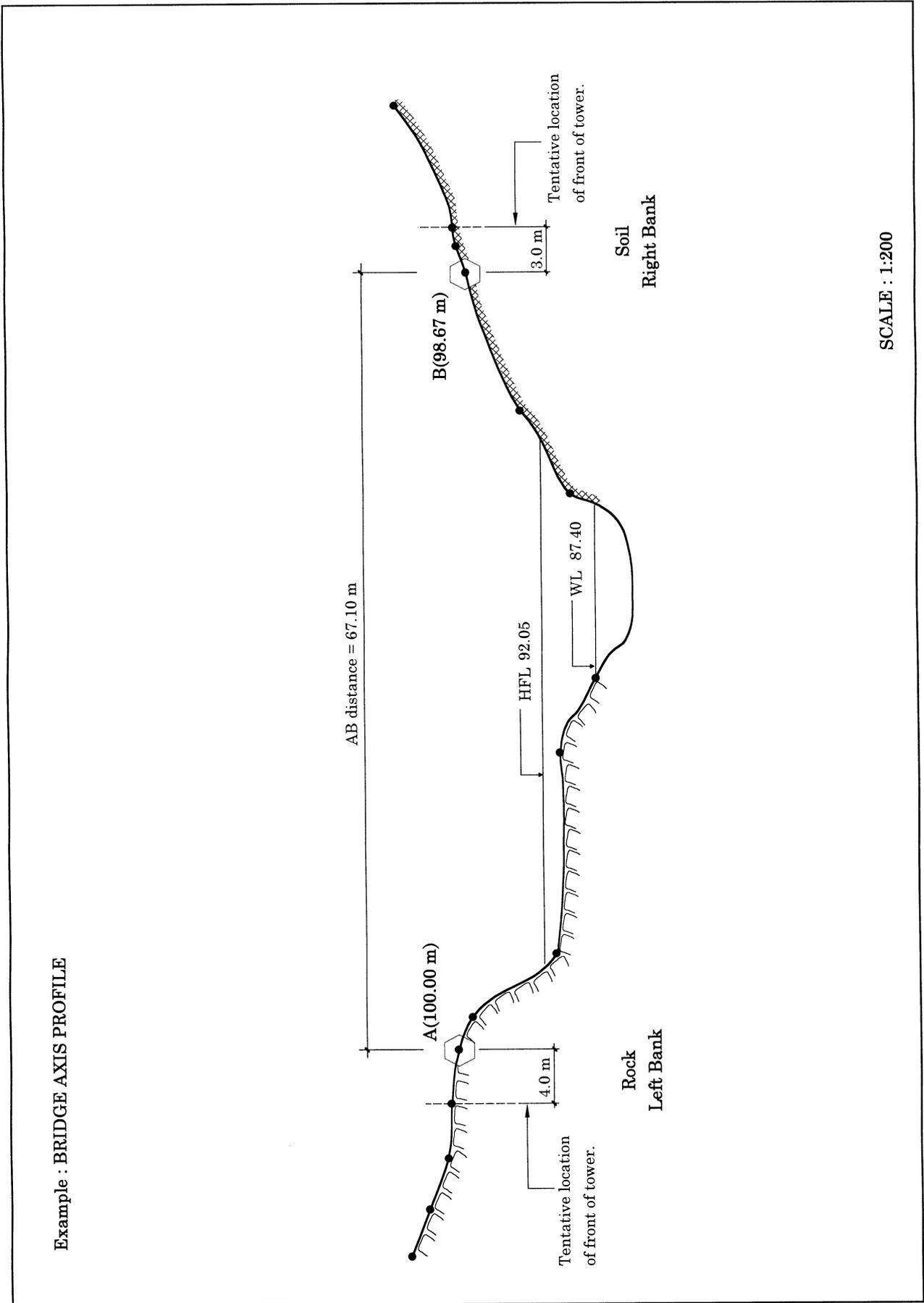
$$\text{or } V = D \times \tan \phi = \frac{D}{\tan \beta}$$

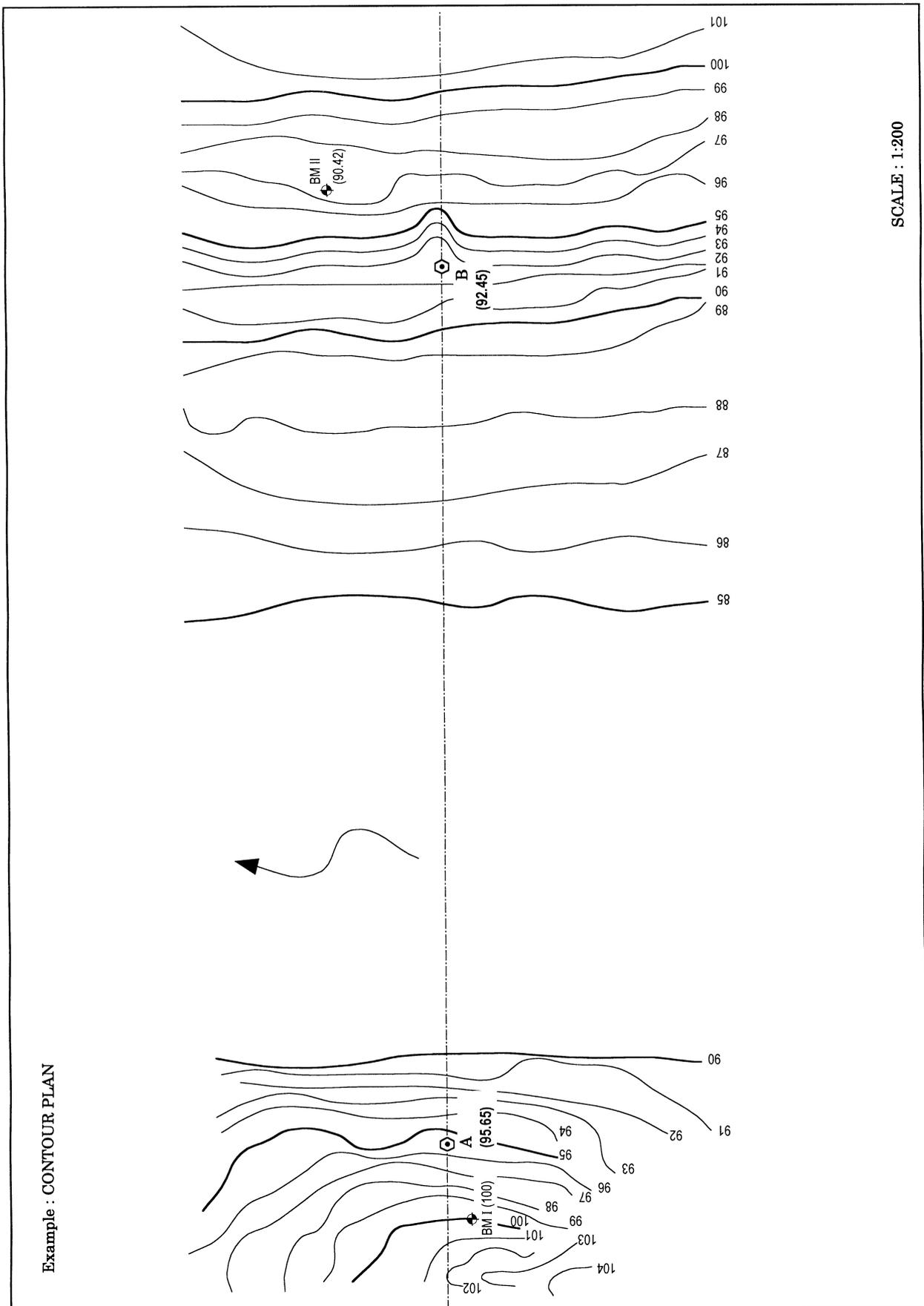
$$H = \text{R.L. of Station} \pm \Delta H$$

$$\ell = \ell_1 - \ell_2$$

$$D = 100 \times \ell \times \cos^2 \phi = 100 \times \ell \times \sin^2 \beta$$

| STATION HEIGHT OF INSTRUMENT, I m | STAFF STATION | HORIZONTAL CIRCLE |     | VERTICAL CIRCLE |     | TOP HAIR $\ell_1$ m | MIDDLE HAIR z m | BOTTOM HAIR $\ell_2$ m | STAFF INTERCEPT $\ell$ m | HORIZONT. DISTANCE D m | VERTICAL DISTANCE +/- V m | DIFF. IN ELEVATION +/- $\Delta H$ m | REDUCED LEVEL H m | REMARKS (Description of Staff Station) |
|-----------------------------------|---------------|-------------------|-----|-----------------|-----|---------------------|-----------------|------------------------|--------------------------|------------------------|---------------------------|-------------------------------------|-------------------|--|
|                                   |               | $\alpha$ g/°      | c/° | $\beta$ g/°     | c/° |                     |                 |                        |                          |                        |                           |                                     |                   |  |
| B/1-17                            | BM1           | 398               | 680 | 107             | 070 | 151                 | 208             | 56                     | 312                      | 131                    | 189                       | 0189                                | 10026             |  |
|                                   | A             | 00                | 00  | 10              | 09  | 13                  | 70              | 73                     | 27                       | 126                    | 197                       | 0138                                | 10077             |  |
|                                   | R/B           | 394               | 070 | 102             | 470 | 193                 | 012             | 65                     | 33                       | 132                    | 25                        | 0525                                | 09690             |  |
|                                   | 4             | 392               | 420 | 103             | 382 | 143                 | 02              | 65                     | 33                       | 132                    | 25                        | 0664                                | 09550             |  |
|                                   | 5             | 392               | 418 | 104             | 120 | 150                 | 00              | 85                     | 30                       | 129                    | 45                        | 0807                                | 09408             | D/S Rocky Part                         |
|                                   | 6             | 394               | 708 | 104             | 820 | 168                 | 81              | 04                     | 40                       | 128                    | 06                        | 0958                                | 09256             |  |
|                                   | 7             | 391               | 540 | 107             | 480 | 147                 | 00              | 83                     | 27                       | 125                    | 25                        | 1445                                | 09770             |  |
|                                   | 8             | 394               | 520 | 107             | 130 | 134                 | 00              | 72                     | 40                       | 122                    | 45                        | 1332                                | 08883             | W.G.?                                  |
|                                   | 9             | 397               | 260 | 106             | 920 | 127                 | 80              | 68                     | 90                       | 116                    | 41                        | 1222                                | 08993             |  |
|                                   | 10            | 395               | 193 | 108             | 962 | 130                 | 00              | 75                     | 00                       | 107                    | 83                        | 1486                                | 08729             |  |
|                                   | 11            | 398               | 277 | 110             | 236 | 116                 | 00              | 60                     | 80                       | 98                     | 99                        | 1549                                | 08666             | Rocky nose                             |
|                                   | 12            | 392               | 053 | 115             | 861 | 120                 | 00              | 61                     | 00                       | 09                     | 65                        | 1759                                | 08455             |  |
|                                   | 13            | 396               | 850 | 106             | 424 | 155                 | 00              | 92                     | 50                       | 123                    | 73                        | 1228                                | 08987             |  |
|                                   | 14            | 398               | 080 | 106             | 240 | 189                 | 81              | 29                     | 90                       | 118                    | 65                        | 1179                                | 09035             | Rocky bank edge                        |
|                                   | Axis          | 00                | 00  | 105             | 260 | 176                 | 01              | 18                     | 00                       | 15                     | 21                        | 0955                                | 09260             |  |
|                                   | Axis          | 00                | 00  | 104             | 752 | 138                 | 00              | 75                     | 10                       | 17                     | 34                        | 0839                                | 09375             |  |
|                                   | Axis          | 00                | 00  | 103             | 330 | 170                 | 00              | 50                     | 00                       | 19                     | 67                        | 0619                                | 09596             | Below cliff                            |
|                                   | 18            | 398               | 326 | 104             | 412 | 140                 | 00              | 80                     | 00                       | 19                     | 42                        | 0792                                | 09423             | Edge                                   |
|                                   | 19            | 049               | 40  | 103             | 570 | 128                 | 00              | 79                     | 00                       | 117                    | 62                        | 0622                                | 09593             | Edge of cliff                          |
|                                   | 20            | 007               | 430 | 102             | 620 | 188                 | 01              | 29                     | 00                       | 117                    | 80                        | 0497                                | 09718             | do                                     |
|                                   | 21            | 011               | 127 | 100             | 370 | 196                 | 01              | 33                     | 00                       | 125                    | 99                        | 0089                                | 09126             |  |
|                                   | 22            | 012               | 852 | 099             | 078 | 165                 | 00              | 97                     | 50                       | 134                    | 97                        | 0215                                | 09430             |  |





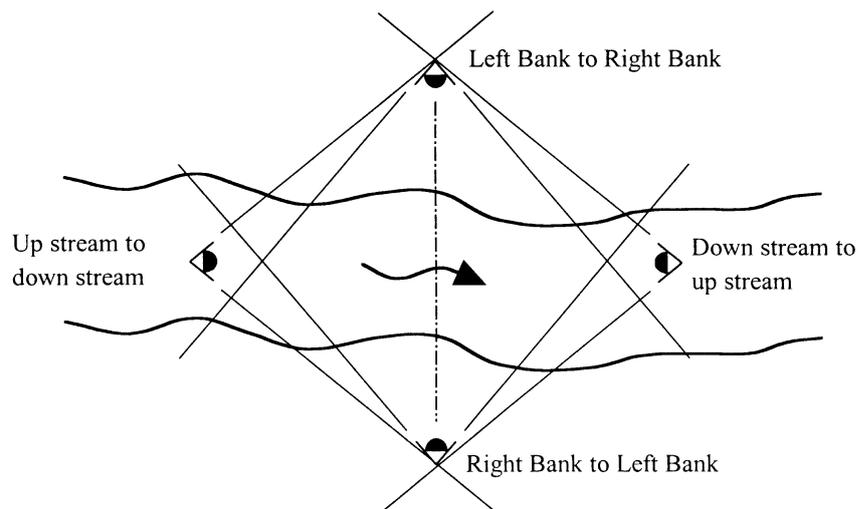
## 2.6 PHOTOGRAPHS

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

Take the following 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 as per sketch below. 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.

## 2.7 SURVEY REPORT

The technical survey report consist of:

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



### 3. BRIDGE DESIGN

#### 3.1 BRIDGE TYPES

There are basically two types of cable bridges developed in trail bridge standard, which are:

- **Suspended Bridge Type**
- **Suspension Bridge Type**

|   |
|---|
| <p><i>* follow</i>      <b>Form No. 2</b><br/><b>Bridge Design Form</b></p> |
|---|

The selection from above bridge types depends mainly on the topography of the bridge site.

#### **Suspended Bridge**

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.

A suspended type bridge

The present handbook deals only with suspended type bridge.

### **Suspension Bridge**

This type of bridge has upward cambered walkway. Main cables are hanged over the towers and anchored to the main anchorage foundation. Walkway cables are anchored to the pylon foundations. The main components of this bridge are: Main cables and Walkway cables, Towers, Walkway system, Main anchorage foundations and Pylon foundations.

This type of bridge is selected when the bridge site is comparatively flat terrain and suspended type bridge is not feasible due to the constraint of free board.

Suspension type Bridge is more expensive and needs more inputs to design and construct than suspended type.

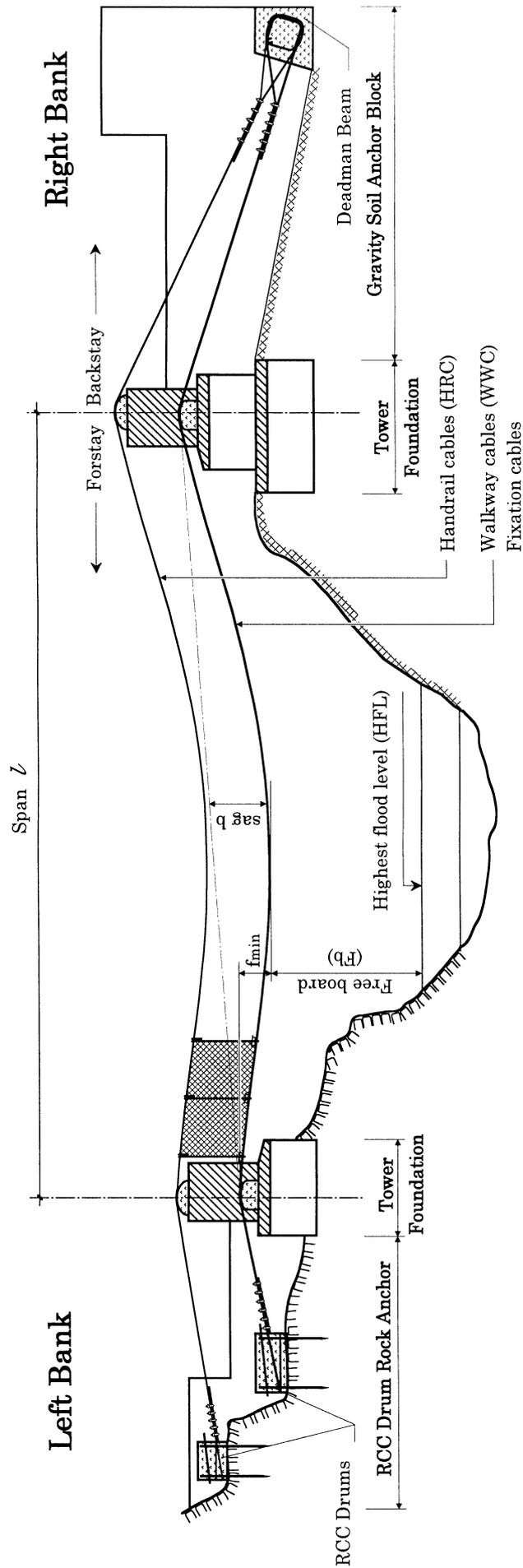
A suspension type bridge

The present handbook will not deal with suspension type bridge.

- **Layout and Sections**

The typical Plan and Profile of a suspended type bridge is given in the next pages.

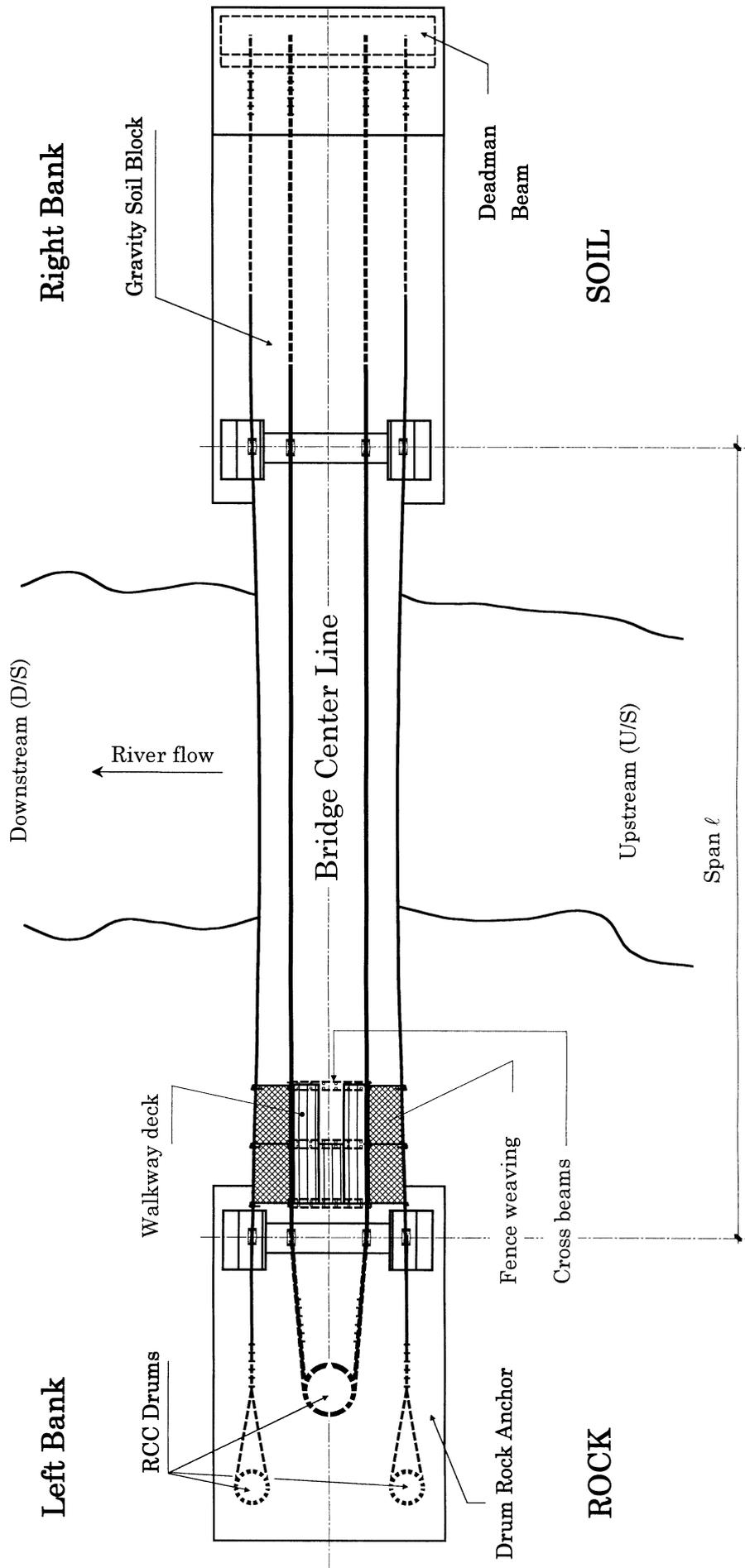
**PEDESTRAIN SUSPENDED BRIDGE**  
**Typical Profile**



**SOIL**

**ROCK**

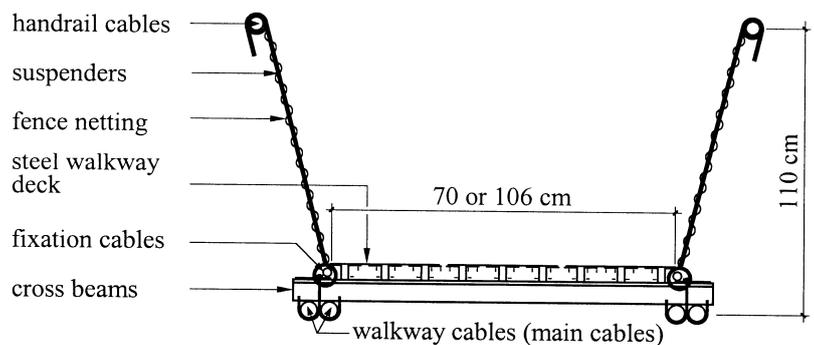
**PEDESTRAIN SUSPENDED BRIDGE  
Typical Plan**



- **Walkway Section**

There are two types of walkway width:

**70cm & 106cm**



### 3.2 BASIC DESIGN CONCEPT

#### 3.2.1 LOADINGS

For designing a bridge structure loadings as per LSTB standard (former SBD standard) is followed. Following are the probable loadings according to this standard.

- **Live load**

Live load for smaller span up to 50m is equivalent to 400 kg/m<sup>2</sup> and for longer span as per formula,

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

- **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 Handrail- and Walkway Cables) | 25 kg/m or<br>0.25 kN/m | 42 kg/m or<br>0.41 kN/m | 57 kg/m or<br>0.56 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/m<sup>2</sup> acting on the lateral bridge area of 0.3 m<sup>2</sup> 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 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 favorable 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.

