5. TRAIL BRIDGE CONSTRUCTION
FABRICATION, TRANSPORTATION AND CONSTRUCTION

By trail bridge construction, we understand that it includes the supply and fabrication of bridge parts, supply of cables, supply of cement, transportation and civil construction and bridge erection works at the site.

- **Implementation Approaches**

The construction of a bridge is carried out in different ways. There are two major ways. One is through community participation with the local people taking on the responsibility. The other is through a contractor on the basis of public tender. The SUPPORTING AGENCY has always been practicing the community approach of construction.

The SUPPORTING AGENCY has clearly defined its approach as thus:

i) The community takes the initiative and completes an application form for submission to the DDC through the VDC and Ilaka. The form shows the tentative quantity of local materials required to build the bridge.
ii) The DDC determines the priority.
iii) The DDC requests the SUPPORTING AGENCY.
iv) The SUPPORTING AGENCY makes a plan on the basis of the financial involvement of the DDC, the VDC and the Users' Committee (UC).
v) The UC comprises an adequate number of users including women and marginalized people.
vi) The DDC makes a social and technical feasibility survey and submits its decision to the SUPPORTING AGENCY and the UC.
vii) The UC collects the approximate quantity of materials. The work of designing and doing the quantity calculation is completed. DMBT training is given.
viii) Concludes an agreement between the community and the DDC.
ix) Completion of collecting local materials as per the final estimate.
x) Delivery of “foreign” materials (cable, cement, fabricated bridge parts, etc.) to the road-head by the SUPPORTING AGENCY to the UC.
xi) The UC starts the construction and the DDC takes the responsibility for follow up.
xii) Completion of the bridge. The community forms a maintenance committee.

LSTB bridges is constructed through turnkey contract. The fabrication and construction part forms one package. Supplying the cable is another package. The survey and design part is an engineering package.

- **Planning of Construction Activities**

The planning of activities is one of the most important management functions comprising of:

a) Organizing
b) Staffing
c) Directing
d) Controlling

The above mentioned procedures are aimed at achieving the objective of construction management, which could be defined as: “Process of coordinating the skill and labour of men using machines and materials for forming the materials into a desired structure.”

Planning, in general, means laying out the activities in an orderly sequence in advance, defining the principles to be followed in carrying out the project, and prescribing the ultimate disposition of the results accomplished. More directly, it serves the Manager/Supervisor by providing him with the following:

a) Things to be done
b) Their sequence
c) How long each and all shall take
d) Who is responsible for what.

The goal of planning is to minimize resource expenditure for the accomplishment of a given task by aiming to produce an even flow of equipment, materials and manpower and ensuring coordinated effort.

Effective planning requires continual checking on events and forecasts, and redrawing of plans to maintain the proper course toward the objective.

Steps to be taken during planning involve the selection of objectives, procedures and programmes. The core of the manager's / supervisor's job in planning is decision-making based on investigations and analysis, rather than on snap judgment. They are to:

- Establish the objective;
- Establish assumptions based on facts;
- Search and examine alternative courses of action;
- Evaluate the alternatives;
- Select the best course of action;

There are three types of planning involved in construction:

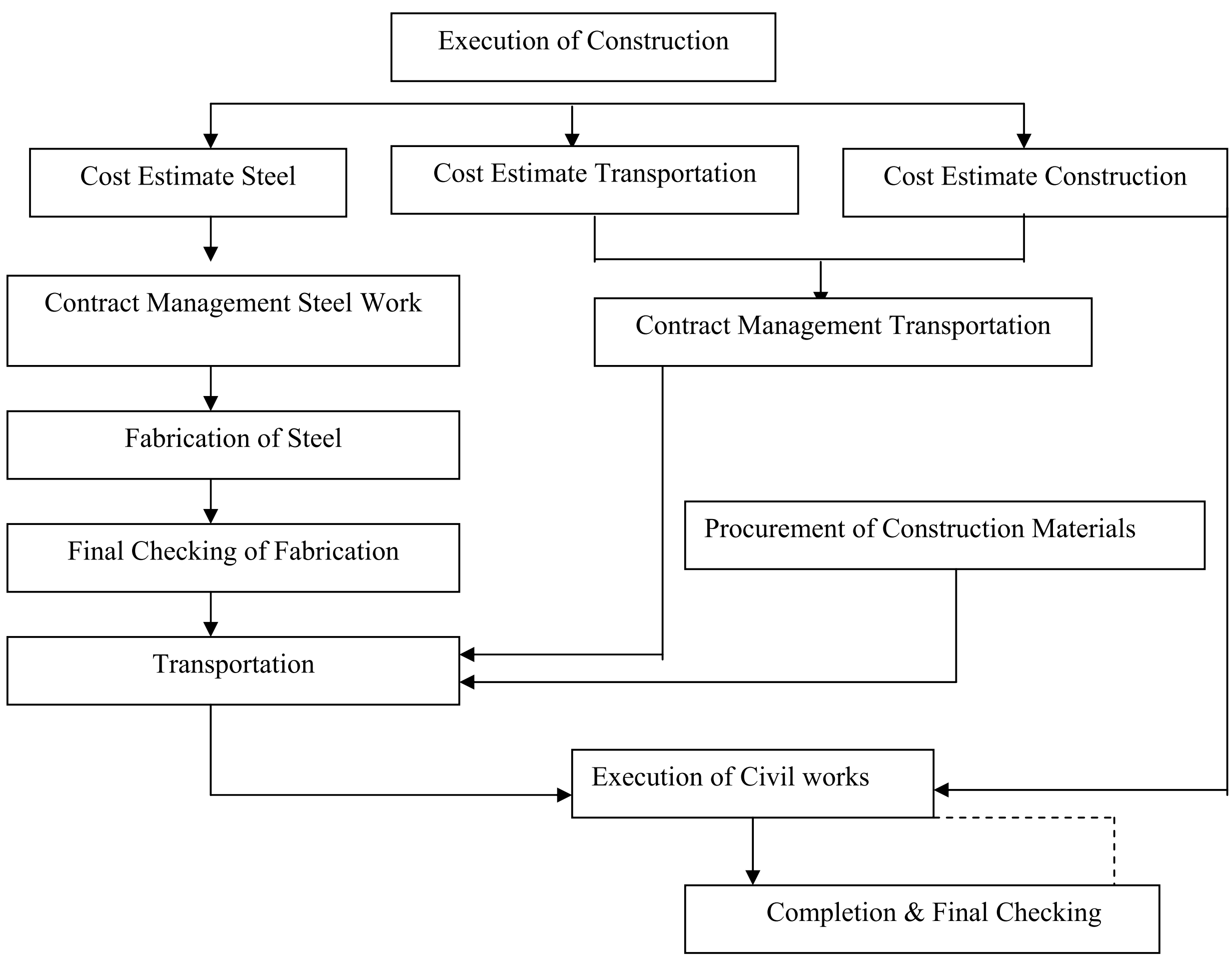
a) Time planning:
  - Schedules
  - Bar charts
  - CPMS

b) Resource planning
  - Fund
  - Material
  - Labour

c) Technical planning
  - Survey
  - Design
  - Revisions

Flow Chart of Activities

A flow chart of processes in general is given below. Based upon it, a detailed flow diagram of activities required for the successful execution of pedestrian bridge construction is to be derived.



The execution of civil works will be carried out in the following order:

S.N.	Work	S.N.	Work
1	Cost Estimate	8	Masonry
2	Contract Management	9	Placement of steel anchorage parts
3	Material Management: Steel, Cement, Cable, Others	10	Erection of bridge superstructure
4	Transportation Management	11	Cable hoisting
5	Site preparation including layout	12	Fitting of bridge parts
6	Excavation	13	Finishing work
7	Concrete	14	Checking of completed work

5.1 FABRICATION

5.1.1 Bridge Parts Fabrication

The fabrication of bridge parts includes:

- Supply of nuts, bolts, washers, thimbles, bulldog grips, G.I.Wire and other fixtures
- Fabrication of bridge parts
- Supply of reinforcement bars

5.1.1.1 Supply of Nuts/Bolts/Washers, thimbles, bulldog grips, G.I. wire and other fixtures

The Specifications are:

- IS 1363-1984 (Part 1) for Hexagonal Head Bolts
- IS 1367-1983 Threaded fasteners
- IS 2315-1978 for Thimbles
- IS 2361-1970 for Bulldog Grips
- IS 2629-1966 for hot dip galvanization of all the above items
- IS 280-1978 for wire mesh netting (60x60mm) wire 10SWG (3.15mm) and for fence netting 12SWG (2.64mm)
- IS 4826-1979 for hot dip galvanization of the wires

<u>The points to be checked are:</u>

- Quality of raw materials

The supplier shall show the manufacturer's certificate. There should be a stamp of the manufacturer.