(See also "Expertise on Windguy Arrangement for BBL Standard Bridges by Dr.Heinrich Schnetzer, WGG Schnetzer Puskas Ingenieure AG SIA/USIC Basel, Switzerland, and para 3.3.6 A Windguy Arrangement.)

- **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.

**3.2.2 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). Refer to Volume A of SBD Manual for detail material specifications. However, for frequently referred material, specifications are given below 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 steel parts, logistics and eventually bridge costs.

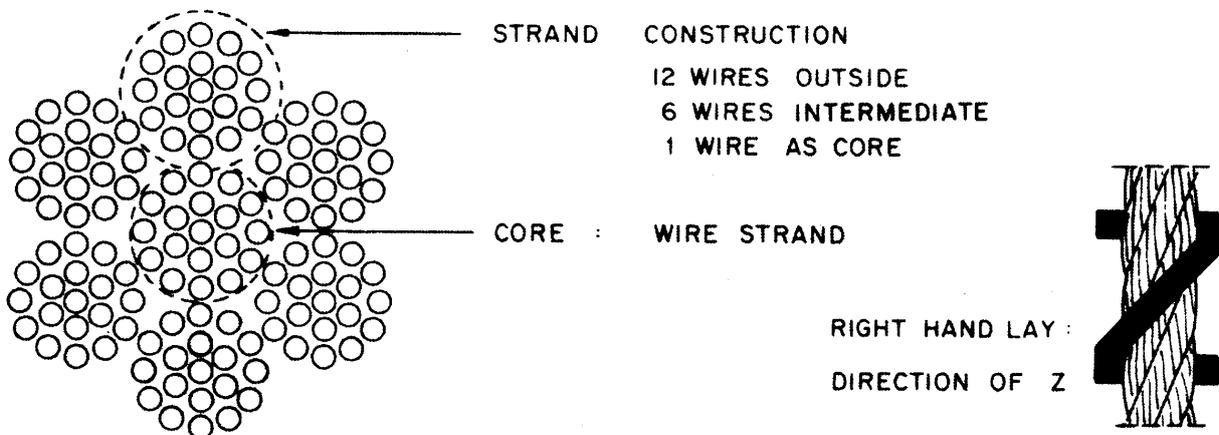
Steel wire ropes should comply with all the requirement of:

- 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

|                           |   |                      |
|---------------------------|---|----------------------|
| <b>Nominal diameters:</b> | <b>13 mm</b>                                      | <b>26, 32 mm</b>     |
| Rope Construction         | 7 x 7 (6/1)                                       | 7 x 19 (12/6/1)      |
| Elongation                | non pre-stretched                                 | <b>pre-stretched</b> |
| Lay                       | RHO, right hand ordinary lay                      |                      |
| Core                      | WRC, Wire Strand Core                             |                      |
| Tensile strength of wire  | 160 kg/mm <sup>2</sup> or 1.57 kN/mm <sup>2</sup> |                      |
| Preforming                | Preformed   |                      |
| Coating                   | Galvanized 'A' heavy                              |                      |
| Impregnation              | Non-drying type and non-bituminous Lubricant      |                      |

| Nominal Diameter of Cable<br>mm | Weight |      | Metallic Area<br>[mm <sup>2</sup> ] | Minimum Breaking Load in |     | Permissible load in |     |
|---------------------------------|--------|------|-------------------------------------|--------------------------|-----|---------------------|-----|
|                                 | kg/m   | N/m  |                                     | 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 kN/mm<sup>2</sup> = 11 t/ mm<sup>2</sup>

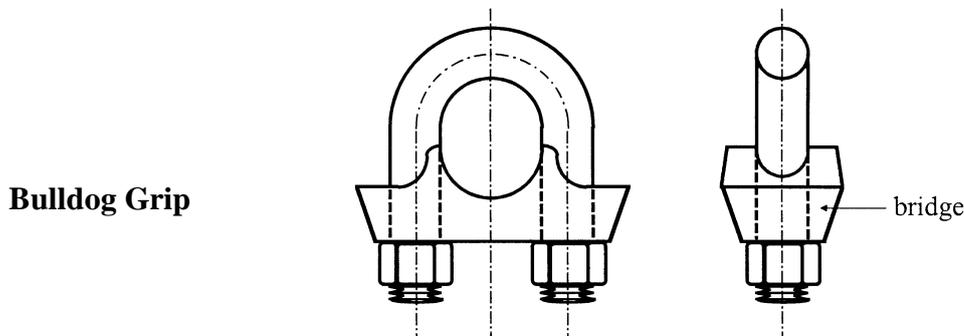


Cross-section and Lay of Wire Rope

- **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 40µm. The size of the bulldog grip is equal to the size of the cable to be anchored or connected.



The methods for applying Bulldog Grips to Wire Ropes at different terminals are given in Chapter 6.6.3 Bridge Construction.

- **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 following mechanical properties :

|                       |   |                        |
|-----------------------|---|------------------------|
| Tensile Strength      | ≥ | 410 N/mm <sup>2</sup>  |
| Yield Stress          | ≥ | 250 N/mm <sup>2</sup>  |
| Modulus of Elasticity | = | 200 kN/mm <sup>2</sup> |
| 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 following mechanical properties :

|                       |   |                        |
|-----------------------|---|------------------------|
| Yield Stress          | = | 415 N/mm <sup>2</sup>  |
| Modulus of Elasticity | = | 210 kN/mm <sup>2</sup> |

- **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

| Products                      | Minimum Mass of Coating |                  | Minimum Thickness of Coating |
|-------------------------------|-------------------------|------------------|------------------------------|
|                               | g/m <sup>2</sup>        | N/m <sup>2</sup> | 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/m<sup>2</sup>. The average tensile strength of the wire should not be less than 380N/mm<sup>2</sup>.

- **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 following table.

| Materials     | Unit Weight,      |                   |
|---------------|-------------------|-------------------|
|               | kg/m <sup>3</sup> | kN/m <sup>3</sup> |
| Concrete      | 2200              | 22.0              |
| Stone Masonry | 2100              | 21.0              |
| Steel         | 7850              | 78.5              |
| Soil          | 1800              | 18.0              |
| Water         | 1000              | 10.0              |

### 3.2.3 STRUCTURAL ANALYSIS AND DESIGN

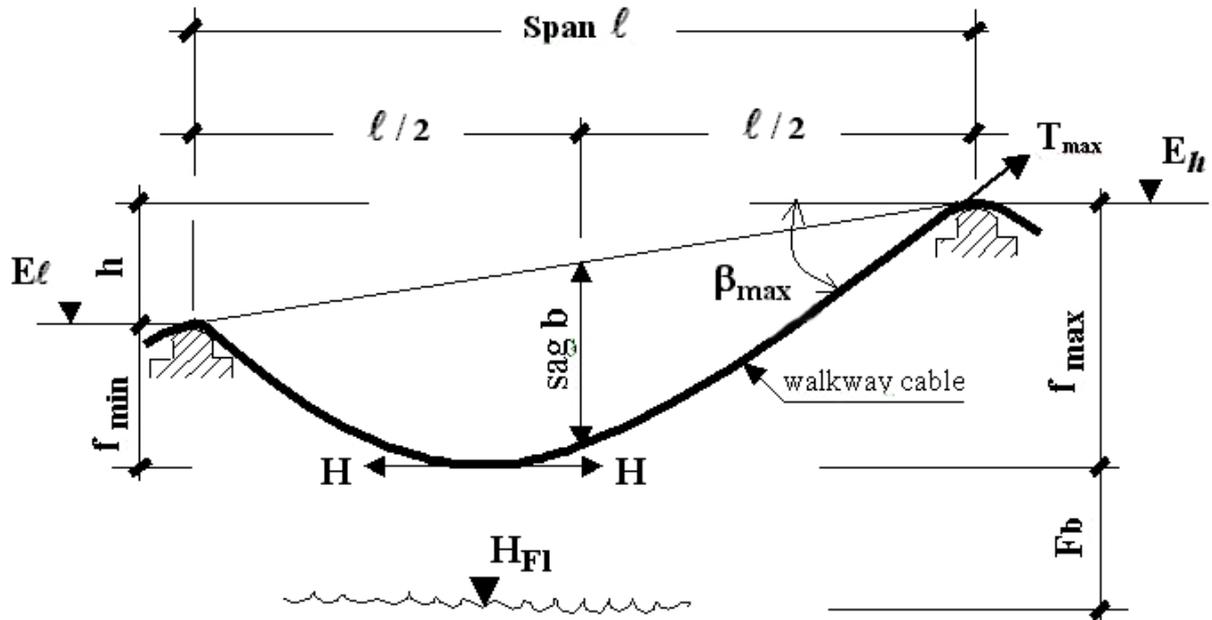
Statical analysis is based on calculation of forces and stresses in the structures due to the external loadings. Calculated forces and stresses are compared with the permissible loads and stresses of these structures with some safety of factors.

The standard suspended bridge has been designed as per the following 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.

The following sketch represents the cable geometry and forces on it.



⇒ Maximum permissible Height Difference of Walkway Cable Saddles,

$$h = \frac{\text{Span } (\ell)}{25}$$

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

$$b = \frac{\text{Span } (\ell)}{20}$$

or for Spans **over 80m**:

$$b = \frac{\text{Span } (\ell)}{22}$$

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

⇒ Total Horizontal Tension,

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

⇒ Total maximum Tension at the higher Foundation Saddle,

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

⇒ Cable Inclination at higher Foundation Saddle,

$$\beta_{max} = a \tan\left(\frac{4b + h}{\ell}\right)$$

Example: 
$$\beta_{max} = a \tan \frac{4 \frac{\ell}{22} + \frac{\ell}{25}}{\ell} = a \tan \frac{0.1818 \cdot \ell + 0.04\ell}{\ell} = a \tan 0.2218 = \beta_{max} = 12.51^\circ$$

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

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. (refer to **Table: Selection of Cables** in Chapter 3.3.4 B).

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 favorable topographic conditions, the cable may seem to be over designed, but, as per analysis this has no significant effect (less than 1%) on the over all cable strength.

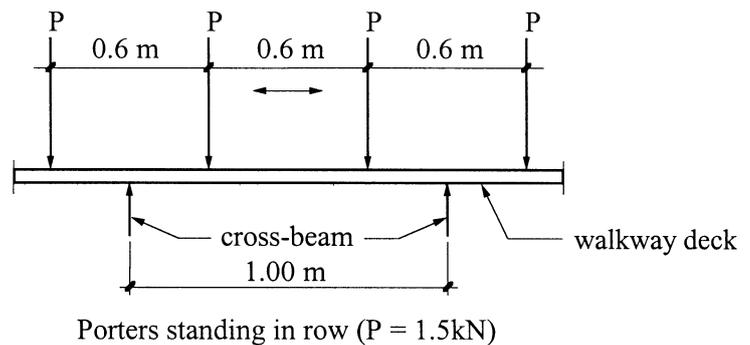
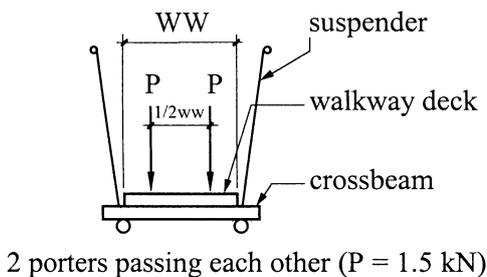
• **Steel Parts**

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 as per sketch below.



• **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 (refer chapter 2.4.5 and 2.4.6). Following mode of failure and respective safety factors are considered in the design:

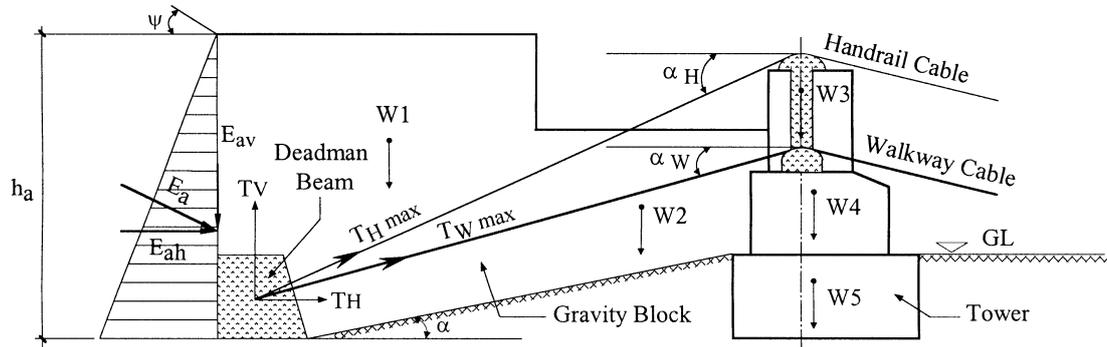
- ⇒ Sliding  $F_{SL} \geq 1.5$
- ⇒ Toppling  $F_T \geq 1.5$
- ⇒ Bearing Capacity  $F_{BC} \geq 2.0$
- ⇒ Maximum Ground Pressure  $\sigma_{max} < \text{Bearing capacity of soil or rock}$

The standard design is without windguy system (refer chapter 3.3.6 for details). Therefore, foundations are designed to take the wind load satisfying the worst case from the following two load cases.

- ⇒ Load case A = dead load + full wind load
- ⇒ 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. The design concept of the foundation is given below.



The foundations have been designed to satisfy the safety against sliding with the following theoretical basis.

**Safety factor against sliding:**

$$F_{sl} = \frac{\text{Resisting Force}}{\text{Driving Force}} = \frac{R'_V \cdot \tan \phi_{sl}}{R'_H} \geq 1.5$$

Where,

$$R'_V = R_V \cdot \cos \alpha + R_H \cdot \sin \alpha \quad R_V = W_1 + W_2 + \dots + W_n + E_{av} - T_V$$

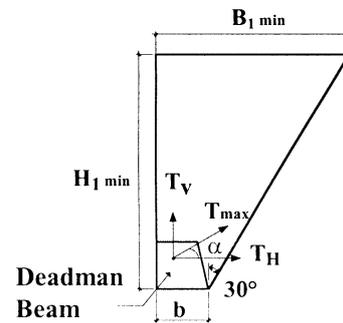
$$R'_H = R_V \cdot \sin \alpha + R_H \cdot \cos \alpha \quad R_H = T_H + E_{ah}$$

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 ( $H_{1min}$ ) as demonstrated below.

**Safety against uplifting:**

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

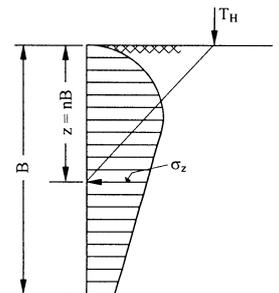
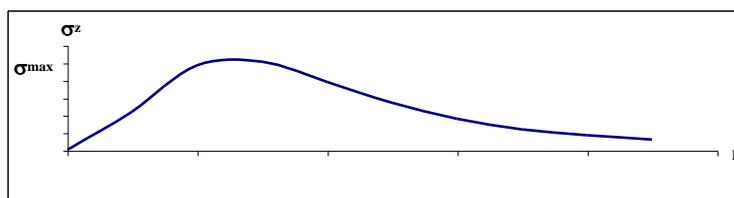
$$B_{1min} = b + H_{1min} \cdot \tan 30^\circ$$



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 following formula.

$$\sigma_z = \frac{0.28 T_H}{B^2} \left[ \frac{n^2}{(0.16 + n^2)^3} \right] \quad n = \frac{z}{B}$$



Distribution of lateral pressure  $\sigma_z$  along  $B$

• **Foundation in Hard Rock**

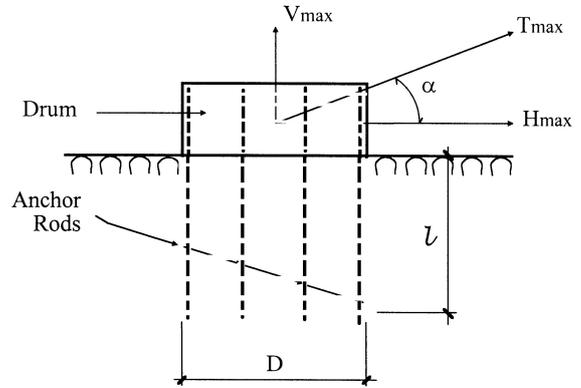
RCC Concrete Drum with rock anchoring is used for foundation on sound hard rock. The sizes of drum and anchorage rods are designed to withstand the shear due to the horizontal tension of the cables. It is also designed to resist the uplift force at Drum.

Required number of anchor rods, N is calculated as:

$$A_{st} = \frac{T_{max} \cdot \cos \alpha}{\tau_{perm}}$$

$$N = \frac{4 \cdot A_{st}}{\pi \cdot d^2} \text{ or } N = \frac{T_{max} \cdot \sin \alpha}{\sigma_{Bperm} \cdot \pi \cdot d \cdot \ell}$$

N is adopted from whichever is higher from above.



• **Foundation in Fractured Hard Rock or Soft Rock**

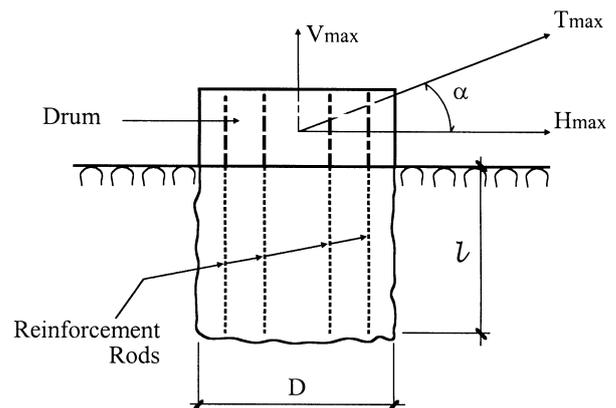
Drum anchorage without rock anchoring is used for foundation on fractured hard rock or fresh soft rock.

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

$$\left( \frac{\pi \cdot D^2}{4} \right) \cdot \tau_c + A_{st} \cdot \tau_{st} = T_{max} \cdot \cos \alpha$$

Required number of anchor rods, N is calculated as:

$$N = \frac{4 \cdot A_{st}}{\pi \cdot d^2}$$



• **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 (see chapter 3.3.3, Step 1 for case 1 & 2). The design concept is as shown in the following sketches.

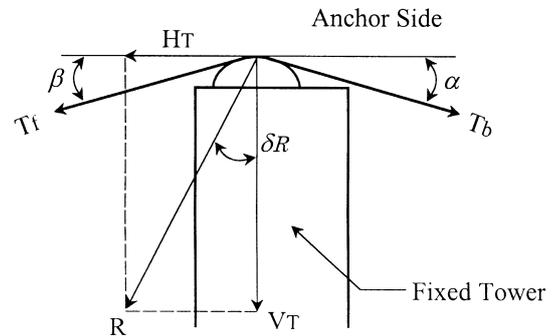
**Forces on top of the Tower:**

$$T_b = T_f - \mu V_T \Rightarrow V_T = \frac{T_f - T_b}{\mu}$$

$$H_T = T_f \cdot \cos \beta - T_b \cdot \cos \alpha \quad \mu \cong 0.1$$

$$T_b = T_f \frac{(1 - \mu \cdot \sin \beta)}{(1 + \mu \cdot \sin \alpha)}, \quad \tan \delta_R = \frac{V_T}{H_T}$$

$$R = \frac{V_T}{\cos \delta_R}$$



**Forces at Tower Base and Soil Pressure**

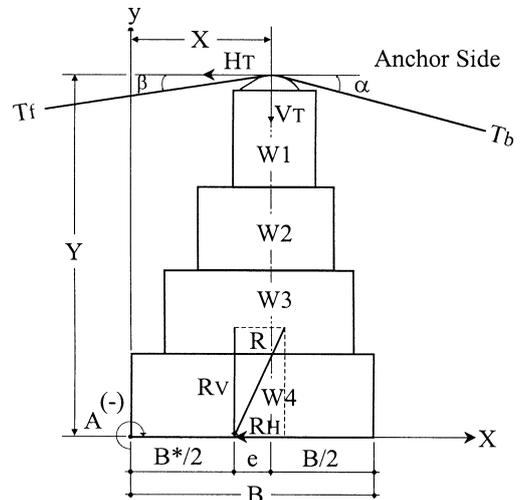
**Safety factor against overturning:**

$$F_{ovt} = \frac{\text{All Resisting Moments}}{\text{All Driving Moments}} = \frac{\Sigma M_A^+}{\Sigma M_A^-} \geq 1.5$$

$$\Sigma M_A^+ = (V_1 \cdot X_1 + V_2 \cdot X_2 + V_3 \cdot X_3 + \dots + V_T \cdot X)$$

$$\Sigma M_A^- = (H_T \cdot Y)$$

$$\Sigma M_A = \Sigma M_A^+ + \Sigma M_A^-$$



**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 following condition.

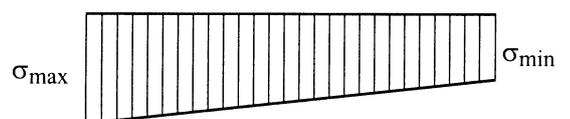
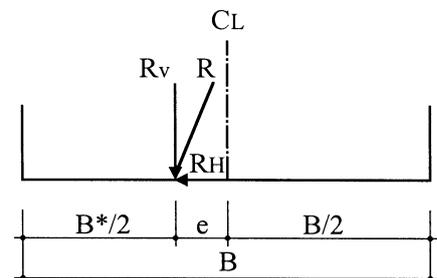
$$B^*/2 = \frac{\Sigma M_A}{\Sigma R_v} \geq B/3$$

Where,  $R_v = W_1 + W_2 + \dots + W_n + V_T$

$$\Sigma M_A = \Sigma M^+ - \Sigma M^-$$

Ground Bearing Pressure should be less than the Bearing Capacity of the soil/rock. It is calculated as:

$$\sigma_{max} = \frac{R_v}{B \cdot L} \left[ 1 + 3 \cdot \left( 1 - \frac{B^*}{B} \right) \right] \leq \sigma_{perm}$$



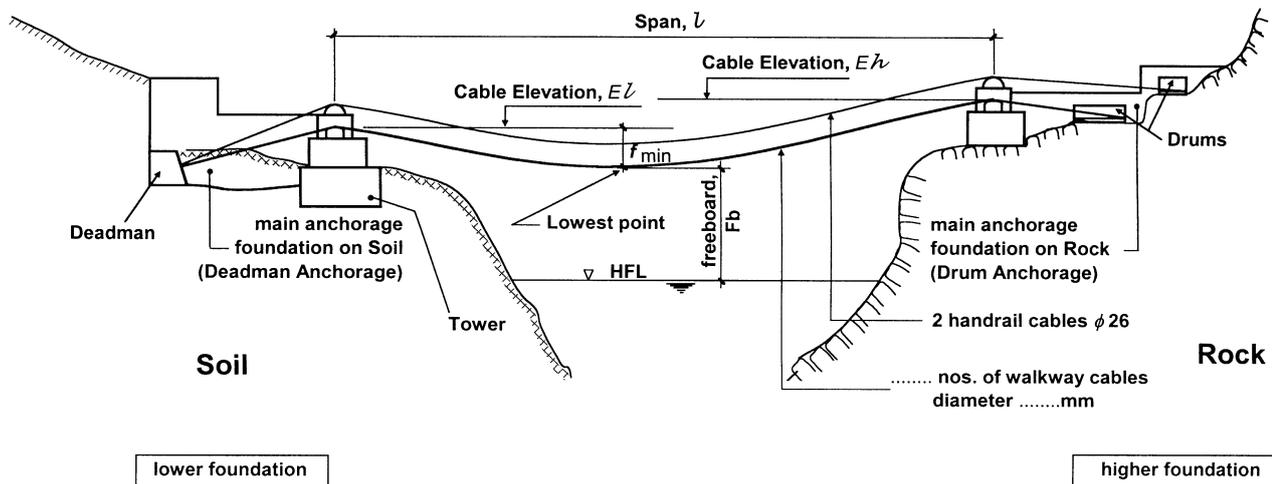
• **Reinforced Concrete Works**

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.