- Correctness of dimensions

The dimensions must be checked. The sizes should conform to the metric system. The threaded part in the bolt, the size of the washer holes, and the thickness of the bolt head and the washers have to be checked.

- Uniformity in all peace

Sometimes the items are not uniform. There may be different head size bolts and nuts. Particularly such differences may be present in big size nuts and bolts.

- Condition of the threads and mobility of the nuts on the threads

The nuts must turn easily around in the bolts. There must not be any damage in the thread. The burrs remaining after galvanization must be absent. While removing the burrs from the thread, the zinc coating must not be shaped.

- Presence of cracks, bends and other defects

There are sometimes cracks and bends in the nuts, bulldog grips and thimbles. Such items must be rejected.

- Correct Assembly

The nuts, bolts and washers must fit in the places they are designed for. The thimbles must fit the pin or anchor rod.

5.1.1.2 Fabrication of steel parts

The specifications are:

- IS 226-1975 for standard quality of structural steel
- IS 808-1989 & IS 800-1984 for dimensions of hot rolled materials
- FE 410 is the grade of standard quality
- IS 816-1989 for welding work

<u>The points to be checked are:</u>

- The fabricator guarantees the standard quality of the raw materials as per the specifications. The low quality of raw materials can be detected visually by their missing uniformity.
- The dimensions of the steel sections must be within a tolerance of +2.5% .
- It must be checked if heat process has been used for bending, straightening or flattening work. It must be cold process.
- The cutting work or holing work shall be as per the terms of steelwork.
- Experienced and qualified welders must do the welding work.
- The use of templates and jigs is mandatory for the welding of the assembly.
- The welding thickness and the lengths of the welded joints have to be verified with the drawing.
- The smoothness and finishing of the welding have to be checked.
- Avoid techniques which could cause distortion and brittleness in the steel.
- All welding slogs shall be removed because they do not react with zinc during galvanization.
- Sections should have the corners cropped to allow free flow of zinc during galvanization.
- The edges of the angles should be sealed by pore-free weld to prevent penetration of pickle acids.
- Each member has to be labeled clearly indicating the drawing number and the part number, but only after galvanization.
- Straight bars and plates shall be bundled.
- All bolts, nuts and other small and loose parts shall be packed in cases or strong bags and labeled (the weight of each not exceeding 50 kg).
- Storing of threaded parts shall be done with grease and jute covers after they are completed.
- The most important work is the assembly of the steel parts. The galvanized parts shall be assembled after treatment by galvanization.

5.1.1.3 Hot Dip Galvanization

Since 1989, the TBS (SBD) has started doing regular galvanization of steel bridge parts. Before that, the rust prevention of bridge parts was done by applying an initial base coat of red oxide and two coats of polyurethane enamel. But they have a limited period of efficiency. After a few years, these coatings on steel become unstable and must be renewed frequently. When these organic paints or coatings are breached, corrosion begins at the exposed area of the steel and spreads rapidly beneath the coating film. A lot of expenses have to be made for such periodic maintenance and repainting. A zinc coating applied to steel by the galvanization process is the most effective, practical and economic method.

The advantages of galvanization are:

- Zinc coating becomes part of the steel surface it protects. Zinc and zinc-alloy after galvanization are bonded to the steel base by metallurgical process.

- Zinc is highly resistant to the corrosive action of the normal atmosphere and therefore provides long term protection to steel surfaces.
- It provides a durable, abrasion resistant coating. It provides outstanding toughness and resistance to mechanical damage in transport, erection and service.
- It is a versatile process as items ranging from small nuts and bolts to big anchorage and tower parts of a bridge can be galvanized. Where continuity of a galvanized coating is broken by cut edges, drilled holes or surface damage, small areas of exposed steel are protected from corrosion catholically by the surrounding coating.
- The mechanical and physical properties of the parent metal (steel) are not affected by it.
- Any part of the steel structures, either inside or at the corners can be coated by zinc, as the structure is immersed in molten zinc. By other processes, the unexposed part cannot be coated.
- The process is self-inspecting as the reaction between the steel and the molten zinc in the bath does not occur unless the steel surface is chemically clean.
- It has the inherent advantage of application of a standard coating thickness.
- The metallic zinc of a galvanized coating is highly resistant to most corrosive environments, with a rate of corrosion between one seventeenth and one eightieth that of steel, depending on the nature of the corrosive environment. The excellent corrosion resistance of zinc in the atmosphere and in most natural waters is due to the formation of a protective layer or patina which consists of insoluble zinc oxides, hydroxides, carbonates and basic zinc salts, depending on the environment. When the protective patina has stabilized, the reaction between the zinc coating and its environment proceeds at a greatly reduced rate resulting in a long coating life. The protection from corrosion provided by galvanized coatings lasts several times longer than the best alternative coatings.
- The protective life of a metallic zinc coating on steel is roughly proportional to the mass of zinc per unit of surface area regardless of the method of application

The application of zinc coating can be achieved by electroplating, mechanical plating, spraying or painting with zinc coating or sherardizing (dry galvanization). Of these, the hot dip galvanization process is widely used and effective. Most of the bridge parts are exposed to the atmosphere and very prone to the rust. **Therefore, hot dip galvanization is adopted for all bridge steel parts and fixtures as a best and effective method of rust prevention**.

The Nature of Corrosion

Corrosion is basically an electrochemical process. It occurs because of differences in electrical potential, which exist between dissimilar metals in contact or between small areas on a metal surface in the presence of an electrolyte.

1. Variations in composition
2. Presence of impurities
3. Uneven internal stresses
4. A non-uniform environment

The environment may be a damp atmosphere, surface moisture or liquid in which the metal is immersed. All serve as electrolytes allowing formation of small electrolytic cells on the metal surface, with resulting corrosion. Each cell comprises a positive electron-producing anode and a negative cathode. The electrons charged negatively flow from the anode to the cathode. The loss of electrons converts some atoms of the anode to positively charged ions, which in turn react with negatively charged ions in the electrolyte. This reaction between the anode and the electrolyte causes disintegration and corrosion of the anode metal. There is no corrosion of the cathode metal.

METALLURGY OF THE GALVANIZING PROCESS

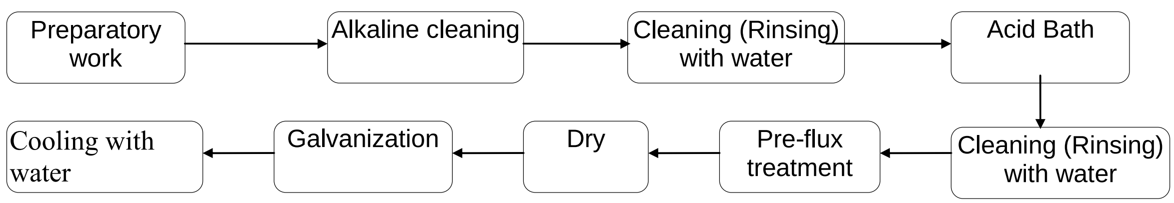
When the cleaned and fluxed steel surface comes in contact with the molten zinc in the galvanizing bath, the protective flux layer is removed, leaving a clean steel surface which is immediately wetted by the zinc. This results in a reaction between the zinc and the steel with the formation of zinc-iron alloy layers.

A typical galvanized coating consists of a progression of zinc-iron alloy layers metalluragically bonded to the base steel. The first layer above the base steel is the Gamma layer, which is a thin moleculer layer containing 21 to 28% iron. Then the second layer is the Delta layer which is a zinc-iron alloy containg 7 to 12 % iron. The third layer is a zinc-iron alloy containing 5.8 to 6.2 % iron. The last or surface layer is relatively pure zinc layer, known as the Eta layer, when it is withdrawn from the bath.