### 3.3 DESIGN OF STANDARD SUSPENDED BRIDGE

#### 3.3.1 THE MAJOR BRIDGE COMPONENTS

The sketch below shows the major bridge components and parameters.



#### 3.3.2 DESIGN PROCEDURE

For designing a suspended standard bridge, follow the steps in sequence as follows:

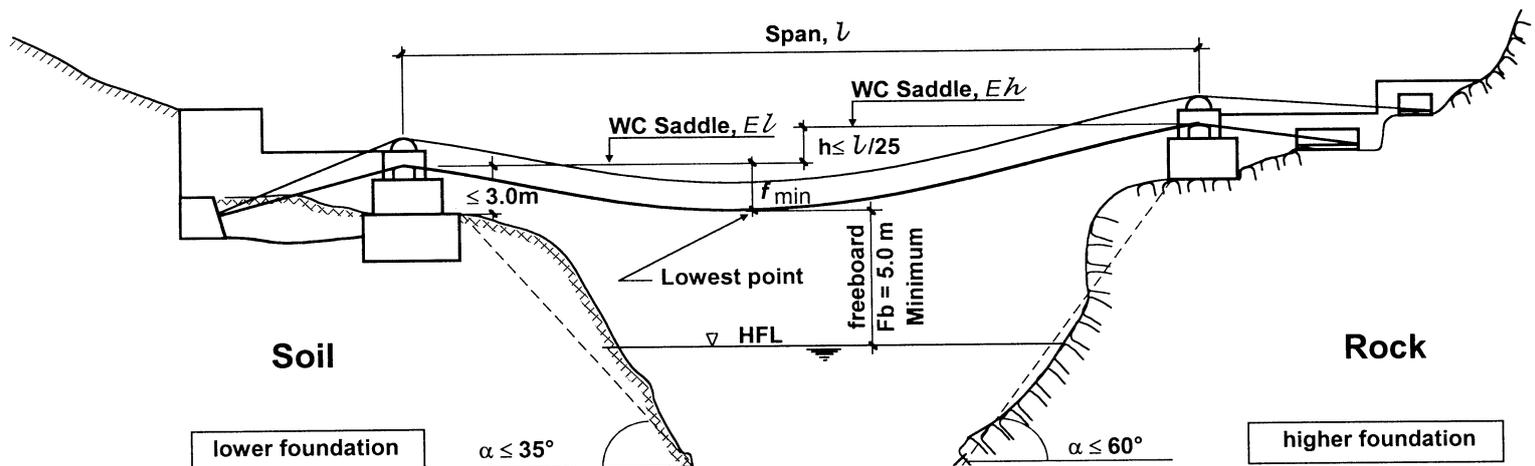
- Draw the bridge profile from the survey data
- Fix the position of the bridge foundations and the span
- Select walkway width
- Select walkway cables and handrail cables from Design Form No. 2 (Volume II)
- Design walkway tower
- Design main anchorage foundations
- Transfer data to the bridge profile and prepare the General Arrangement Drawing
- Compile and fill in the standard design drawings
- Calculate the quantities of works and prepare the Cost Estimate

### 3.3.3 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 following 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 from 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  $35^\circ$  for soil and  $60^\circ$  for rock.
- Level difference between the walkway cable saddles of two banks,  $h$  should not be more than  $\text{span}/25$
- 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 profile as per following steps.

- 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 as described in the chapter 2.5.6.
- Fix location of the walkway towers at both banks as per following procedure.

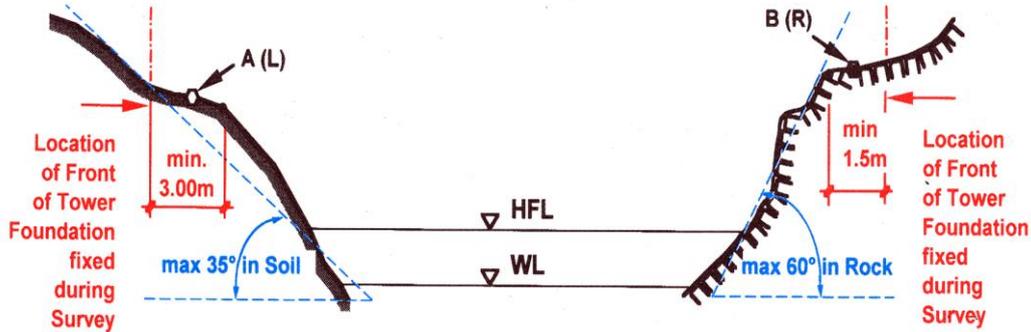
### Case-1: When Tentative Position of the Towers has been fixed during the Survey.

#### 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.

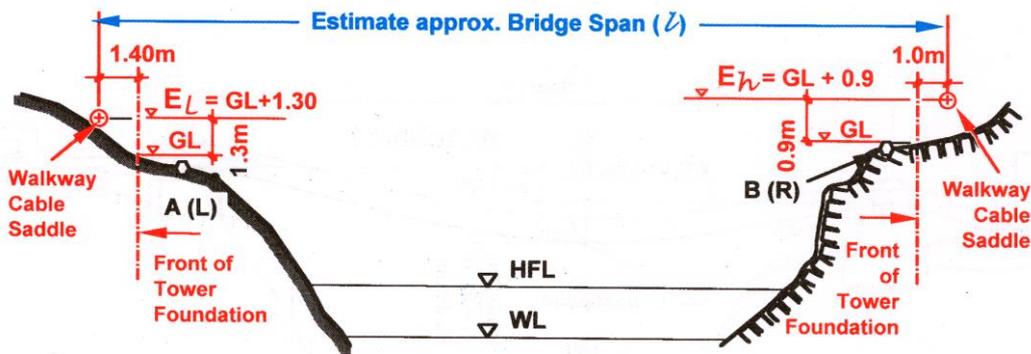
If minimum required distance from bank edge is not sufficient, shift its position backward.

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, $l$ .

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,  $E_L$ ,  $E_h$  &  $l$ .



#### Step 3: Check the Level Difference, $h$ .

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

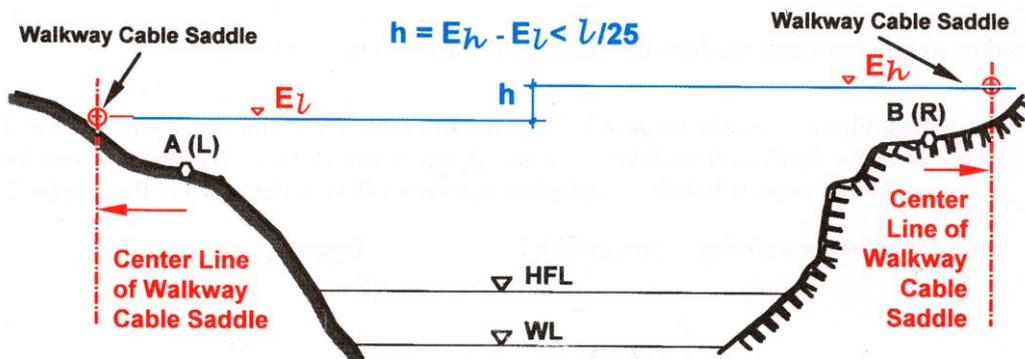
Rise the elevation of the walkway cable saddle of lower bank by increasing saddle height (in the series of 1.3, 2.3, 3.3 meter) but not more than 3.3 meter from the ground level in case of Flat slope

Or

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.



**Case-1:** (continued)**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,

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

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, $l$ 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,  $b = \frac{l}{20}$

### 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,  $E_1$  and  $E_2$ .

**Case-2: (continued)****Step 4: Check the Level Difference, h.**

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

Raise 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 ground.

*or*

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 5: 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.

Draw actual line of lowest point of the bridge 
$$f_{min} = \frac{(4 \cdot \ell - 20h)^2}{320 \cdot \ell}$$

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.

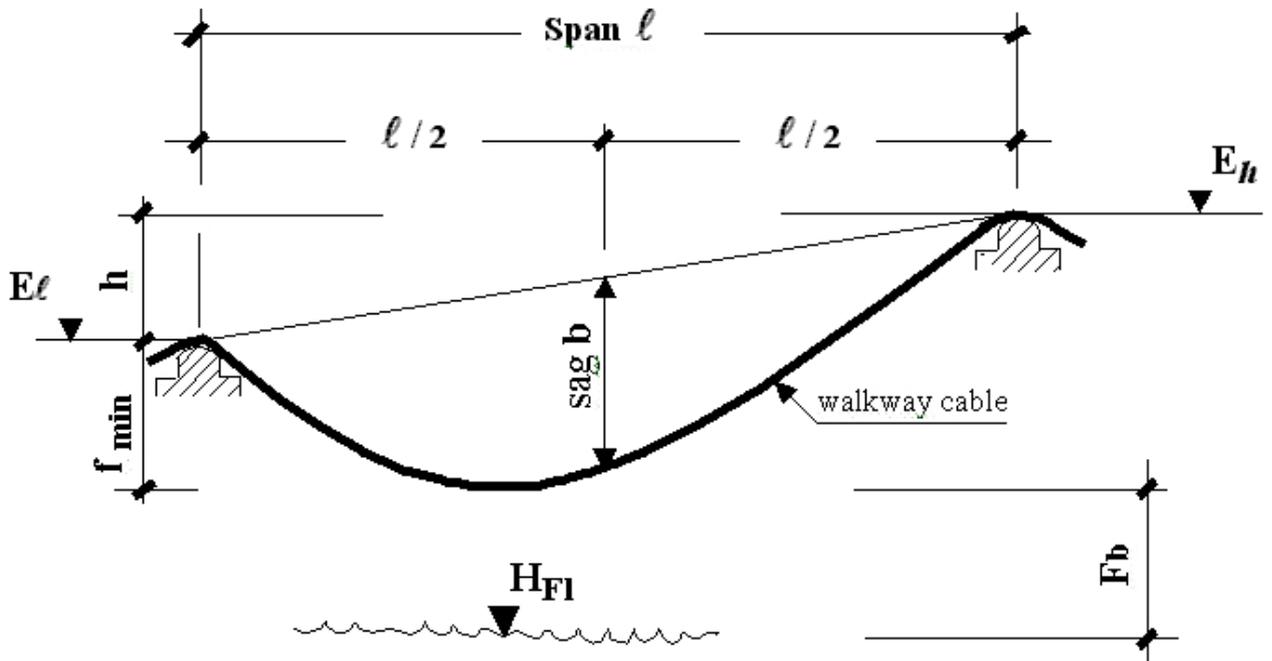
**3.3.4 CABLE DESIGN**

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 proceed as per the steps below.

- Select the appropriate walkway width (70cm or 106cm) according to the nature of the traffic and type of trail. (refer to Survey Form and Check List)
- Fix the span of the bridge and height difference of cable saddles of the right bank and left bank from the bridge profile (refer chapter 3.3.3).
- Select cables from the Table: Selection of Cable according to the span and selected walkway width.

*Design the Cable Structure as per following Checklist.*

**A. Survey Data & Calculation of Freeboard**



- |  |  |   |           |           |
|--|--|---|-----------|-----------|
| 1. Span of the Bridge  | $l$  | = | .....     | m         |
| 2. Saddle Elevation of the Walkway Cable on the <i>higher</i> Side         | $E_h$  | = | .....     | m         |
| 3. Saddle Elevation of the Walkway Cable on the <i>lower</i> Side          | $E_l$  | = | .....     | m         |
| 4. Difference in Elevation<br>(max. permissible height: $h_{max} = l/25$ ) | $h = E_h - E_l$                                      | = | $h$       | = ..... m |
| 5. <b>Dead Load Sag:</b> for Span up to 80m                                | $b_d = \frac{l}{20}$                                 | = | $b_d$     | = ..... m |
| for Span over 80m  | $b_d = \frac{l}{22}$                                 | = | $b_d$     | = ..... m |
| 6. $f_{min}$ in Dead Load Case<br>(at the lowest point of the cable)       | $f_{min} = \frac{(4 \cdot b_d - h)^2}{16 \cdot b_d}$ | = | $f_{min}$ | = ..... m |
| 7. Highest Flood Level   | $H_{Fl}$   | = | .....     | m         |
| 8. <b>Free Board</b> (min. 5.00m)  | $F_b = E_l - H_{Fl} - f_{min}$                       | = | $F_b$     | = ..... 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 at  $l / b_d = 20$  or  $l / b_d = 22$ )*

**B. Selection of Cables**

Select a cable combination according to the span and walkway width of the bridge from the following 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 $g_h$<br>[kg/m] |
|---------------------------------|----------|--------------------|------------------|----------------|------------------|--------------------------------------|
| 70cm                            | 106cm    | Handrail Cables    |                  | Walkway Cables |                  |                                      |
| span [m]                        | span [m] | nos                | $\varnothing$ mm | nos            | $\varnothing$ mm |                                      |
| 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                                |

**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 ( $f_{min}$ ) Hoisting Sag**

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

|  |  |                         |                   |
|--|--|-------------------------|-------------------|
| 1. Actual Span measured in the Field                               | $\ell$   | =                       | ..... m           |
| 2. Saddle Elevation of the Walkway Cable <i>on the higher Side</i> | $E_h$  | =                       | ..... m           |
| 3. Saddle Elevation of the Walkway Cable <i>on the lower Side</i>  | $E_\ell$   | =                       | ..... m           |
| 4. Difference in Elevation   | $h = E_h - E_\ell$                                   | = $h$                   | = ..... m         |
| 5. Dead Load Sag: <i>for Spans up to 80m</i>                       | $b_d = \frac{\ell}{20}$                              | = $b_d$                 | = ..... m         |
|  | <i>or for Spans over 80m</i>                         | $b_d = \frac{\ell}{22}$ | = $b_d$ = ..... 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         |

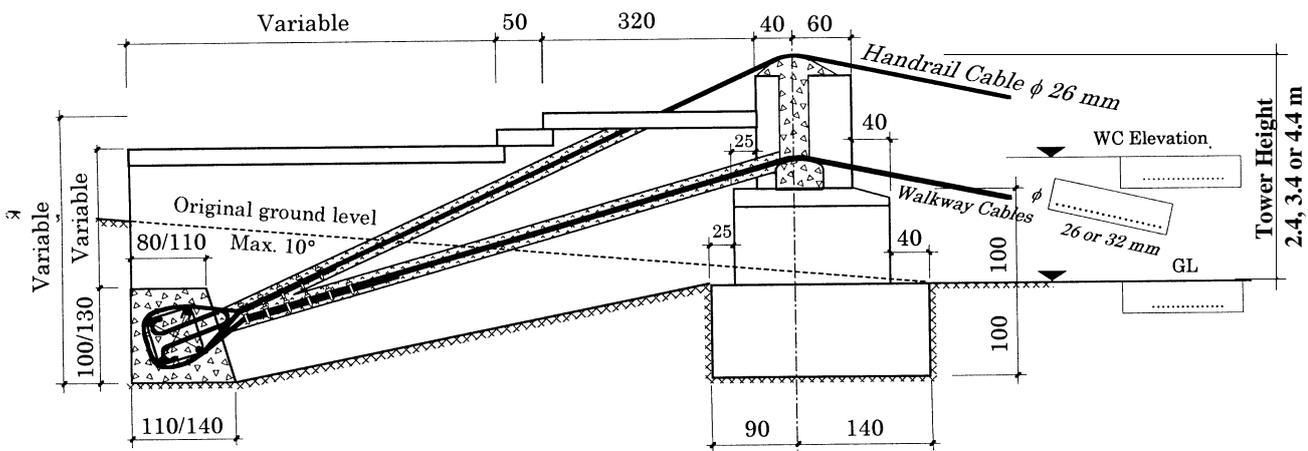
### 3.3.5 DESIGN OF BRIDGE FOUNDATION STRUCTURES

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.

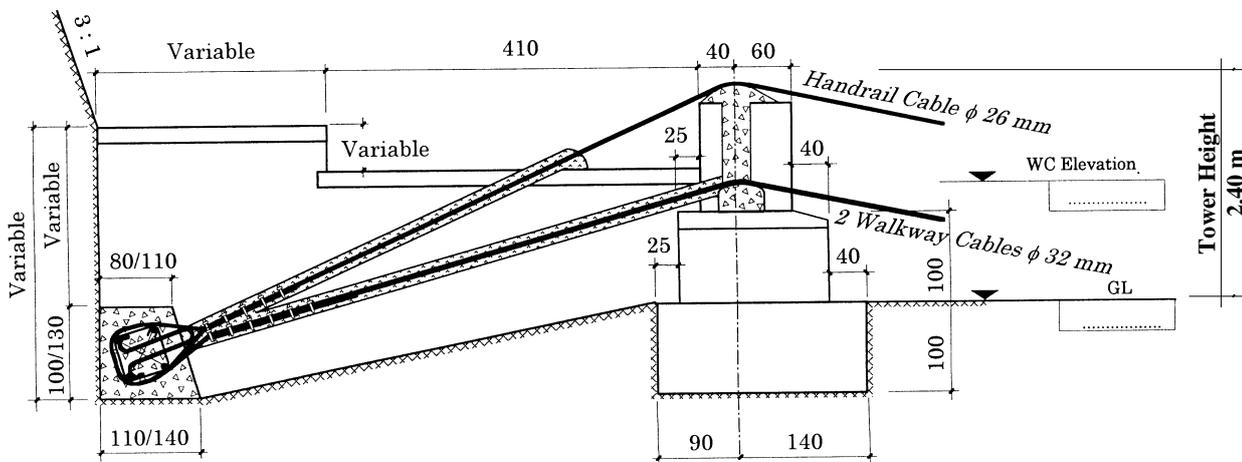
Standard anchor block (bridge foundation structure) types have been developed for all possible cases up to span 120m. The design concept and statical analysis has been followed as per chapter 3.2.3, while developing the standard anchor block types.

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

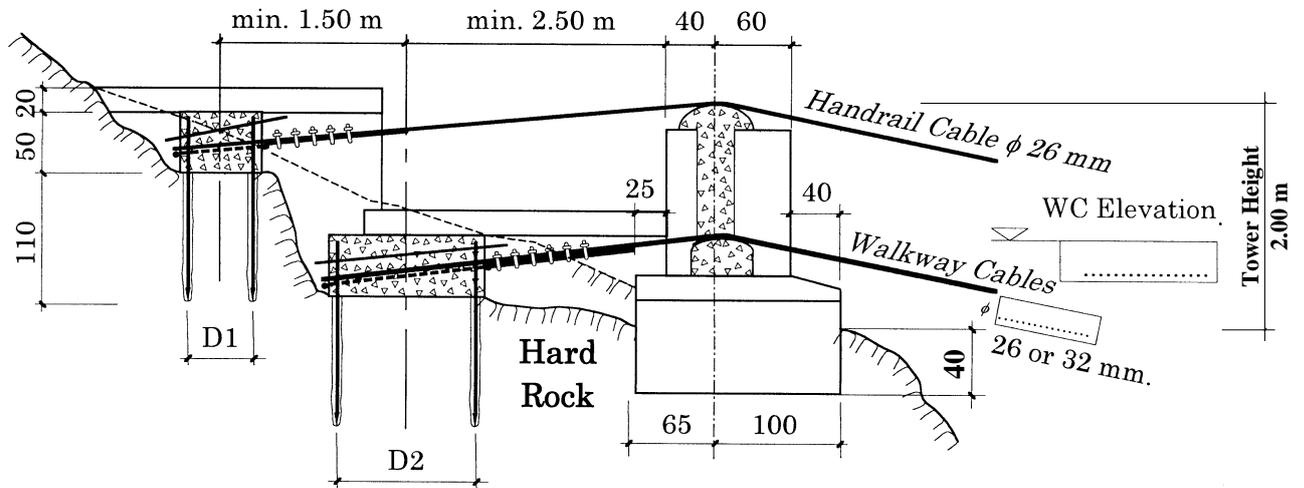
#### 1. RCC Deadman and Gravity Soil Anchor Block on Flat Topography



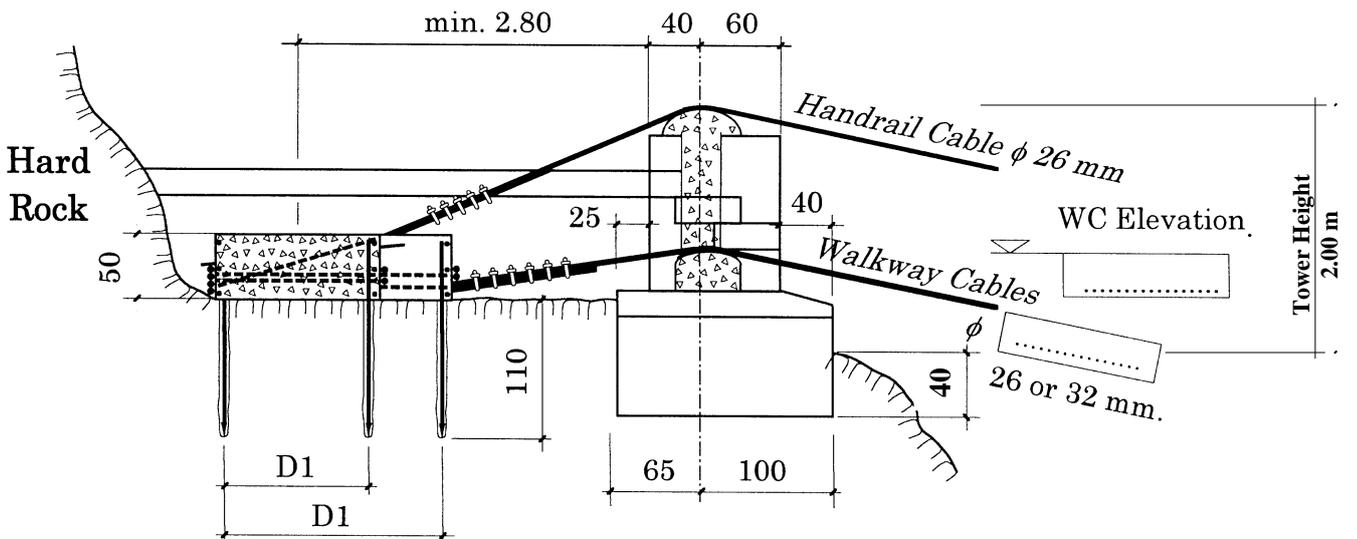
#### 2. RCC Deadman and Gravity Soil Anchor Block on Slope Topography



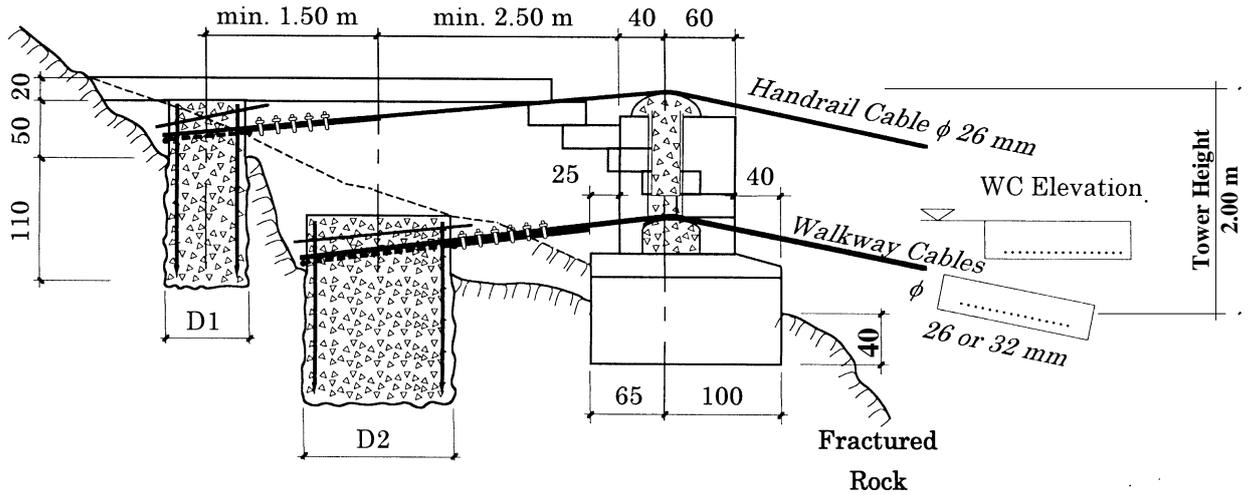
**3. RCC Single Drum Rock Anchor Block in Hard Rock.**



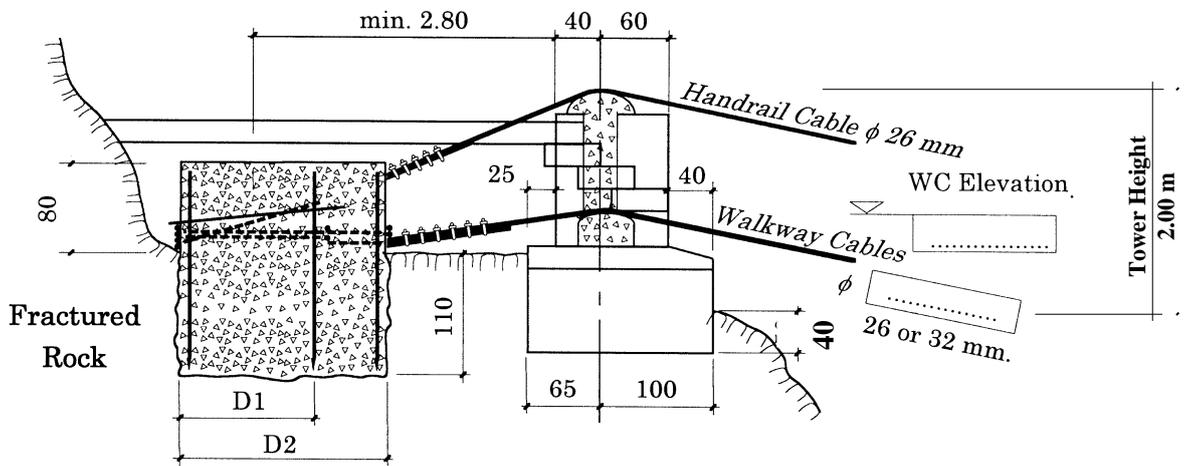
**4. RCC Double Drum Rock Anchor Block in Hard Rock.**



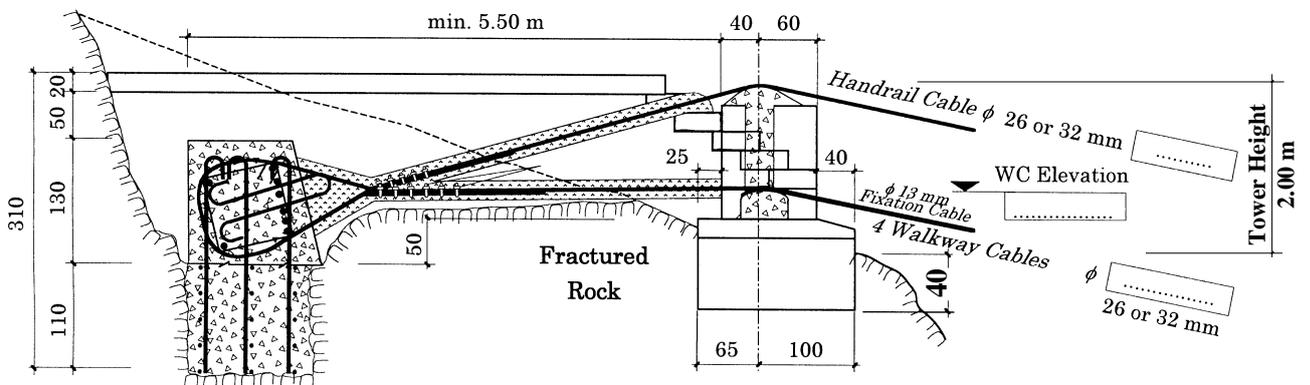
**5. RCC Single Drum Rock Anchor Block in Fractured Hard Rock and Soft Rock**



**6. RCC Double Drum Rock Anchor Block in Fractured Hard Rock and Soft Rock**



**7. RCC Deadman Anchor Block in Fractured Hard Rock and Soft Rock**



**To select an Anchor Block Type proceed as follows.**

- define the walkway width (refer chapter 3.3.4).
- define the span of the bridge from the bridge profile (refer chapter 3.3.3).
- 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 Form No 1: Survey Form and Checklist, chapter 4.6.
- define the tower height from bridge profile (refer chapter 3.3.3). 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 as per following Checklist.*

**A. Design Data**

**\* Fill in the following Design Data from Form No. 1: Survey Form and Checklist**

|   |  |  |  |
|---|--|--|--|
| <ul style="list-style-type: none"> <li>• <b>Walkway Width, WW (70 or 106cm):</b> ..... cm</li> <li>• <b>Bridge Span:</b> ..... m</li> </ul> |  |  |  |
| <b>Right Bank Condition</b>   |  |  |  |
| <b>Geology:</b>   | Soil <input type="checkbox"/>                              |  |  |
| If <b>Soil</b> , how is the Ground Surface?   | Flat <input type="checkbox"/><br>(up to 10° slope)         | or   | Hill Slope <input type="checkbox"/><br>(more than 10° slope) |
| What is the Soil Type?  | Gravelly <input type="checkbox"/>                          | Sandy <input type="checkbox"/>                           | Silty <input type="checkbox"/>                               |
| Tower Height from Ground up to H.C.Saddle (data from bridge profile):   | 2.4m <input type="checkbox"/>                              | 3.4m <input type="checkbox"/>                            | 4.4m <input type="checkbox"/>                                |
| If <b>Rock</b> , what is the Rock Type?   | Hard Rock <input type="checkbox"/><br>(only few fractures) | Hard Rock <input type="checkbox"/><br>(highly fractured) | Soft Rock <input type="checkbox"/>                           |
| Tower Height  | 2.0m in Case of Rock <input type="checkbox"/>              |  |  |
| <b>Left Bank Condition</b>  |  |  |  |
| <b>Geology</b>  | Soil <input type="checkbox"/>                              |  |  |
| If <b>Soil</b> , how is the Ground Surface?   | Flat <input type="checkbox"/><br>(up to 10° slope)         | or   | Hill Slope <input type="checkbox"/><br>(more than 10° slope) |
| What is the Soil Type?  | Gravelly <input type="checkbox"/>                          | Sandy <input type="checkbox"/>                           | Silty <input type="checkbox"/>                               |
| Tower Height from Ground up to H.C.Saddle (data from bridge profile):   | 2.4m <input type="checkbox"/>                              | 3.4m <input type="checkbox"/>                            | 4.4m <input type="checkbox"/>                                |
| If <b>Rock</b> , what is the Rock Type?   | Hard Rock <input type="checkbox"/><br>(only few fractures) | Hard Rock <input type="checkbox"/><br>(highly fractured) | Soft Rock <input type="checkbox"/>                           |
| Tower Height  | 2.0m in Case of Rock <input type="checkbox"/>              |  |  |

## B. 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 as per below.

for Soil and Flat Ground

: **Table 1**

for Soil and Hill Slope

: **Table 2**

for Hard Rock

: **Table 3** or **Table 4**

for Fractured Hard Rock or Soft Rock:

Span up to 90m (WW = 70cm) and up to 60m (WW = 106cm) : **Table 5** or **Table 6**

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

## C. Anchor Type Selection Tables

- In Soil and Flat Ground:**

**Table 1:** Selection of RCC Deadman and Gravity Soil Anchor Block in Flat Ground

| Span Range, m |                | Tower Height [m] | Foundation Soil Type | Block Type | Drawing No. |
|---------------|----------------|------------------|----------------------|------------|-------------|
| Walkway: 70cm | Walkway: 106cm |                  |                      |            |             |
| 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              | Gravelly             | 12F        | 32Dcon      |
|               |                |                  | Sandy, Silty         | 14F        | 34Dcon      |
|               |                | 3.4              | All                  | 15F        | 35Dcon      |
|               |                |                  |                      | 4.4        | 13F         |

- **In Soil and Slope Ground:**

**Table 2:** Selection of RCC Deadman and Gravity Soil Anchor Block in Hill Slope

| Span Range, m |                | Tower Height [m] | Foundation Soil Type | Block Type | Drawing No. |
|---------------|----------------|------------------|----------------------|------------|-------------|
| Walkway: 70cm | Walkway: 106cm |                  |                      |            |             |
| 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      |
| -             | 76 - 90        | 2.4              | Gravelly             | 4S         | 44Dcon      |
|               |                |                  | Sandy                | 5S         | 45Dcon      |
|               |                |                  | Silty                | 6S         | 46Dcon      |
| -             | 91 - 105       | 2.4              | Gravelly, Sandy      | 7S         | 47Dcon      |
|               |                |                  | Silty                | 8S         | 48Dcon      |
| -             | 106 - 120      | 2.4              | Gravelly, Sandy      | 8S         | 48Dcon      |
|               |                |                  | Silty                | 9S         | 49Dcon      |

- **In Hard Rock for all Span Range:**

**Table 3:** Selection of RCC Single Drum Anchor in Hard Rock

| Span Range, m |                | Tower Height [m] | Block Type | Drawing No |
|---------------|----------------|------------------|------------|------------|
| Walkway: 70cm | Walkway: 106cm |                  |            |            |
| 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 (Table 3), select the double drum system from following table 4.

**Table 4:** Selection of RCC Double Drum Anchor in Hard Rock

| Span Range, m |                | Tower Height [m] | Block Type | Drawing No |
|---------------|----------------|------------------|------------|------------|
| Walkway: 70cm | Walkway: 106cm |                  |            |            |
| 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 5:** Selection of RCC Single Drum Anchor in Fractured Hard Rock/Soft Rock

| Span Range, m |                | Tower Height [m] | Block Type | Drawing No |
|---------------|----------------|------------------|------------|------------|
| Walkway: 70cm | Walkway: 106cm |                  |            |            |
| 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 5), select the double drum system from following table 6.

**Table 6:** Selection of RCC Double Drum Anchor in Fractured Hard Rock/Soft Rock

| Span Range, m |                | Tower Height [m] | Block Type | Drawing No |
|---------------|----------------|------------------|------------|------------|
| Walkway: 70cm | Walkway: 106cm |                  |            |            |
| 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 7:** Selection of RCC Deadman Anchor in Fractured Hard Rock/Soft Rock

| Span Range, m |                | Tower Height [m] | Block Type | Drawing No |
|---------------|----------------|------------------|------------|------------|
| Walkway: 70cm | Walkway: 106cm |                  |            |            |
| 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..... |
| Left Bank:  | Anchor Type..... | Drawing No..... |

**D. List of Drawings**

Select the required Steel Drawings and Construction Drawings according to the walkway width, selected cables and selected Anchorage Block types. For this, refer to Chapter 4: Bridge Standard Drawings.

Prepare a General Arrangement drawing for individual bridge design. For this, refer to Chapter 3.3.7: General Arrangement Drawing.

**3.3.6 OTHER STRUCTURES**

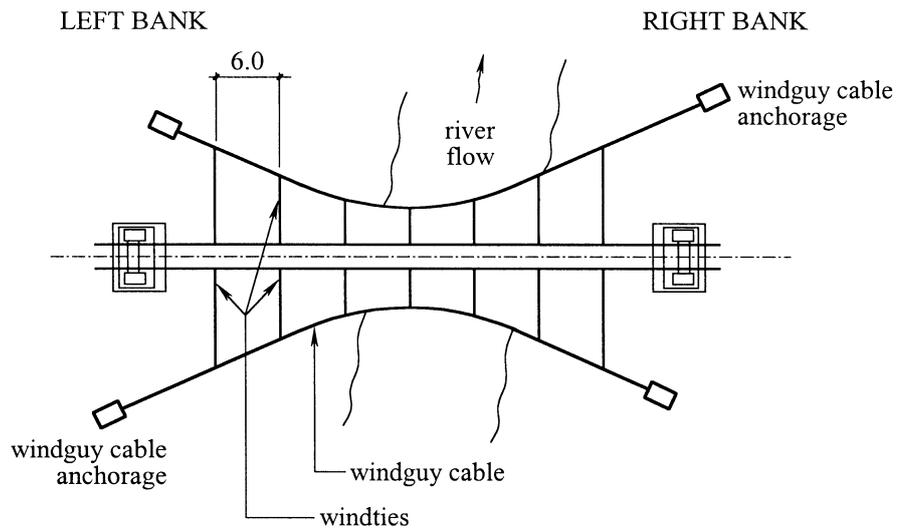
Besides the bridge structure, some other adjacent structures may be required for overall bridge stability and for safety measures. These are the following structures.

- A. Windguy Arrangement
- B. Retaining Structures
- C. Slope Protection works
- D. River Bank Protection

**A. Windguy Arrangement**

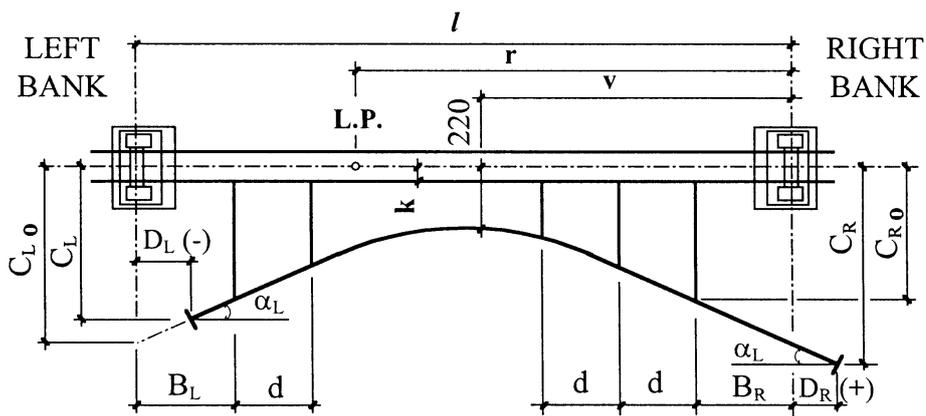
Generally Windguy Arrangements are not required for bridges with span of up to 120m. Therefore, no lateral stabilizing measures (windguy system) is considered in this standard suspended bridge design. However, for special cases (spans more than 120m or extreme windy areas exceeding wind speed of 160km/h) there is a provision for fixing a windguy system. (see also chapter 3.2.1 Loadings). For such cases the general layout for Windguy Arrangements is shown on the following pages. For detailed geometric calculations refer to the Design Manual, Volume A of the Suspension Bridge Project, Nepal. The Steel Drawing for the windtie cable clamps is shown on Drawing No. 11A and respective Construction Drawings for different types of windguy cable anchorages are given in Drawing Nos 51Acon, 52Acon, 53Acon, 54Acon, 57Acon and 58Acon in Volume III.

**The Layout of the Windguy Arrangement**

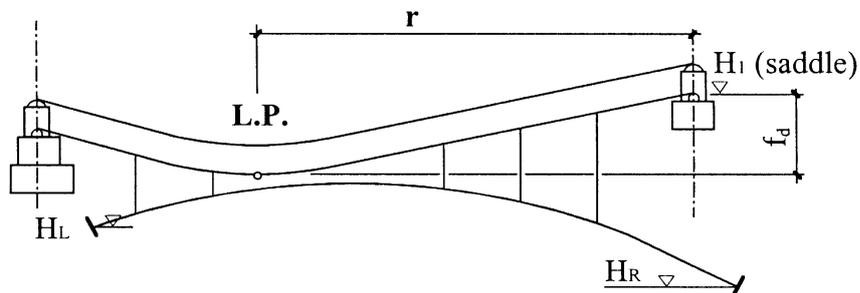


**The Geometry of the Windguy Arrangement**

**Plan**



**Profile**



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 following 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.

For details refer to respective construction drawings in Volume III.

\* Select the Windguy Cable Anchorage Type from following 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     |

\* 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.

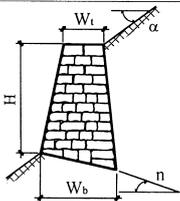
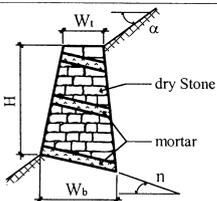
**B. Retaining structures**

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.

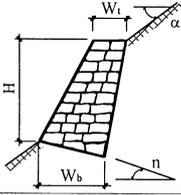
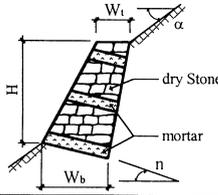
Retaining walls are used when the earth to be retained is loose soil with large protection height. For the design of the retaining wall use the following table.

**Retaining Walls**

| Type                          | Dry Stone   | Banded Dry Stone / Masonry  |
|-------------------------------|---|---|
| Section                       |  |  |
| 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              | $\geq 0.50$ m   | $\geq 0.50 - 1$ m   |
| Range of height, $H$          | 1 - 6 m   | 6 - 8 m   |
| Hill slope angle, $\alpha$    | $< 35^\circ$  | $20^\circ$  |

Breast walls are used when earth to be retained is fractured or weathered rock or compact soil with temporarily unstable nature. For designing breast walls use the following table.

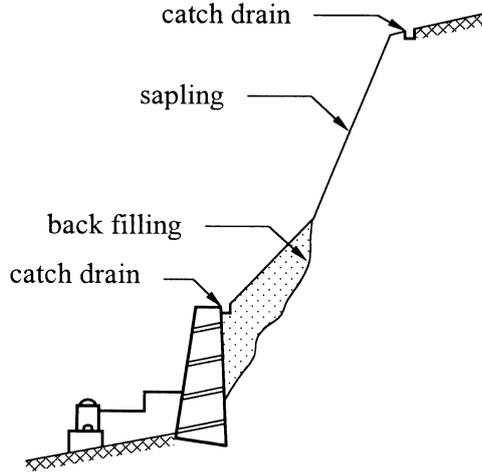
**Breast Walls**

| Type                          | Dry Stone   |               |               | Banded Dry Stone / Masonry  |
|-------------------------------|---|---------------|---------------|---|
| Section                       |  |               |               |  |
| Top width, $W_t$              | 0.50 m  |               |               | 0.50 m  |
| 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              | $\geq 0.50$ m   | $\geq 0.50$ m | $\geq 0.50$ m | $\geq 0.50$ m   |
| Range of height, $H$          | $< 6$ m   | $< 4$ m       | $< 3$ m       | 3 - 8 m   |
| Hill slope angle, $\alpha$    | 35 - $60^\circ$   |               |               | 35 - $60^\circ$   |

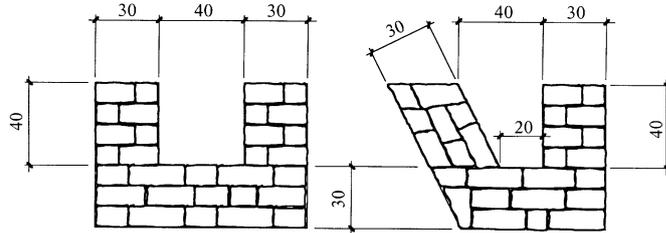
**C. Slope Protection Measure**

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 (refer chapter 3.4.3). However, often it is necessary to drain out the surface runoff and seepage water from the slope as a slope protection measure.

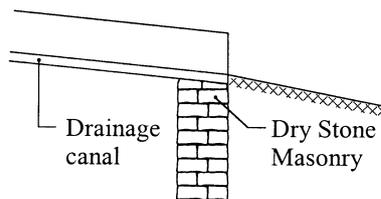
Water should be collected as closely as possible from its origin and safely channeled to a nearby watercourse. The surface drainage can be catch drain on the slope or drainage around the anchorage foundation or combination of both. The choice depends on the position of the anchorage foundation and the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



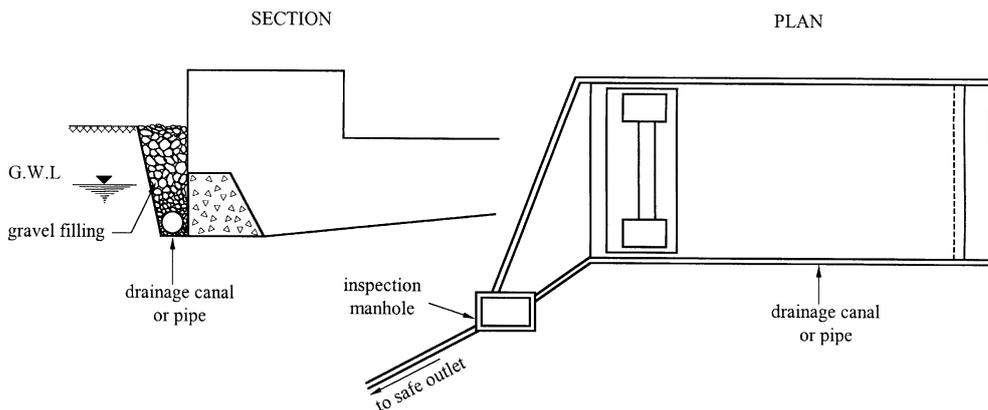
The drain should be open type and section of the drain as per following design.



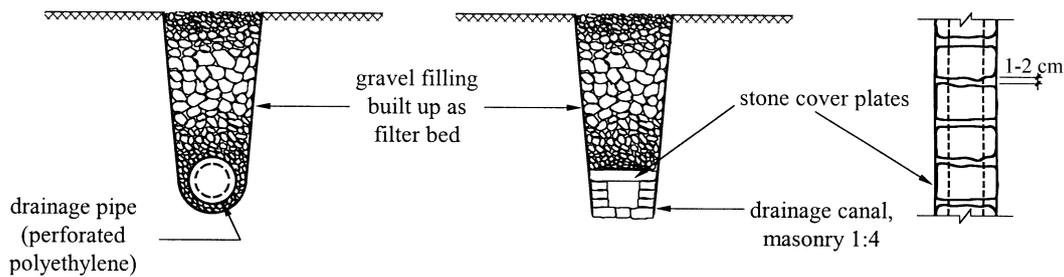
To avoid self-scouring, the drain outlet should be protected as shown in the following sketch.