The delta and zeta zinc-iron alloy layers are actually harder than the base steel. Abrasive or heavy loading conditions in service may remove the relatively soft eta layer of zinc from a galvanized surface, but the very hard zeta alloy layer is then exposed to resist further abrasion and heavy loading, providing continued corrosion protection.

Hot Dip Galvanization Process

Galvanizing should follow the process as below :



- **Preparatory work**
  All welding slags should be removed from the steel parts to be galvanized. Acid traps should be avoided.

- **Alkaline cleaning**
  Rust, oil and other contaminants should be removed from the steel by preliminary treatment with <u>Alkaline cleaning</u> in Sodium Hydroxide Solution of 10 ~ 15% concentration.
  The concentration of the solution should be monitored at regular intervals and adjusted accordingly to have good cleaning effect.

- **Rinsing**
  After Alkaline cleaning, steel should be flushed with running water.

- **Acid Bath**
  The preliminary treated steel is then cleaned by Acid Bath in Hydrochloric Acid Solution of 50% concentration.

  During the operation, close control of acid content in the solution is necessary. It is done by testing for acid and iron contents at regular intervals. The strength of the solution should be maintained by periodic addition of fresh concentrated acid. If the iron content in the solution is more than 100g/l, it should be changed by the new fresh solution.

- **Rinsing**
  After Acid Bath steel should be flushed with running water.

- **Pre-flux treatment**
  Acid bathed steel is dipped in a solution of Zinc Ammonium Chloride ($ZnCl_2 3NH_4Cl$) of 20 ~ 40% concentration. This solution is prepared by mixing 45% of Zinc Chloride ($Zncl_2$) + 55% of Ammonium Chloride (NH_4Cl).

  The concentration of solution should be controlled at regular intervals. For this specific gravity of the solution is maintained by adding required quantities of pre-flux chemicals.

- **Dry**
  After pre-flux treatment, steel is dried for galvanization.

- **Galvanization**
  The treated steel is dipped into the molted Zinc (zinc bath). Temperature of the molted Zinc should be maintained within the range of 440^0 C to 460^0 C. Appropriate dipping time also should be maintained.

- **Cooling**
  After the hot dipp, steel is cooled with water.

The variations in the appearance of galvanized coatings listed below and their influence on coating quality are discussed on the following pages.

1. Dull grey coating
2. Rust stains
3. Blisters
4. General roughness
5. Lumpiness and runs
6. Bare spots
7. Bulky white deposit
8. Dark spots

Dull grey coating
General comment: Acceptable.
A dull grey appearance is caused by the growth of the zinc-iron alloy layers through to the surface of the galvanized coating. Grey coatings may appear as localized dull patches or lacework patterns on an otherwise normal galvanized coating or may extend over the entire surface. Dull grey coatings usually occur on steels with relatively high silicon content which are highly reactive to molten zinc.
Dulll grey coatings are often thicker than the normal bright or spangled coatings and therefore have a longer life. It is rarely possible for the galvanizer to minimize or control the development of dull grey coatings which are dependent basically on the composition of the steel.
Rust stains
General comment : Acceptable when present as a surface stain.
Rust staining on the surface of galvanized coatings is usually due to contact with or drainage from other corroded steel surfaces. Steel fillings or saw-chips produced during erection and fabrication operations should be removed from galvanized surfaces to prevent possible localised rust staining.
Rust staining may also be caused by the weeping of pickling acid from seams and joints causing damage to the galvanized coating, and, in such cases, requires modifications in the design.
A thin brown surface staining sometimes occurs in service when the galvanized coating comprises entirely zinc-iron alloys. Staining arises from corrosion of the iron content of the zinc-iron alloy coating and is therefore outside the control of the galvanizer. It has no effect on the corrosion resistance of the coating. Long term exposure testing has shown that the corrosion resistance of zinc-iron alloys is similar to that of normal galvanized coatings.
Blisters
General comment: Small intact blisters acceptable.
Extremely rare. Small blisters in galvanized coatings are due to the hydrogen absorbed by the steel during the process in which pickling is expelled as a result of the heat of the galvanizing process.