In seepage area, sub-surface drainage is required around the anchorage foundation. The typical layout design of the sub-surface drain is as shown in the sketch bellow.



The typical design of the sub-surface drain is as shown in sketch below.



## 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)

For more and in-depth details about bioengineering techniques refer to the respective literatures and Manuals. One of the recommended manual is: " Road Side Bio-Engineering, Reference Manual by John Howell, published by HMG/Department of Roads".

## D. 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 handbook. For detail refer to SBD Design Manual Vol.A.

### 3.3.7 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.

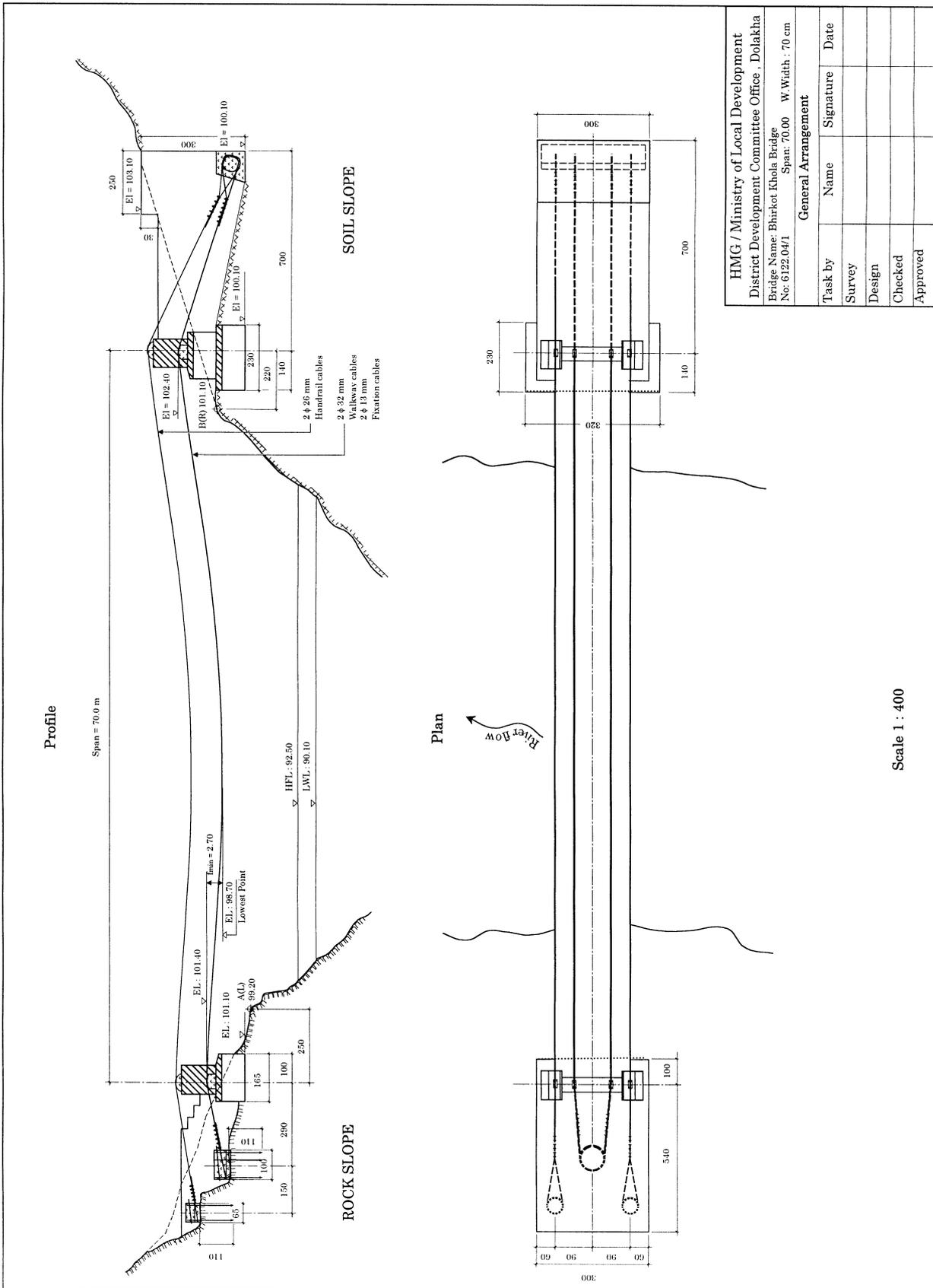
Draw the GA on the same bridge profile as already done under chapter 3.3.3, and mention the following data on the plan and the profile of the bridge:

- 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. An example of a GA drawing of a bridge is given on the next page.

### 3.4 DESIGN EXAMPLE

A complete design example of a bridge is given in the Annex.



## 4. BRIDGE STANDARD DRAWINGS

### 4.1 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:

- **Construction Drawings**
- **Steel Drawings**

**\* see Volume III  
Steel & Construction Drawings**

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

#### Construction Drawings

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

## Steel Drawings

| Drawing Titles                         |   | Drawing Nos.   |       |
|--|---|--|-------|
| <b>WALKWAY<br/>CROSS BEAMS</b>         | Crossbeam for 2 Walkway Cables for walkway width = 34 cm*     | 01D*   |       |
|  | Crossbeam for 2 Walkway Cables for walkway width = 70 cm      | 02D  |       |
|  | 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   |       |
| <b>STEEL DECK</b>                      | Steeldeck Standard Panel, length = 198 cm / width = 34 cm     | 08A  |       |
|  | Steeldeck Standard Half Panel, length = 98 cm / width = 34 cm | 09A  |       |
|  | Steeldeck Special Panel, length = 223 cm / width = 34 cm      | 10A  |       |
| <b>SADDLES &amp;<br/>REINFORCEMENT</b> | <b>SOIL</b>   | Saddles & Reinforcement for<br>RCC Deadman & Gravity Soil Anchor for 2 Walkway Cables    | 20D2  |
|  |   | Saddles & Reinforcement for<br>RCC Deadman & Gravity Soil Anchor for 4 Walkway Cables    | 20D4  |
|  | <b>ROCK</b>   | Saddles & Reinforcement for<br>RCC Deadman Anchor in fractured Rock for 4 Walkway Cables | 20D4S |
|  |   | Saddles & Reinforcement for<br>Drum Rock Anchor for 2 Walkway Cables                     | 60D2  |
|  |   | Saddles & Reinforcement for<br>Drum Rock Anchor for 2 Walkway Cables                     | 60D4  |
|  |   |  |       |
| <i>optional</i>                        | Windties Cable Clamps for Windguys Cable $\phi$ 26 or 32 mm   | 11A  |       |
|  | Windguys Cable Anchorage for one Cable End $\phi$ 26 or 32 mm | 50A  |       |

\*Also a narrow walkway of 34cm width (1panel 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.

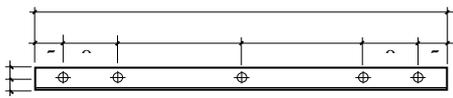
## Legend for the Drawing Numbers and Suffixes:

|                                  | Drawing No.                          | Suffix                                     | Bridge or Drawing Type                         |
|----------------------------------|--------------------------------------|--|--|
| <b>STEEL<br/>DRAWINGS</b>        | 11                                   | <b>A</b>                                   | For All bridge types                           |
|                                  | 02                                   | <b>D</b>                                   | For suspended bridge types                     |
|                                  | 02                                   | <b>D4</b>                                  | For 4 walkway cables                           |
|                                  | 02                                   | <b>D4W</b>                                 | Suitable for Windguy cables                    |
|                                  | 20                                   | <b>D4S</b>                                 | Special  |
| <b>CONSTRUCTION<br/>DRAWINGS</b> | 42                                   | <b>Dcon</b>                                | construction drawings                          |
|                                  | 20                                   | <b>Dcon 70</b>                             | For 70 cm walkway width                        |
|                                  | <b>Anchor Drawings (Block Types)</b> |  |  |
|                                  |                                      | <b>3F</b>                                  | Block Type 3 in Flat Ground                    |
|                                  |                                      | <b>5S</b>                                  | Block Type 5 in Hill Slope                     |
|                                  |                                      | <b>1HRS</b>                                | Block Type 1 in Hard Rock for Single Drum      |
|                                  |                                      | <b>1HRD</b>                                | Block Type 1 in Hard Rock for Double Drum      |
|                                  |                                      | <b>1FRS</b>                                | Block Type 1 in Fractured Rock for Single Drum |
|                                  | <b>1FRD</b>                          | Block Type 1 in Fractured Rock for Deadman |  |

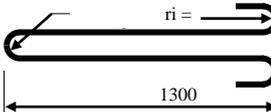
### 4.2 CONCEPT OF THE STANDARD DRAWINGS

#### 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 as per example below.

| Part No. | Section [mm]                        | Quantity [nos] | Working Drawing  | Weight |          |
|----------|-------------------------------------|----------------|--|--------|----------|
|          |                                     |                |  | kg/pc  | total Kg |
|          | Angle (spacer) 40/40/5<br>l = ..... |                | <br>Width of walkway L      X      Weight / pc<br>70 cm    910      740      2.73 kg<br>106 cm    1270      1100      3.81 kg<br>5 holes $\phi$ 14 |        |          |

fill in weight and length per piece (kg/pc) according to width of walkway and multiply by the quantity for computing total Kg.

|           |                               |   |  |  |      |
|-----------|-------------------------------|---|--|--|------|
| <b>8</b>  | Ri-Bar $\phi$ 16<br>l = ..... |   | <br>Width of walkway L      Weight / pc<br>70 cm    2100      3.32 kg<br>106 cm    2500      3.95 kg |  | ...R |
| <b>9</b>  | Bulldog Grip $\phi$ .....     |   | for fixing first suspender at handrail cable $\phi$ 26 or 32 MS forged. according to ISI standard, galvanized.   |  | ...D |
| <b>10</b> | Plain Rod $\phi$ 20<br>*      | * | <br>* Erection Hooks needed at one bank only  |  | ...R |

fill in the  $\phi$  and corresponding weight of the handrail cable

fill in the weight of erection hooks if needed.

|  |  |  |   |  |                  |
|--|--|--|---|--|------------------|
| <b>13</b>  | Bulldog Grips<br>MS forged ISI standard<br>$\phi$ 13 | 12   | for fixing first & joining <b>Fixation Cable</b> $\phi$ 13 mm | $\downarrow$                           | 1.4 <sup>D</sup> |
| <b>14</b>  | $\phi$ ....  | 2  | for <b>Handrail Cable</b> $\phi$ 26 or 32 mm                  | $\downarrow$                           | ...D             |
| <b>15</b>  | $\phi$ ....  | 2  | for <b>Walkway Cable</b> $\phi$ 26 or 32 mm                   | $\downarrow$                           | ...D             |
| A = ..... kg<br>Total transportation Weight<br>B+C+D+R+0.16 kg |  | B = ..... kg<br>Total Structural Steel = (u+g) |   | g = 10.64 kg<br>Steel to be galvanized |                  |
| C = 0.32 kg<br>Nuts, Bolts, Washers                            |  | D = ..... kg<br>Bulldog Grips                  |   | R = .....kg<br>Reinforcement Steel     |                  |

fill in the  $\phi$  of the required Bulldog Grips plus the weight from the table below

compute total weights from weight column of material list

Fill in :

Bridge Name  
No, Bank & Span

Width of Walkway

No of required foundation

**HMG / Ministry of Local Development**  
**DoLIDAR / Short Span Trail Bridge Standard**

Bridge Name: \_\_\_\_\_

No: \_\_\_\_\_ Bank: \_\_\_\_\_ Span: \_\_\_\_\_

Steel Drawing:  
**Saddles & Reinforcement for RCC  
Deadman & Gravity Soil Anchor  
for 2 Walkway Cables**

Walkway Width : \_\_\_\_\_ cm

Set for one Foundation

1 or 2 \_\_\_\_\_

Date : Sept 20, 2001      Drawing No. 20 D2

| Cable<br>$\phi$ mm | Bulldog Grips<br>for two cables | Weight  |          |
|--------------------|---------------------------------|---------|----------|
|                    |                                 | (kg/pc) | Total kg |
| 26                 | 10                              | 1.10    | 11.00    |
| 32                 | 12                              | 1.30    | 15.60    |

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 No. 3 or 4.

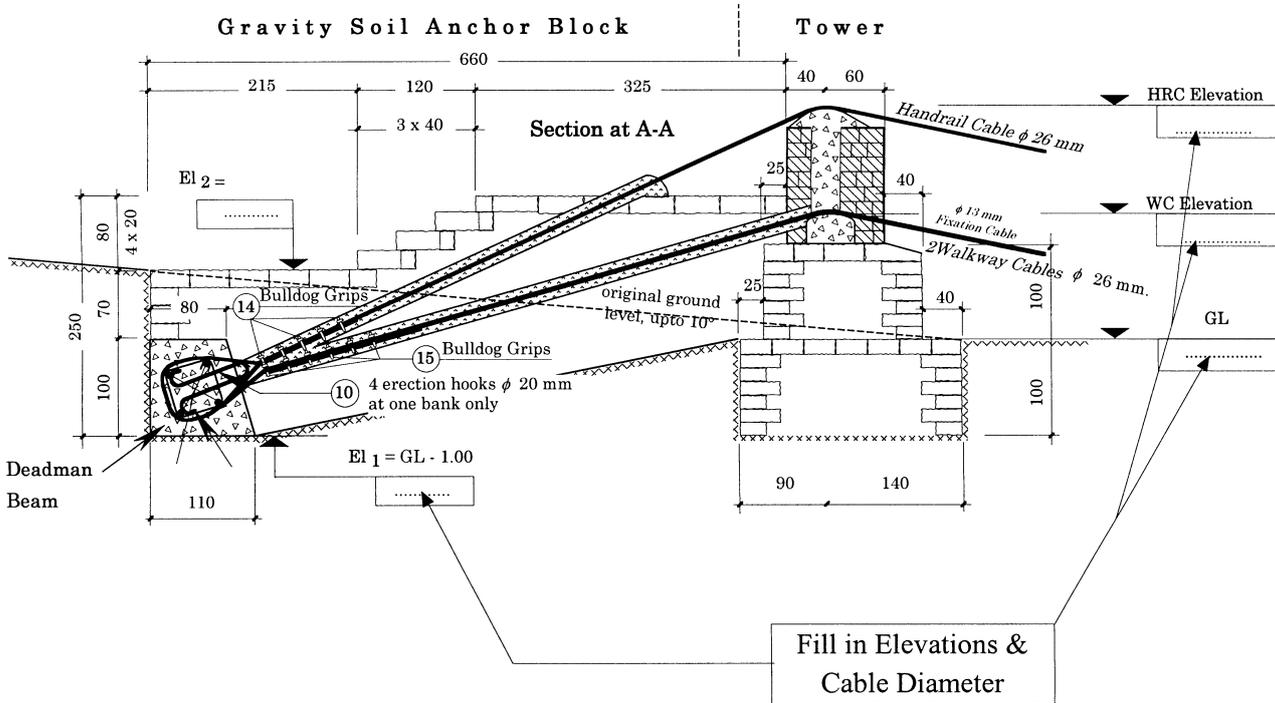
The Soil Anchor Drawings are sub-divided in to:

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

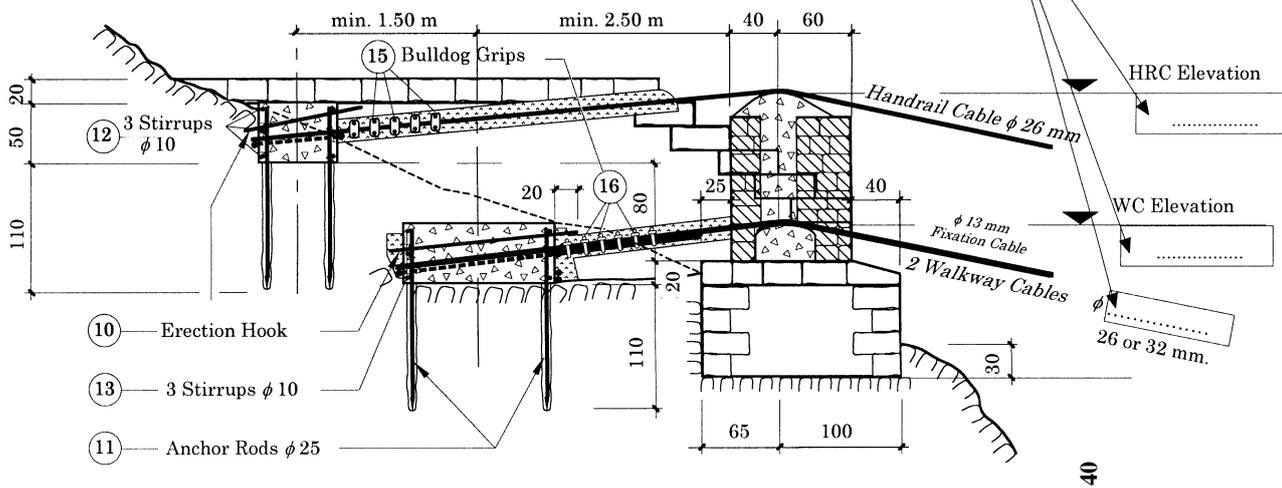
In flat ground with a gradient of max  $10^\circ$  the block types 1F – 15F are applicable, whereas in slopes over  $10^\circ$  the block types 1S – 9S are to be applied.

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 the survey whereas the cable diameter can be taken from the design form.

**Example : Soil Anchor**



**Example : Rock Anchor**

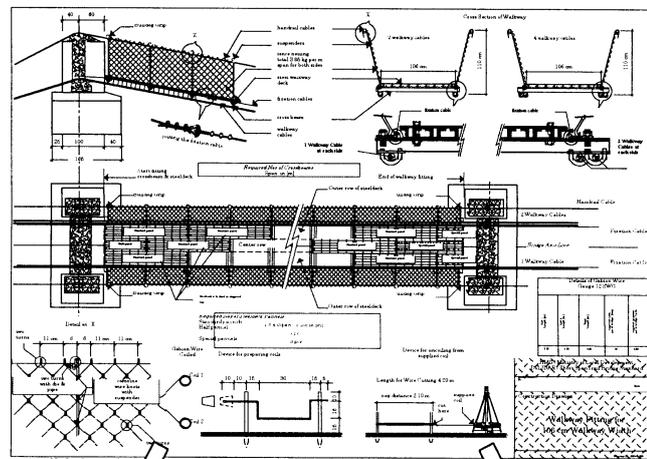


### 4.3 RELATIONSHIP BETWEEN CONSTRUCTION AND STEEL DRAWINGS

Each Construction Drawing has related Steel Drawings. Respective related drawing numbers are mentioned on the drawing itself and also respective steel parts numbers are shown 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 Steeldrawings are the corresponding Steel Crossbeam and Steeldeck Drawings.

### Construction Drawing No 19 "Walkway Fitting"



| Part No. | Section Name | Quantity | Working Drawing | Weight | Assembly Details   |
|----------|--------------|----------|-----------------|--------|--|
| 1        | Part 001     | 1        | 1 x 100 x 14    | 0.09   | <p>Working Detail of Part No. 1</p> <p>For Assembly: See use of completion of flange at assembly.</p> <p>Working Detail of Part No. 1 &amp; II</p> <p>Working Detail of Part No. 1 &amp; III</p> <p>Working Detail of Part No. 1 &amp; IV</p> <p>Working Detail of Part No. 1 &amp; V</p> <p>Working Detail of Part No. 1 &amp; VI</p> <p>Working Detail of Part No. 1 &amp; VII</p> <p>Working Detail of Part No. 1 &amp; VIII</p> <p>Working Detail of Part No. 1 &amp; IX</p> <p>Working Detail of Part No. 1 &amp; X</p> <p>Working Detail of Part No. 1 &amp; XI</p> <p>Working Detail of Part No. 1 &amp; XII</p> <p>Working Detail of Part No. 1 &amp; XIII</p> <p>Working Detail of Part No. 1 &amp; XIV</p> <p>Working Detail of Part No. 1 &amp; XV</p> <p>Working Detail of Part No. 1 &amp; XVI</p> <p>Working Detail of Part No. 1 &amp; XVII</p> <p>Working Detail of Part No. 1 &amp; XVIII</p> <p>Working Detail of Part No. 1 &amp; XIX</p> <p>Working Detail of Part No. 1 &amp; XX</p> <p>Working Detail of Part No. 1 &amp; XXI</p> <p>Working Detail of Part No. 1 &amp; XXII</p> <p>Working Detail of Part No. 1 &amp; XXIII</p> <p>Working Detail of Part No. 1 &amp; XXIV</p> <p>Working Detail of Part No. 1 &amp; XXV</p> <p>Working Detail of Part No. 1 &amp; XXVI</p> <p>Working Detail of Part No. 1 &amp; XXVII</p> <p>Working Detail of Part No. 1 &amp; XXVIII</p> <p>Working Detail of Part No. 1 &amp; XXIX</p> <p>Working Detail of Part No. 1 &amp; XXX</p> |
| 2        | Part 002     | 1        | 1 x 100 x 14    | 0.09   |  |
| 3        | Part 003     | 1        | 1 x 100 x 14    | 0.09   |  |
| 4        | Part 004     | 1        | 1 x 100 x 14    | 0.09   |  |
| 5        | Part 005     | 1        | 1 x 100 x 14    | 0.09   |  |

| Part No. | Section Name | Quantity | Working Drawing | Weight | Assembly Details   |
|----------|--------------|----------|-----------------|--------|--|
| 1        | Part 001     | 1        | 1 x 100 x 14    | 0.09   | <p>Working Detail of Part No. 1 &amp; II</p> <p>Working Detail of Part No. 1 &amp; III</p> <p>Working Detail of Part No. 1 &amp; IV</p> <p>Working Detail of Part No. 1 &amp; V</p> <p>Working Detail of Part No. 1 &amp; VI</p> <p>Working Detail of Part No. 1 &amp; VII</p> <p>Working Detail of Part No. 1 &amp; VIII</p> <p>Working Detail of Part No. 1 &amp; IX</p> <p>Working Detail of Part No. 1 &amp; X</p> <p>Working Detail of Part No. 1 &amp; XI</p> <p>Working Detail of Part No. 1 &amp; XII</p> <p>Working Detail of Part No. 1 &amp; XIII</p> <p>Working Detail of Part No. 1 &amp; XIV</p> <p>Working Detail of Part No. 1 &amp; XV</p> <p>Working Detail of Part No. 1 &amp; XVI</p> <p>Working Detail of Part No. 1 &amp; XVII</p> <p>Working Detail of Part No. 1 &amp; XVIII</p> <p>Working Detail of Part No. 1 &amp; XIX</p> <p>Working Detail of Part No. 1 &amp; XX</p> <p>Working Detail of Part No. 1 &amp; XXI</p> <p>Working Detail of Part No. 1 &amp; XXII</p> <p>Working Detail of Part No. 1 &amp; XXIII</p> <p>Working Detail of Part No. 1 &amp; XXIV</p> <p>Working Detail of Part No. 1 &amp; XXV</p> <p>Working Detail of Part No. 1 &amp; XXVI</p> <p>Working Detail of Part No. 1 &amp; XXVII</p> <p>Working Detail of Part No. 1 &amp; XXVIII</p> <p>Working Detail of Part No. 1 &amp; XXIX</p> <p>Working Detail of Part No. 1 &amp; XXX</p> |
| 2        | Part 002     | 1        | 1 x 100 x 14    | 0.09   |  |
| 3        | Part 003     | 1        | 1 x 100 x 14    | 0.09   |  |
| 4        | Part 004     | 1        | 1 x 100 x 14    | 0.09   |  |
| 5        | Part 005     | 1        | 1 x 100 x 14    | 0.09   |  |

**Steel Drawing Nos 01 - 03**  
"Crossbeam"

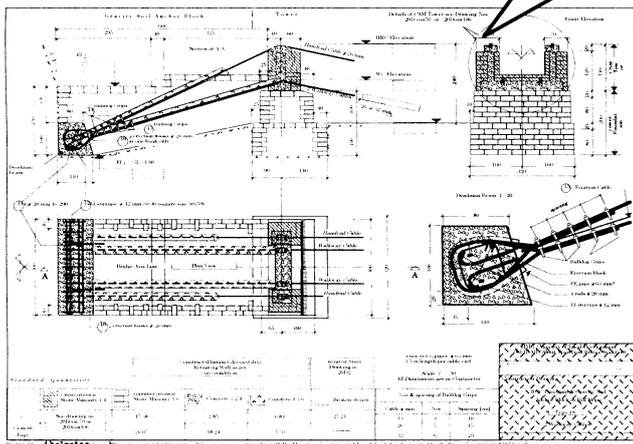
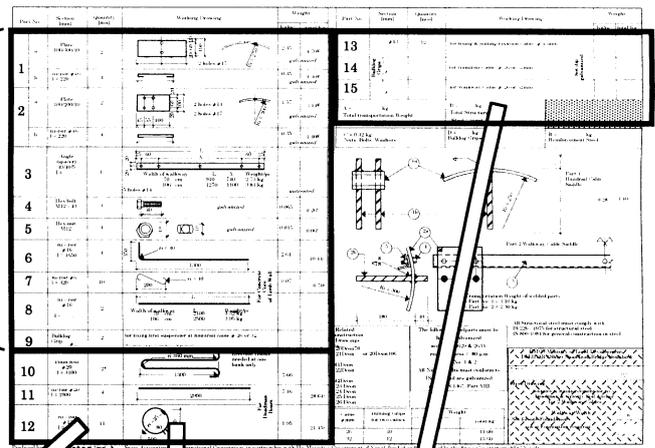
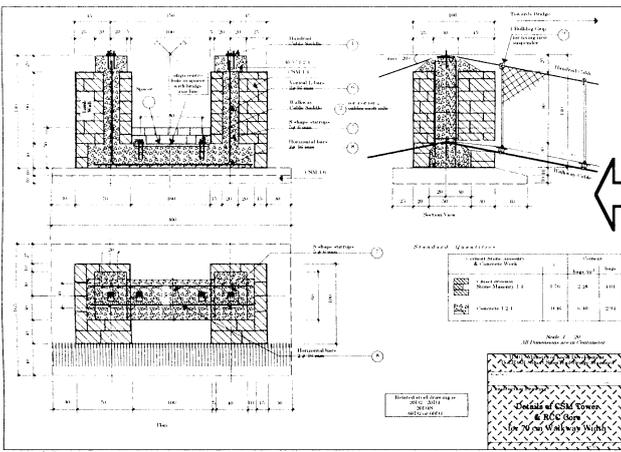
**Steel Drawing Nos 08 - 10**  
"Steeldeck"

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).