Their occurrence is due to the nature of the steel and is outside the control of the galvanizer. Blisters do not reduce the corrosion resistance of the coating.

General roughness

General comment : Acceptable, when agreed.

Rough galvanized coatings usually result from uneven growth of zinc-iron alloys because of the composition or surface condition of the steel.

General roughness may also be caused by over-pickling, prolonged immersion in the galvanizing bath or excessive bath temperature, factors which are frequently dictated by the nature of work and may be beyond the control of the galvanizer.

Rough coatings of this type are usually thicker than normal and therefore provide a longer protective life.

Lumpiness and runs

General comment : Acceptable unless specified otherwise .

Lumps and runs arising form unevern drainage are not detrimental to coating life.

When zinc drainage spikes are present on galvanized articles and their size and position are such that there is a danger they may be knocked off in service which removes the coating down to the alloy layers, they should be filed off by the galvanizer, and where necessary, the coating should be repaired using a zinc rich paint coating.

Pimples

Geneal comment: May provide grounds for rejection depending on size and extent.

Pimples are caused by inclusions of dross in the coating. Dross, which is a zinc-iron alloy particle, has a corrosion rate similar to the galvanized coating and its presence as finely dispersed pimples is not objectionalble.Gross dross inclusions may provide grounds for rejection as they tend to embrittle the coating.

Bare spots

General comment: Acceptable if small in area and suitably repaired, depending on the nature of the product.

Transport and storage of galvanized products

New galvanized products should be handed, transported and stored with the normal care given to any other surface finished material. New galvanized steel surfaces which normally contribute to the long life of aged coatings are highly reactive and susceptible to premature corrosion under poor conditions of exposure.

Transport should be under dry, well ventilated conditions. When stored on-site, the material should be covered where possible and raised clear off the ground on dunage or spacers. When shelter is not possible, the material should be stacked to allow drainage of rain water. Storage in contact with cinders, clinkers, unseasoned timber, mud or clay will lead to surface staining, and in severe cases, premature corrosion.

5.1.1.4 Supply of Reinforcement Steel

The specifications are:

- IS 1786-1985 for high yield strength deformed bars
- FE 415 is the grade of the bar (ribbed)

The points to be checked are:

- They should be clean and free of loose mill-scales, dust, loose rust and paints, oil or other coating, which may destroy or reduce bonding with concrete.
- They should be cold bent.
- Welded joints or mechanical connections are not acceptable.
- Grinding shall make the points in the anchor rods.
- All items should be checked individually instead of doing a sample check.

5.2 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.

5.2.1 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.

5.2.2 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.

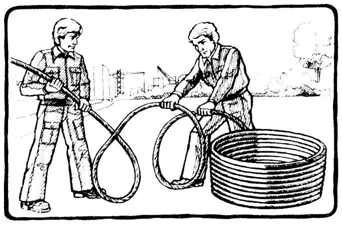
5.2.3 Wire Rope Transportation and Storing

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.

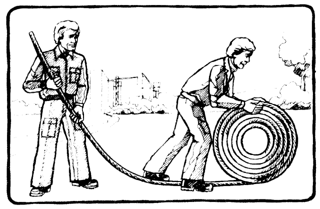
Also pulling or dragging the cable along the road for transportation is not permitted.

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

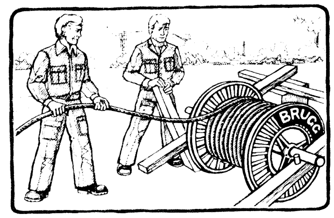
- Method of Unreeling Light Cables with the Help of a Reel Support



Wrong

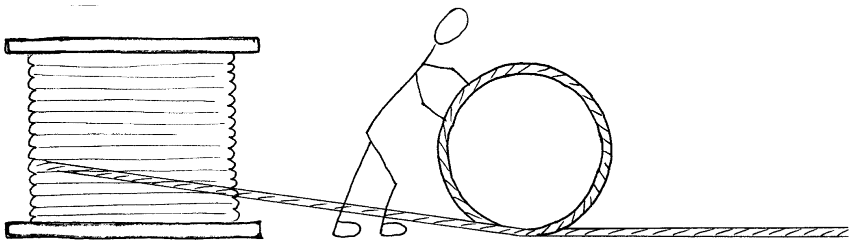


Correct

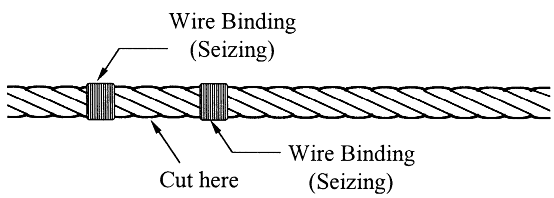


Correct

- 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.