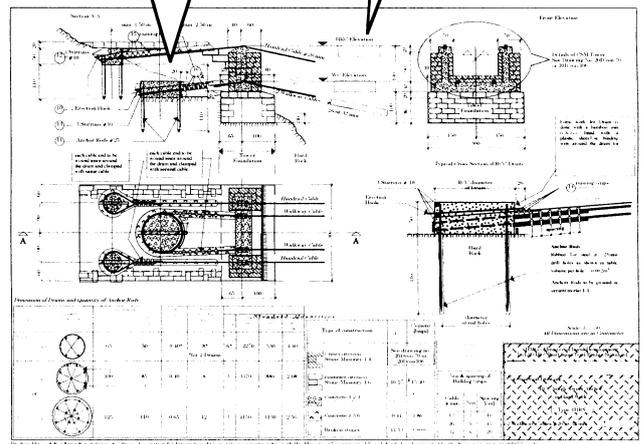
Furthermore, depending of the soil conditions (soil or rock), the Steel Drawing Nos 20 & 60 are related either to Anchor Drawings "Soil" or "Rock" as shown below.

**Construction Drawing No 20**  
"Details of CSM Tower & RCC Core"

**Steel Drawing Nos 20 or 60**  
"Saddles and Reinforcement"



OR



**Construction Drawings Nos 21 - 49**  
"SOIL ANCHORS"

**Construction Drawing Nos 61 - 67**  
"ROCK ANCHORS"

## 5. CALCULATION OF QUANTITY AND COST ESTIMATE

Calculation of quantities and cost estimate is required for the purpose of planning and implementation. The selected approach of implementation determines the methodology of calculating the quantities & cost estimate. There are basically two approaches of implementation. These are:

- **Implementation by the Community**

*\* follow*      **Form No. 3**  
**Quantity & Cost Estimate**  
**for Community Approach**

- **Implementation by Contractor through Public Tender**

*\* follow*      **Form No. 4**  
**Quantity & Cost Estimate**  
**for Public Tender & Contracting**

Standard forms for calculation of quantities and cost estimate for both implementation approaches are presented in the Vol. II as Form No.3 and Form No.4. The methodology of calculating quantities and preparing cost estimate for the two approaches of implementation and how to use the respective Forms is described in the chapter below.

### 5.1 IMPLEMENTATION BY THE COMMUNITY

Use the Form No.3: Cost Estimate (Mode of Execution: Community Approach).

To calculate the quantities and to prepare the cost estimate in Form No.3, follow in sequence the procedure outlined below:

- **Quantity Calculation**

- ⇒ Calculate quantities of cables from the Form No.2: 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.

## 5.2 IMPLEMENTATION BY THE CONTRACTOR THROUGH THE PUBLIC TENDER

Use the Form No.4: Cost Estimate (Mode of Execution: Contractor).

To calculate quantities and to prepare the cost estimate in Form No.4, follow in sequence the procedure outlined below:

- **Quantity Calculation**

- ⇒ Calculate quantities of cables from the Form No.2: Cable Design. Fill in the Quantity Calculation Sheet of Wire Rope (Cables).
- ⇒ Calculate quantities of Steel Parts 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 the transportation weight for cable and other construction materials locally not available.

- **Rate Analysis**

Prepare the Rate Analysis for all items of works as per unit quantity, unit cost and standard norms. The Rate Analysis should include all taxes and overheads of the contractor.

- **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. Abstract of Cost should also include contingency of 5%. This contingency amount will cover miscellaneous costs of the project.

- **Summary of Estimated Cost**

Calculate the Estimated Bridge Cost by summarizing the Abstract of Cost. Finally also calculate bridge cost per m span.

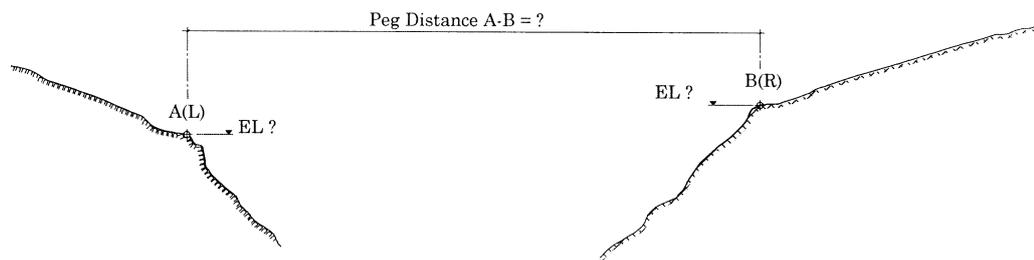
## 6. CONSTRUCTION

### 6.1 BRIDGE LAYOUT

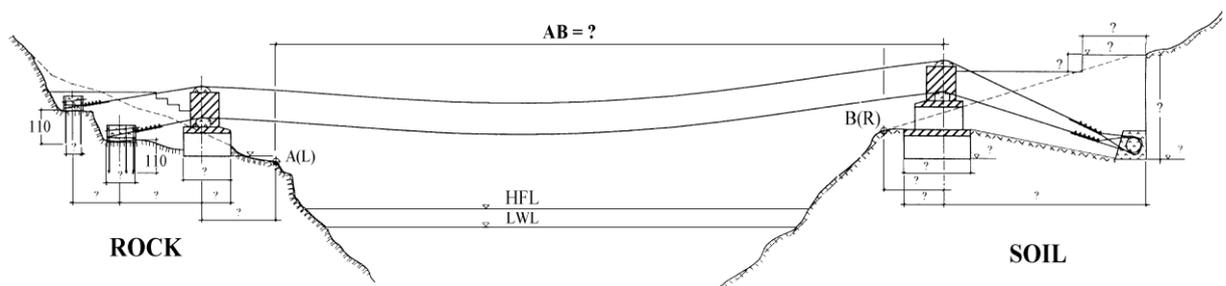
The Bridge Layout is to fix the bridge position and foundations at the site as per design.

**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.

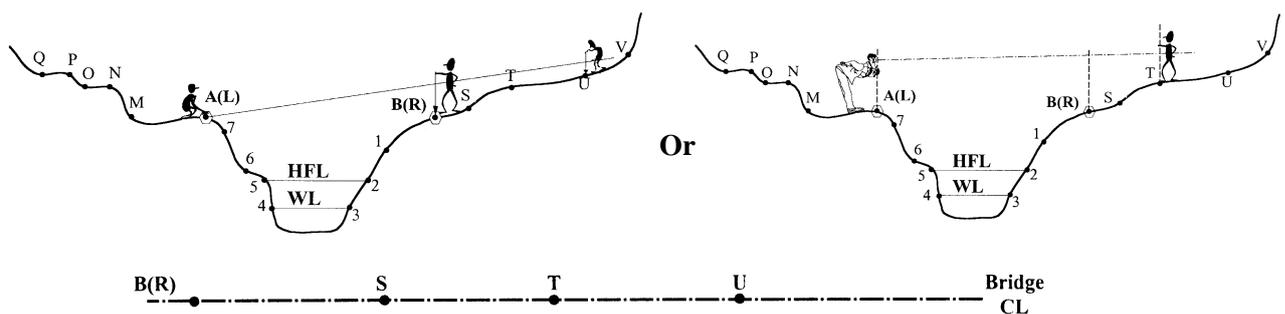


- If the horizontal distance between axis pegs A (L) and B(R) and its elevations is not similar to the measurements given in the GA, readjust the design according to the actual measurements
- If the horizontal distance between axis pegs A (L) and B(R) and its elevations is identical to the measurements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

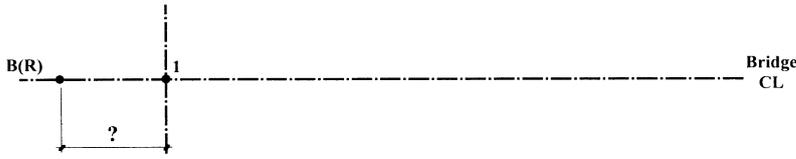


**Procedure for Detailed Foundation Layout:**

- Align the centerline of the bridge by joining the permanent points with mason threads or by ranging between axis pegs 'A' and 'B' as shown in the following sketches.



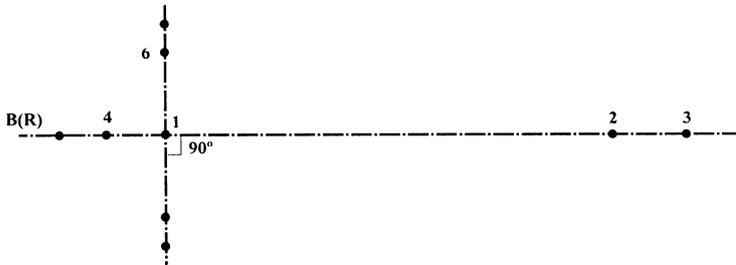
- Mark the front of the tower foundation on the bridge centerline (peg 1) with reference to the axis peg. The distance between front of the tower foundation and axis peg is given in the GA.



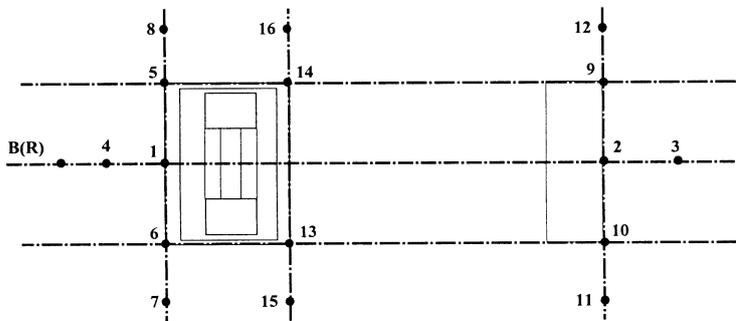
- Check the location of the front of the tower to ensure it has sufficient distance (minimum 3 m for soil slope and 1.5m for rock slope) from the bank edge.
- Measure the length of the foundation from peg 1 and fix peg 2. Set up two additional centerline pegs at safe distance for the excavation works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



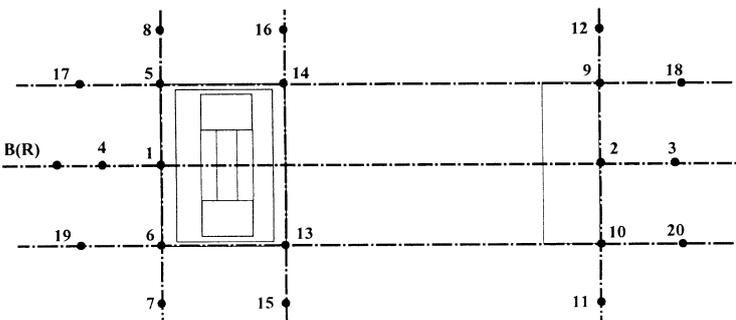
- Draw offset line (right angle) through peg 1 by 3-4-5 method (refer chapter 2.5.4). Starting from peg 1 set out pegs 5, 6, 7, and 8 for the reference line of the front edge.



- 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).



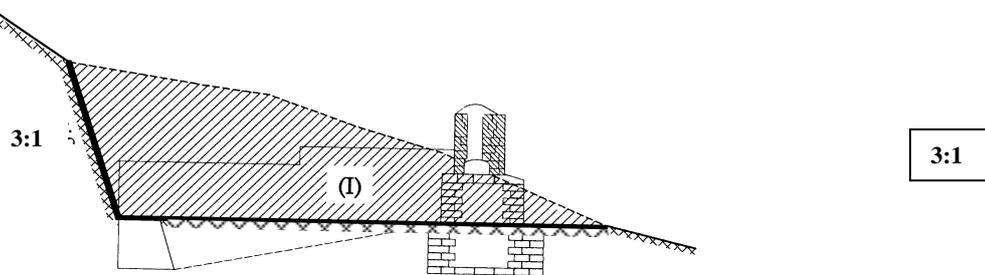
- Fix the elevation line (datum level) and indicate the depth of the excavation work for tower and deadman or drum anchorage as per elevations shown in the GA and Anchorage Block drawings.

## 6.2 FOUNDATION EXCAVATION

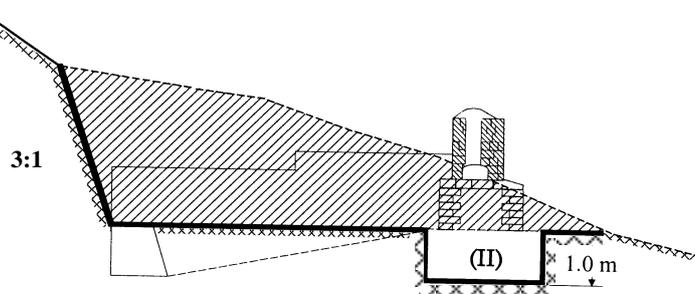
### In Soil:

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 as illustrated below.

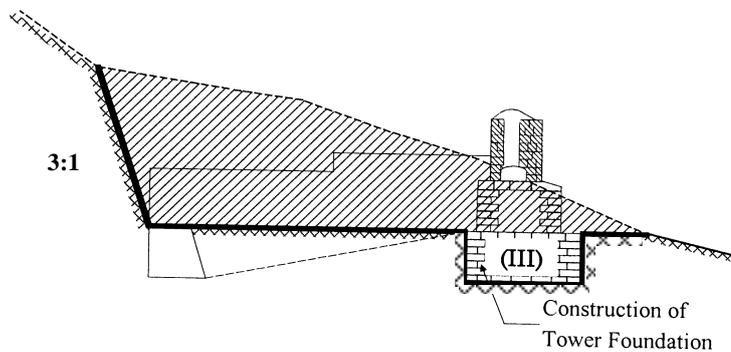
- 1st Stage – All excavation as shown in the sketch below.



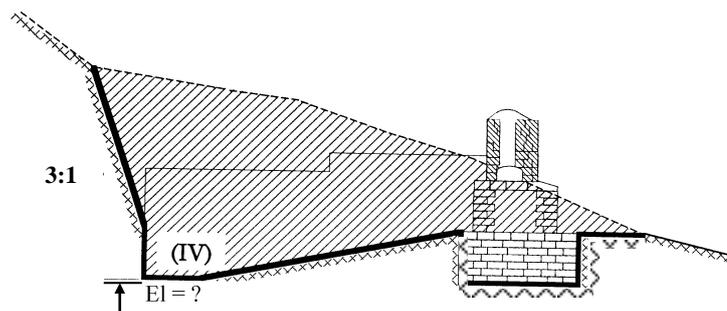
- 2nd Stage – Foundation excavation for tower as shown in the sketch below.



- 3rd Stage – Construction of tower as per design. Refer also to chapter 6.5 and 6.6.



- 4th Stage – Final Excavation for dead man beam as shown in the sketch below.



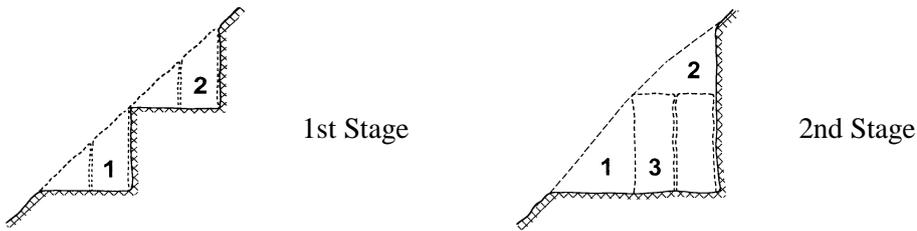
In all of the above excavation stages, excavation depth should be accurately maintained. For this, establish an elevation line (datum level) and measure the foundation depths with fixed stick.

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.

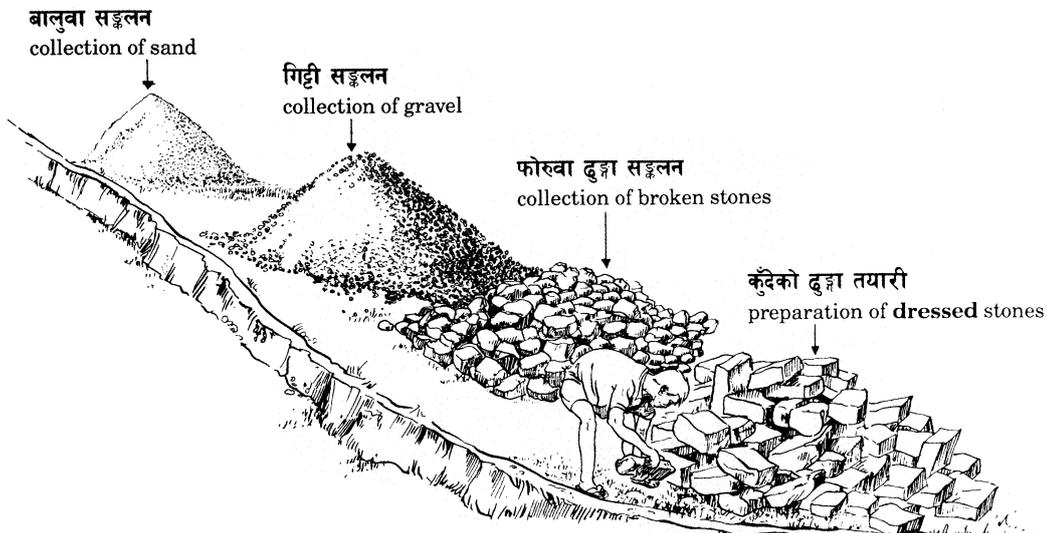
Excavation in rock is done by first drilling holes to weaken the rock and then using the crowbars to break up and dig out the rock parts. The cutting can be carried out by forming steps, as shown in the following sketches.



Further detail on drum anchorage foundation in rock is given in chapter 6.6.4.

**6.3 LOCAL MATERIAL COLLECTION**

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



**6.3.1 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.

The quality requirement for the stone/boulders is further detailed in chapter 6.5.

### 6.3.2 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.

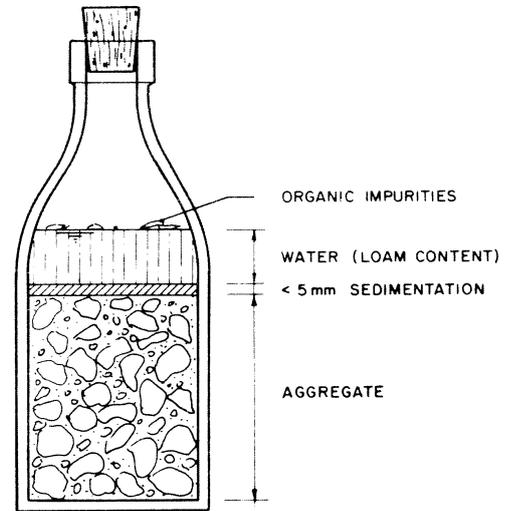
Fill a bottle with sand and water and shake vigorously and leave to settle. If the sand is clean the sedimentation will be less than 5mm after two hours. And the water above will only be lightly cloudy.

The quality for the sand is further detailed in chapter 6.6.1.

### 6.3.3 GRAVEL

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

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

The quality requirement for the gravel is further detailed in chapter 6.6.1.

## 6.4 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.

### 6.4.1 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 following 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.

### 6.4.2 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 following 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.

### 6.4.3 WIRE ROPE TRANSPORTATION AND STORING

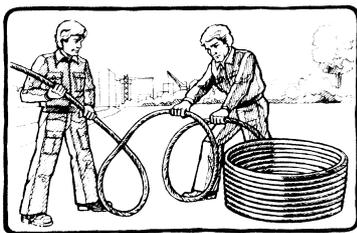
It is vital to handle and transport the cable carefully to avoid any defects like kinks, splices and broken strands. Some examples of defects on cables due to mishandling and improper transportation are shown in the photographs below.

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

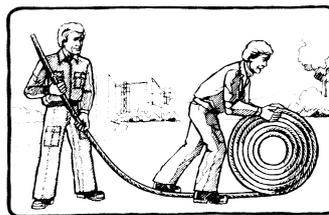


To avoid such defects, follow handling and transportation methods as described below.

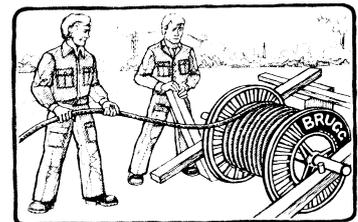
- Method of Unreeling Light Cables with the Help of a Reel Support



Wrong

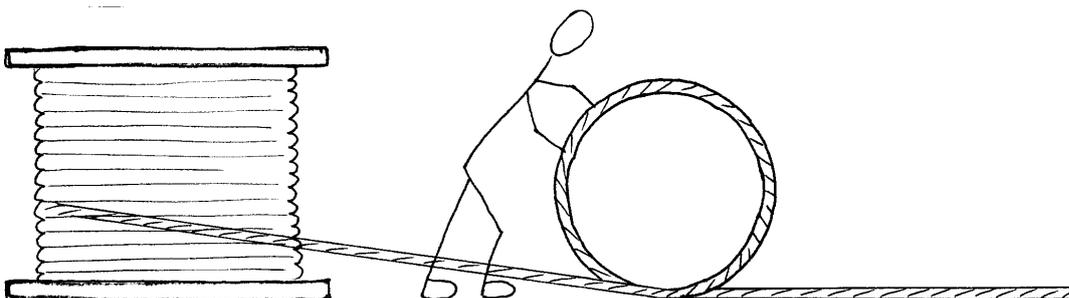


Correct

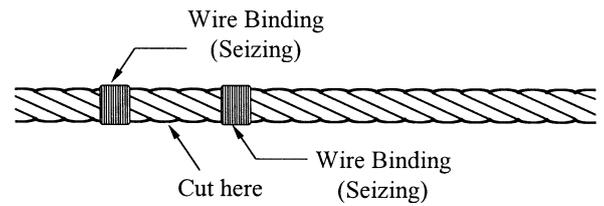


Correct

- 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 as shown in the following sketch.



- Method of Transportation by Porters

There are mainly two methods of cable transportation as illustrated in the following photos.

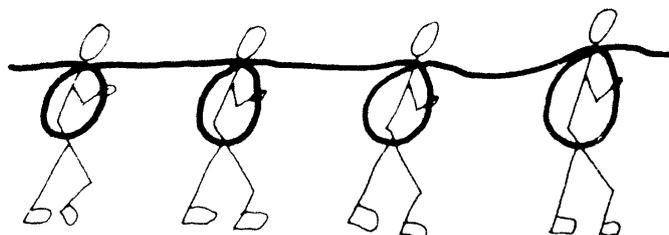


Cable Transportation on the Shoulder (for short distances)

Bundled Cable Transportation  
(for longer distances)



Cable transportation as shown in the sketch below, is wrong and should not be practiced.



Wrong method of transportation

## 6.5 MASONRY AND STONE DRESSING WORK

### 6.5.1 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.

### 6.5.2 QUARRYING

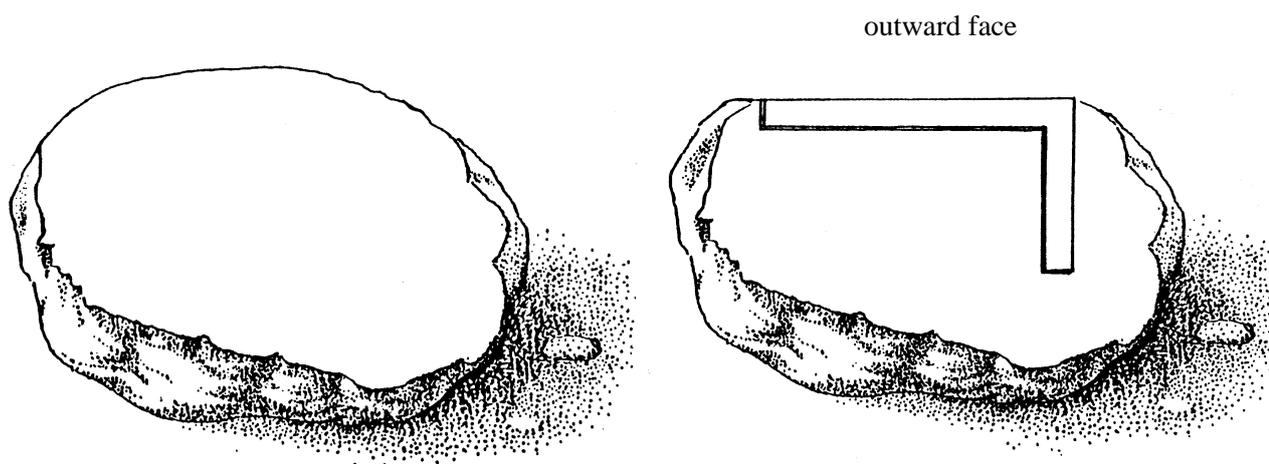
Rocks for stone masonry works should be broken from a quarry by crowbars and wedges. Natural fractures and bedding planes of stratification are the weak features of rock. These natural joints are taken as advantage to break and separate one block from the other.

It is advised that only when natural joints do not exist that 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, then outward faces must be dressed well with the help of the square bottom as shown below.

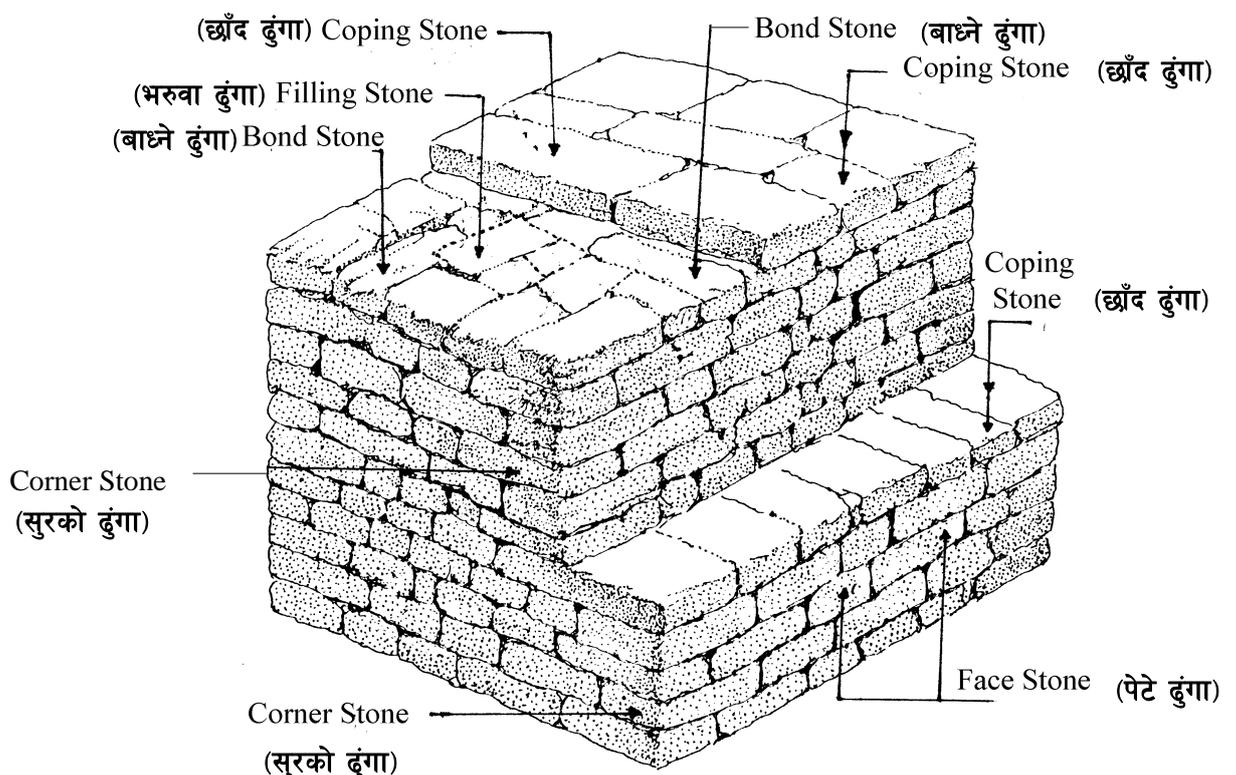


Stones from the riverbed are generally very hard and durable and can be used as filling stone, but are not suitable for stone dressing.

### 6.5.3 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 following 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 below:  
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.



### 6.5.4 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.

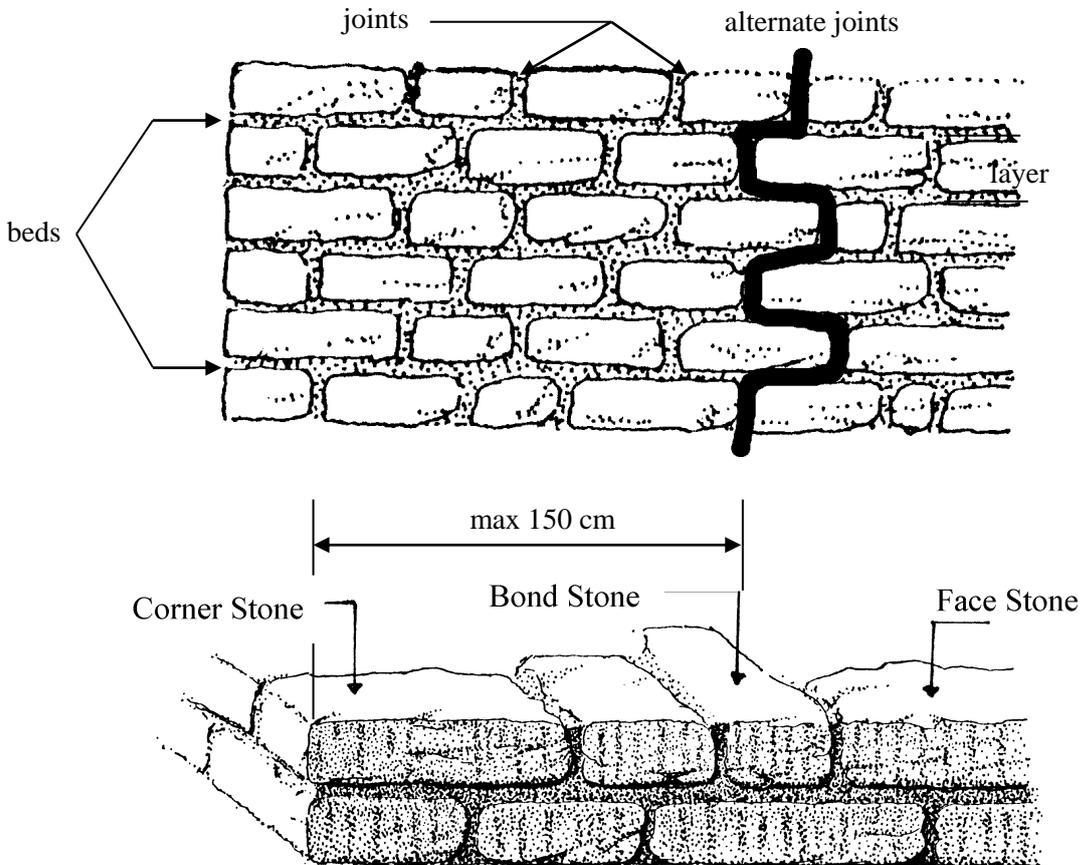
- **Coursed Block Stone Masonry**

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.

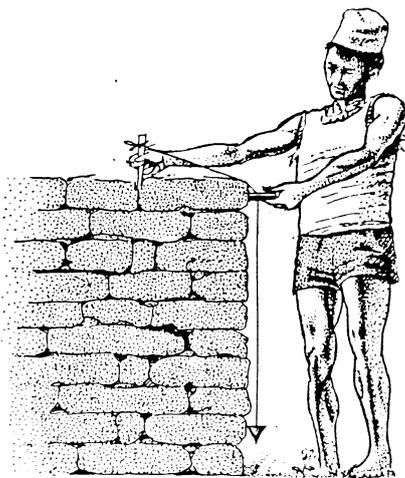
**Bond Stones** running right through the wall are inserted in each course at least at every 150 cm intervals.

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 as shown in the following sketch.

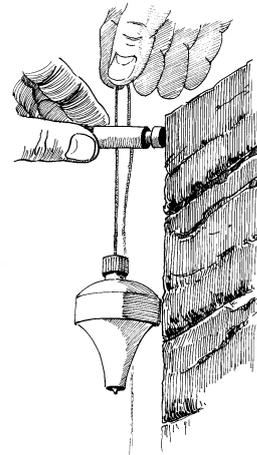


In a reasonably well made stone masonry the inner friction between the beds amounts to approx. 35°.

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 described in the table below.

| ...bigger...                             | The Strength of Stone Masonry is... |                                   |  | ...smaller...                               |
|--|-------------------------------------|-----------------------------------|--|---|
| ...with rectangular stones.              |                                     | <b>Form or Shape</b>              |  | ...with irregular stones.                   |
| ...the less stones are used.             |                                     | <b>Number</b>                     |  | ...the more stones are used.                |
| ...the rougher the joints are.           |                                     | <b>Roughness of joints</b>        |  | ...the smoother the joints are.             |
| ...the smaller the beds are.             |                                     | <b>Bed</b>                        |  | ...the bigger the beds are.                 |
| ...the more compact the stones are.      |                                     | <b>Height &amp; Width</b>         |  | ...the slimmer the stones are.              |
| ...the better the bond across is.        |                                     | <b>Bond Across (in plan view)</b> |  | ...the worse the bond across is.            |
| ...the higher strength of the mortar is. |                                     | <b>Strength of Mortar</b>         |  | ...the lower the strength of the mortar is. |

## 6.6 CEMENT WORKS

### 6.6.1 COMPOSITION AND MIXTURES

Cement concrete is a mixture of following 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. 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 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 5 mm.

**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 is 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 below depicts the most commonly used mix proportions and required quantities:

### Quantities for various Types of Cement Works

| Type of Cement Work                                 | Mix. proportions<br>Cement : Sand : Gravel | Dry required quantities for one cubic meter wet: |      |                        |                          |                                      |
|---|--|--|------|------------------------|--------------------------|--------------------------------------|
|   |  | Cement bags @ 50 kg                              | kg   | Sand [m <sup>3</sup> ] | Gravel [m <sup>3</sup> ] | Stones or Boulders [m <sup>3</sup> ] |
| <b>Cement Mortars</b>                               | 1 : 1 -                                    | 20.4   | 1020 | 0.71                   | -                        | -                                    |
|   | 1 : 2 -                                    | 13.6   | 680  | 0.95                   | -                        | -                                    |
|   | 1 : 3 -                                    | 10.2   | 510  | 1.05                   | -                        | -                                    |
|   | 1 : 4 -                                    | 7.6  | 380  | 1.05                   | -                        | -                                    |
|   | 1 : 6 -                                    | 5.0  | 250  | 1.05                   | -                        | -                                    |
| <b>Cement Plaster</b><br>(20 mm includes 12% waste) | 1 : 4 -                                    | 0.18   | 9    | 0.024                  | -                        | -                                    |
|   | 1 : 6 -                                    | 0.12   | 6    | 0.024                  | -                        | -                                    |
| <b>Cement Stone Masonries</b>                       | 1 : 4 uncoursed stone masonry              | 2.66   | 133  | 0.37                   | -                        | 1.2                                  |
|   | 1 : 6 uncoursed stone masonry              | 1.75   | 87.5 | 0.37                   | -                        | 1.2                                  |
|   | 1 : 4 coursed stone masonry                | 2.28   | 114  | 0.32                   | -                        | 1.25                                 |
|   | 1 : 6 coursed stone masonry                | 1.50   | 75   | 0.32                   | -                        | 1.25                                 |
| <b>Cement Concretes</b><br>(plain or reinforced)    | 1 : 4 : 8                                  | 3.4  | 170  | 0.47                   | 0.94                     | -                                    |
|   | 1 : 3 : 6 (M10)                            | 4.4  | 220  | 0.46                   | 0.92                     | -                                    |
|   | 1 : 2 : 4 (M15)                            | 6.4  | 320  | 0.45                   | 0.90                     | -                                    |
|   | 1 : 1½ : 3 (M20)                           | 8  | 400  | 0.42                   | 0.84                     | -                                    |
| <b>"Plum" Concrete</b>                              | 1 : 3 : 6<br>with 50% boulders             | 2.64   | 132  | 0.28                   | 0.54                     | 0.50                                 |

Source: Indian practical Civil Engineers' Handbook, Section 20

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.

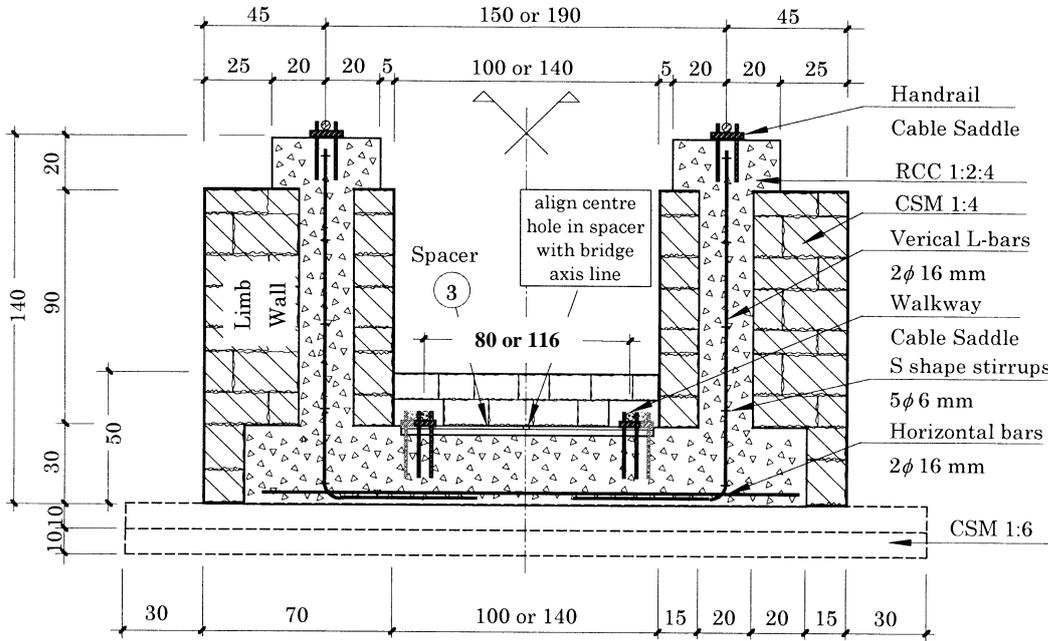
**Curing** means keeping completed cement works wet until its setting process is completed. If concrete works are not continuously kept wet during its setting process, cement mortars, cement stone masonry work and especially concrete does not develop its full strength. Curing should be done for at least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

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

**6.6.2 CONCRETE WORK FOR CEMENT STONE MASONRY (CSM) TOWERS**

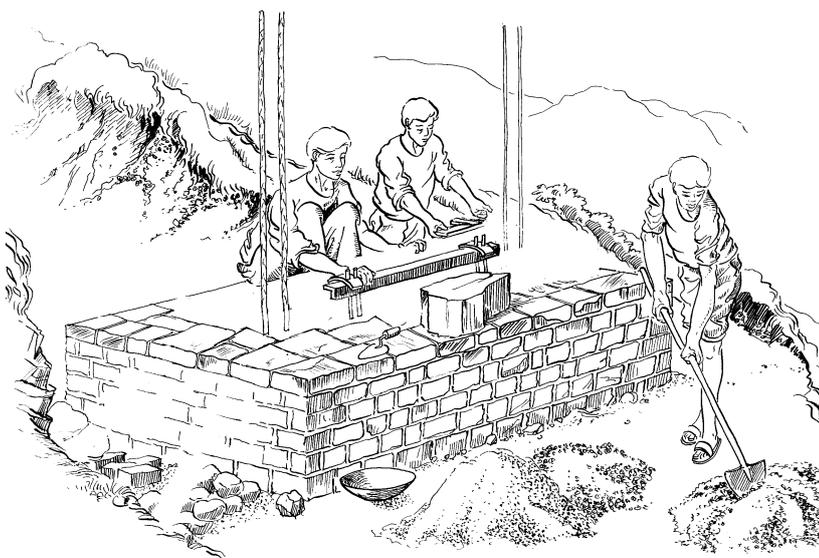
The CSM Towers or Limb Walls are concreted together to form one solid unit (See Drawing Nos. 20Dcon70 & 20Dcon106). The core and the connection of both the towers are made in R.C.C 1:2:4, whereas the limb walls are made in CSM 1:4.