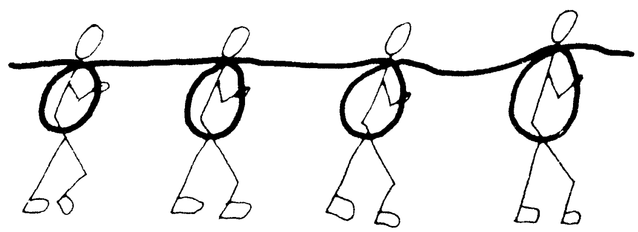
- Method of Transportation by Porters

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

5.3 CONSTRUCTION

5.3.1 Demonstration Model Bridge Training (DMBT)

The Demonstration Model Bridge Training (DMBT) is provided for technical orientation and social orientation to local bridge builders ("bridge-craft persons") and a selected UC member. Usually, 3 local bridge builders (1 either Dalit or Woman) and 1 UC-member are selected to take part in this training. The basic aim of this training is to achieve a good quality bridge, which starts with the quality of the local materials. Furthermore, this training aims at capacitating, especially the UC member, in matters such as the overall planning and management of the bridge construction, including social mobilization. It is very important to select and send the right participants to the DMB training. Bear in mind that their services will not be confined to one bridge only, but will also be required in the future for other sites. Considerable attention is to be given during the Social and Site Assessment and Community Agreement processes to select the most appropriate participants.

The UC has to give preference to previously trained local bridge builders that live in the near vicinity. Only if experienced bridge builders are not available should the UC select other persons for this DMB Training.

The DMBT is carried out in a district for 5 bridges. Hence, there are usually 20 participants. The duration of the training is 7 days. During the training, the participants complete a model bridge of miniature size. If there are bridge builders at the bridge site who have gone through the DMBT for other bridges in the past, then the DMBT may not be required for the present bridge.

In the DMBT, the following topics are discussed:

DMBT Training Curriculum

- **Social orientation**

The DDC technician takes the lead in facilitating the training. The objectives are to master the skills required to obtain good quality materials, to master the skills that yield a certain bridge quality standard and to become proficient in various management aspects like local resource mobilization and division of labour.

- **Process of bridge building**

The DDC technician, as the facilitator, has to show the process of bridge building, starting from the collection of local materials up to the completion of the bridge, and to the formation of the Bridge Maintenance Committee.

- **Local resources mobilization**

Brainstorm about issues like the type of local resources and the use of such resources. Then make a list of the local resources that are within reach of the users. Ask the participants to share their experiences gained in other projects concerning mobilization of local resources. Conclude by summarizing the discussion and giving tips on how to mobilize local resources, bearing their particular situation in mind.

- **Division of work**

Discuss on the need and importance of division of work. Let the trainees (in random groups) practice dividing the work.

- **Record keeping**

Persuade the trainees to identify the kind of records they need to keep. Ask for their experiences regarding how they kept such records during the implementation of similar projects. Visualize the need and importance of record keeping by randomly asking questions on the need and importance of record keeping to the group members and by writing the outcome on newsprint. Summarize the outcome and proceed by giving examples on how to keep records of resources received and used, attendance and decisions made by the UC. Form small groups while doing group works.

- **Decision-making process**

Focus on how to make the decision-making process a participatory one.

- **Correspondence**

Let the participants identify the level (e.g. DDC, VDC, UC, users, BBLL) and means (e.g. post, fax, courier, email) of correspondence they have to maintain regarding bridge building.

- **Routine and major maintenance**

Emphasize the importance of routine and major maintenance of a bridge. Highlight the basic differences in routine and major maintenance on the different bridge components like foundations, cables, wire mesh and others and their specific condition.