Section through CSM Tower (Bridge Entrance)

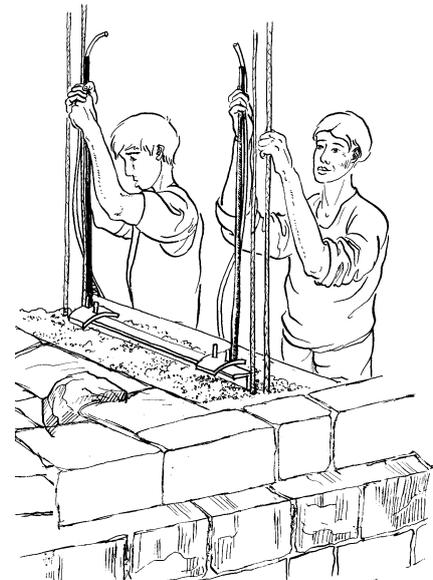


• **Placing the Saddles for the Walkway Cables**

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

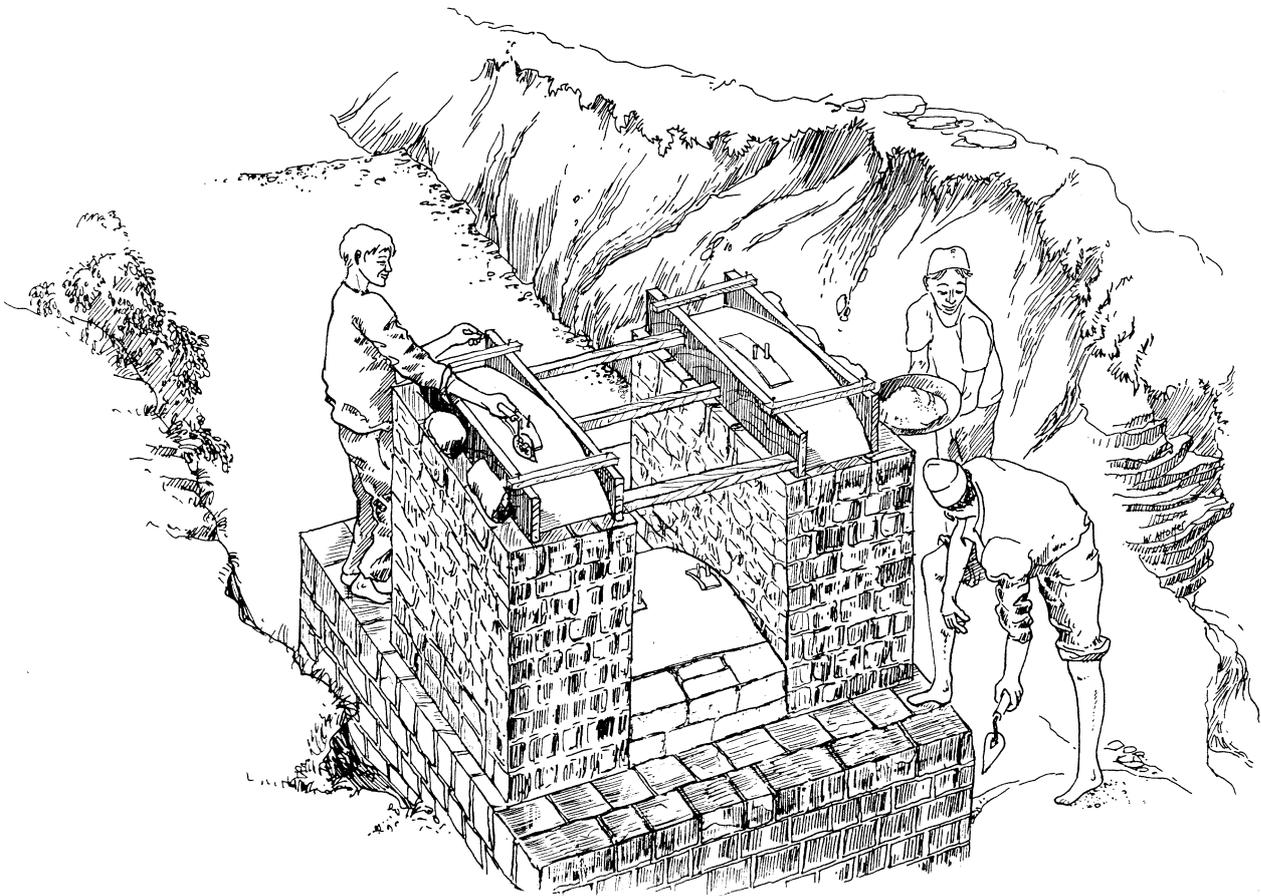
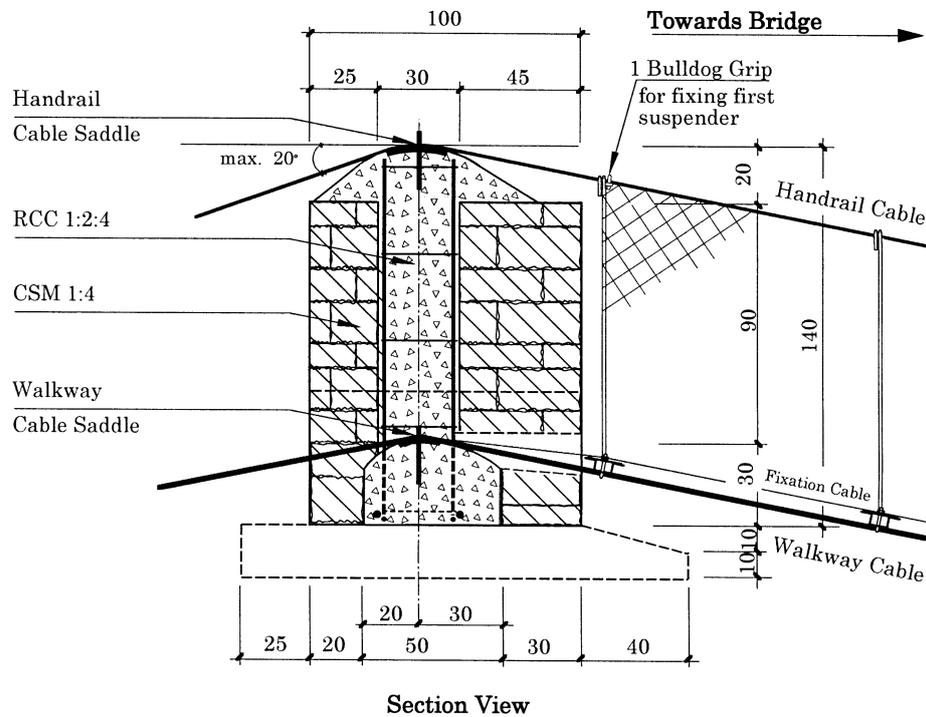


Checking Level of Walkway Cable Saddles

• **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.



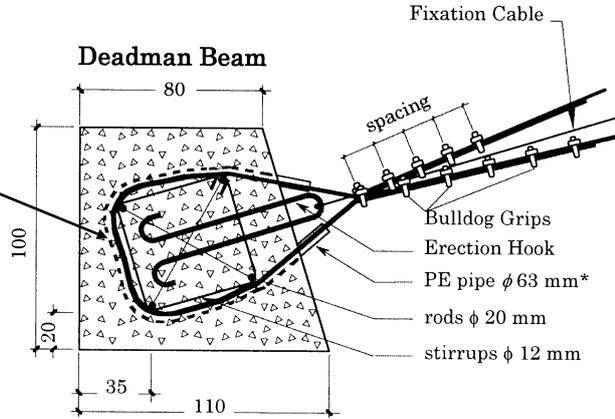
Finishing off the CSM Tower

**6.6.3 CONSTRUCTING THE DEADMAN BEAM**

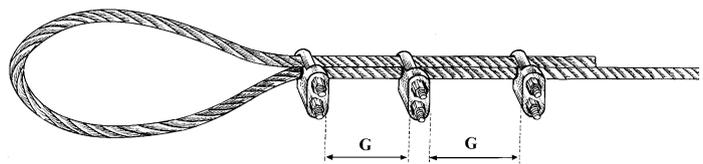
The Deadman Beam is a **soil anchor** cast in reinforced cement concrete R.C.C that lies buried under the gravity structure. The handrail and walkway cables are placed around the reinforcement bars **before** concreting the beam. At one bank the cables are inserted into a polyethylene (PE) pipe, so that the cables can still be moved while sag setting (See Chapter 6.6). 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.

The PE pipe has to be cut by two thirds at several places so that it can easily be bound around the reinforcement bars.

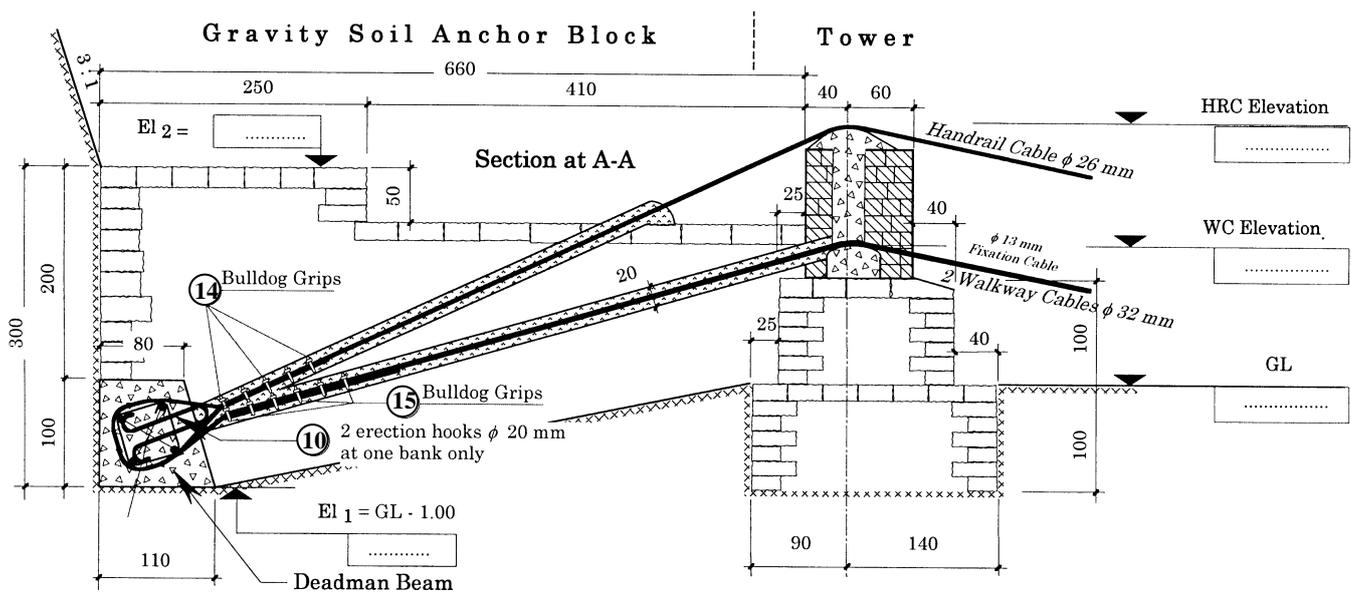
The PE pipe can also be bent by preheating it before bending.



| Nos & spacing of Bulldog Grips |     |       |
|--------------------------------|-----|-------|
| Cable $\phi$ mm                | Nos | G     |
| 13                             | 3   | 10 cm |
| 26                             | 5   | 15 cm |
| 32                             | 6   | 20 cm |



Place and Fix Reinforcement Bars, Stirrups and Erection Hooks as Shown in Respective Drawings.



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.

### 6.6.4 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.

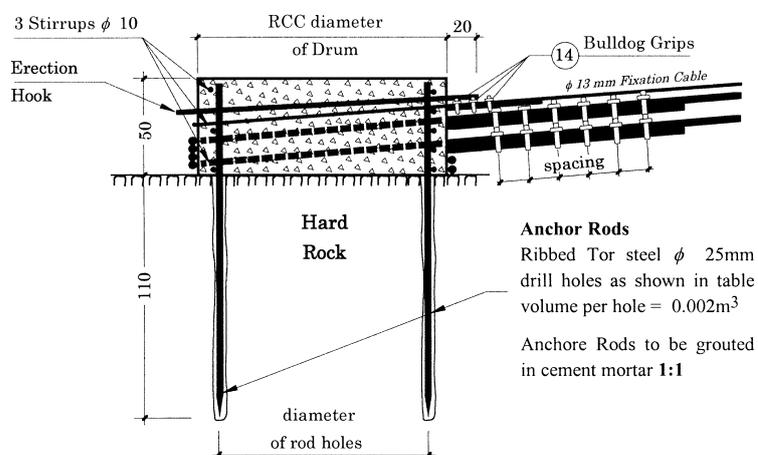
Drilling starter holes (up to 1 foot) for Anchor Rods of a Drum Anchorage in Hard Rock.

Rotate chisel from time to time.

Use crow bar for making holes deeper.

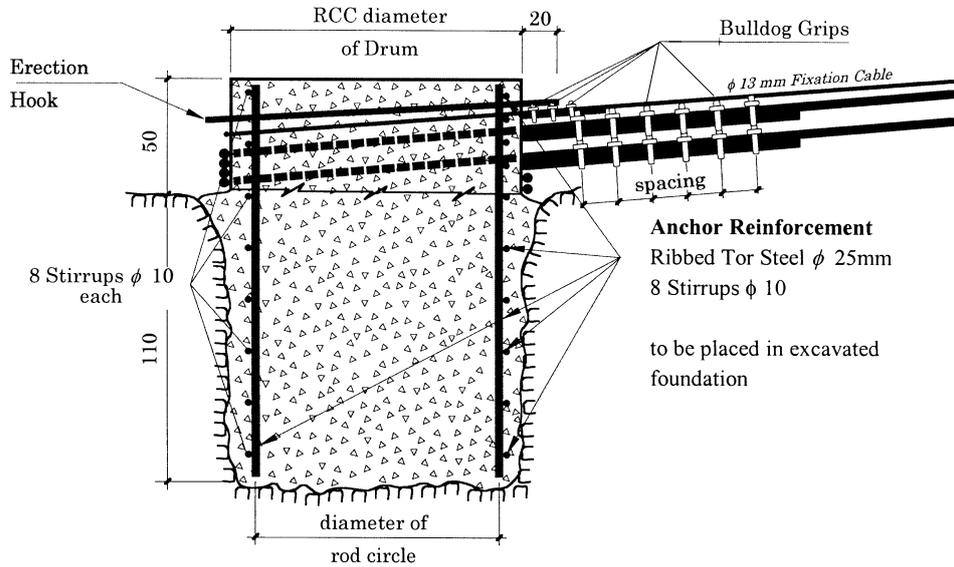


Typical Cross Section of RCC Drum in Hard Rock



**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.

**Typical Cross Section of RCC Drum in Soft or Fractured Rock**



Concreting of a Drum Anchorage

### 6.7 CABLE HOISTING AND SAG SETTING

Cables are hoisted and the prescribed sag set after the Deadman Beams (see 6.5.3) 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.

#### 6.7.1 CALCULATION OF HOISTING SAG

Before starting any hoisting work, the actual span  $\ell$  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 Form No. 2 Chapter 1D: Calculation of Hoisting Sag (see also Chapter 3.3.4 D).

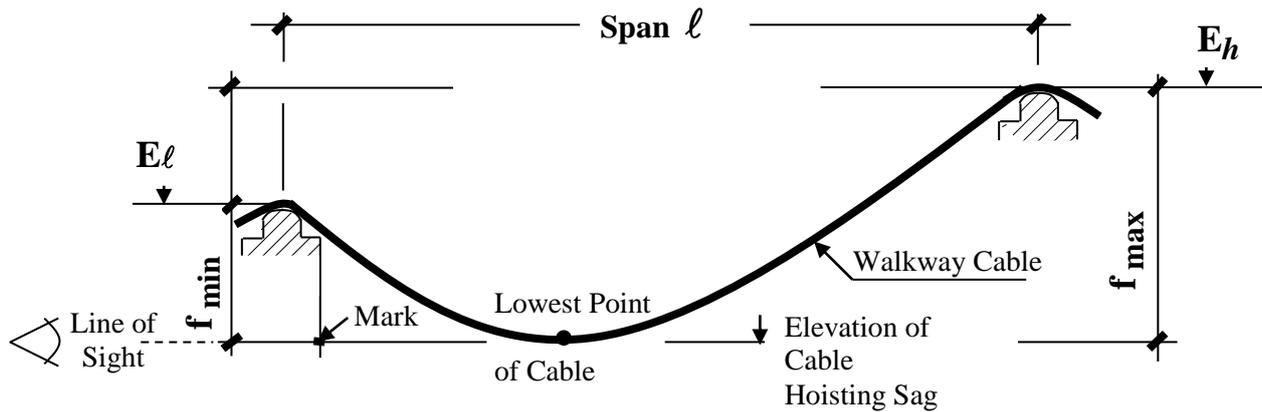


Table for Calculating Elevation of Low Point for Cable Hoisting

|  |           |   |  |                     |         |
|--|-----------|---|--|---------------------|---------|
| 1. Actual Span measured in the Field                               | $\ell$    | = | .....                                      | m                   |         |
| 2. Saddle Elevation of the Walkway Cable on the <b>higher</b> side | $E_h$     | = | .....                                      | m                   |         |
| 3. Saddle Elevation of the Walkway Cable on the <b>lower</b> side  | $E_\ell$  | = | .....                                      | m                   |         |
| 4. Difference in Elevation   | $h$       | = | $E_h - E_\ell$                             | = $h$ = .....       | m       |
| 5. Dead Load Sag   |           |   |  |                     |         |
| For Span up to 80 meters:  | $b_d$     | = | $\frac{\ell}{20}$                          | = $b_d$ = .....     | m       |
| For Span over 80 meters:   | $b_d$     | = | $\frac{\ell}{22}$                          | = $b_d$ = .....     | 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                                      | $f_{max}$ | = | $f_{min} + h$                              | = $f_{max}$ = ..... | m       |
| 9. Elevation of Cable low point in hoisting case                   |           | = | $E_\ell - f_{min}$                         | =                   | ..... 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.

### 6.7.2 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.

## 6.8 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.**

### 6.8.1 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 x 20 cm cement concrete 1:3:6. Before painting, the bulldog grips need to be checked and retightened if required.

### 6.8.2 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 given in Volume III. 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 far as possible. (Refer also to chapter 6.4 Masonry and Stone Dressing Work).

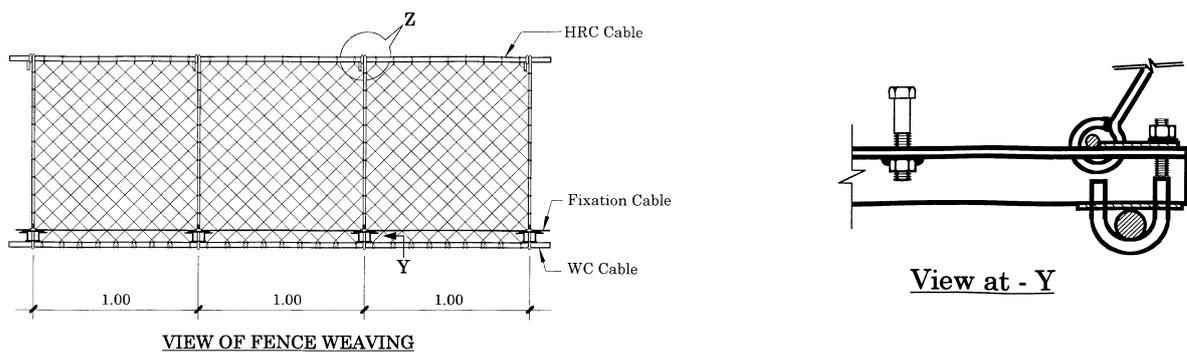
Only **after** the gravity structure is completed can fitting work for the walkway structure start.

## 6.9 WALKWAY FITTING

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

Following points must be observed:

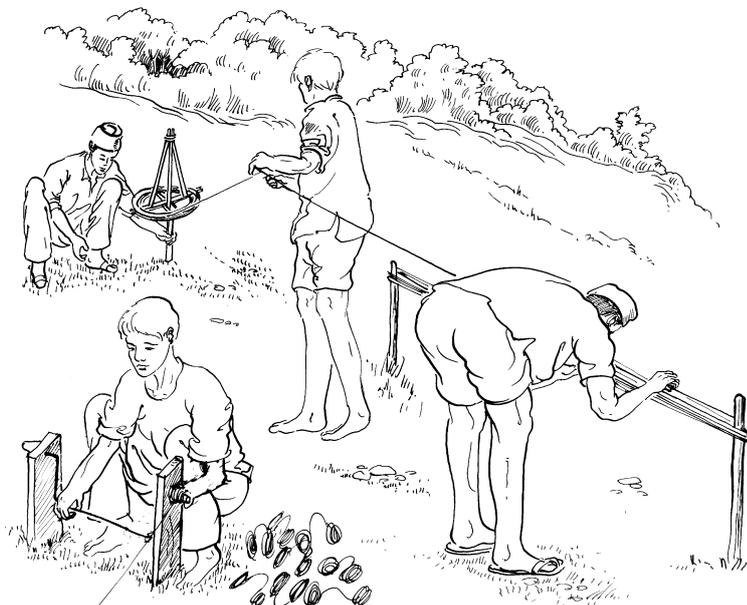
- Start fitting from one bank only
- First fit crossbeam, steel panels or wooden planks as close as possible to the bridge entrance.
- Always start fitting walkway deck with a "Half Panel" then continue with "Standard Panels" only.
- Fix J-bolts at crossbeams first loosely and hang pre-bent suspender 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.

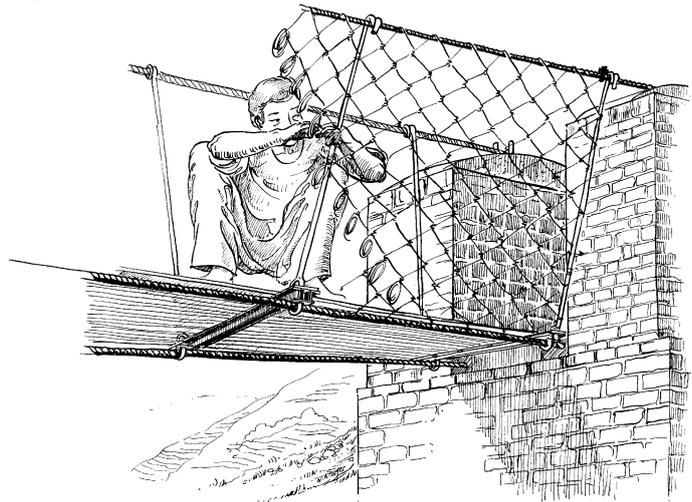
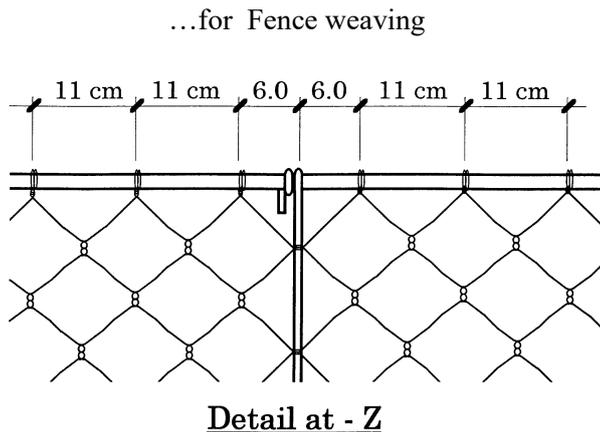


Fencing is woven on the spot with gabion wire (12SWG) between the handrail cable and the fixation cable. First fix the fixation cable by pulling it through the bottom eye of the suspender along either side of the walkway, and then join it with the short piece at the other end of the bridge.

Preparing Coils

Cutting  
Length is  
4.20 Meters





## 6.10 WATER MANAGEMENT BACKFILLING AND GENERAL FINISHING WORKS

### 6.10.1 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 !!!**

### 6.10.2 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.

## **7. BRIDGE MAINTENANCE**

### **7.1 INTRODUCTION**

Maintenance of trail bridges is very crucial for keeping the mule 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 following two categories:

- **Routine Maintenance**
- **Major Maintenance**

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

### **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 following important tasks:

#### **1. 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.

#### **2. Fixing and re-tightening of bridge parts**

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

#### **3. Repairing the walkway deck**

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

#### **4. 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.

#### **5. Reporting of the bridge condition**

Inspection and checking the general condition of all the bridge parts and structures and reporting to the concerned DDC and/or VDC 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 VDCs are responsible for ensuring that routine maintenance is done. The DDCs, who bear the overall responsibility, shall monitor the routine maintenance and shall support the VDCs for cases beyond their capacity.

### **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 following tasks:

- 1. Replacing rotten wooden planks with galvanized steel decks.**
- 2. Replacing rotten wooden crossbeams with galvanized steel beams.**
- 3. Repairing of windguy arrangements/system.**
- 4. Repair, adjustment or replacement of suspenders including adjustment of camber of for suspension bridges.**
- 5. Re-painting of all non-galvanized steel parts.**
- 6. Re-tensioning of all loose cables and adjusting bridge alignment.**
- 7. Coal tar treatment of all non-galvanized threads.**
- 8. River bank and slope protection works.**

The existing bridges, which were constructed in the past with wooden walkway decks and non-galvanized steel, need in the first instance major maintenance work. These bridges may require almost all tasks mentioned above under major maintenance.

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 DDCs are becoming better prepared to implement the major maintenance and are responsible for the execution independently or with the support of the Trail Bridge Section (TBS), or other concerned bridge building agencies.

Reference Documents for Maintenance:

- A. Bridge Maintenance Concept, Suspension Bridge Division, DoLIDAR, HMG/N, August 2000.
- B. Routine Maintenance Manual for Trail Bridges, Suspension Bridge Division, HMG/N 1999.
- C. Directives on execution of Routine Maintenance of Main Trail Bridges through Bridge Wardens, Suspension Bridge Division, DoLIDAR, HMG/N, Shrawan 2057.
- D. Local Bridge Repair, Maintenance and Management, BBL, Kathmandu.