- **Involvement of local bridge builders**

Reconfirm that the DMBT trainees will certainly be involved in the actual bridge building. The ultimate quality of the bridge and the required construction time primarily depend on the dedication of the bridge builders. Let the individuals commit themselves, in front of others, so that they are fully dedicated towards delivering top quality work. For this, encourage the individuals to speak in front of others. Encourage the bridge craft persons to express their doubts, if any, in front of others regarding their involvement. Let the UC representatives help them to overcome these doubts.

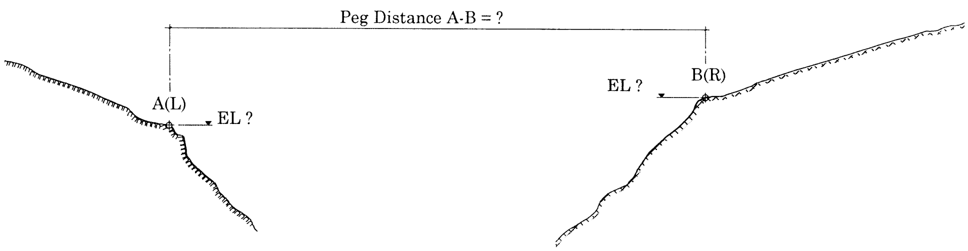
5.3.2 Construction of Suspended Type Bridge

5.3.2.1 Bridge Layout

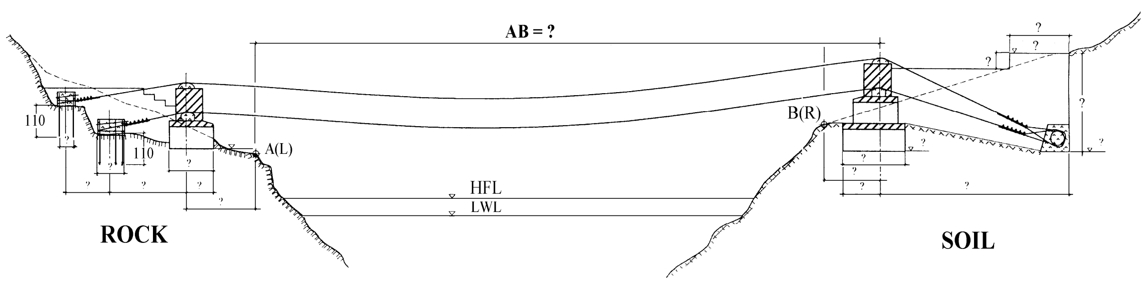
The Bridge Layout is to fix the bridge position and foundations at the site as per the design.

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

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

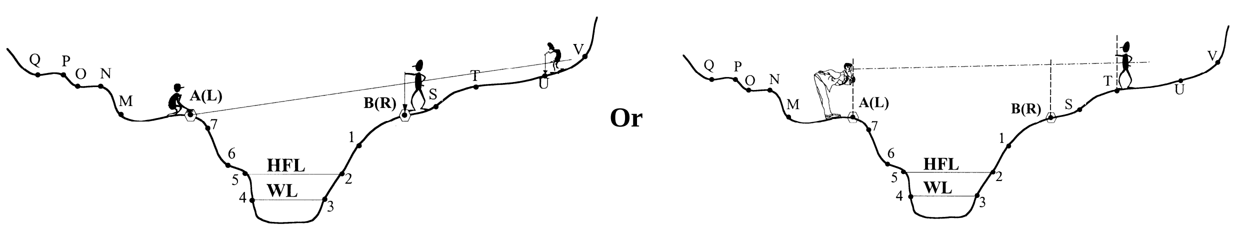


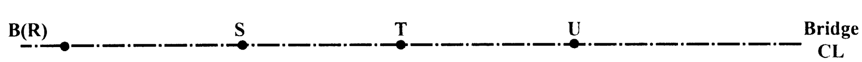
- If the horizontal distance between the axis pegs A (L) and B(R) and their elevations are not similar to the measurements given in the GA, readjust the design according to the actual measurements.
- If the horizontal distance between the axis pegs A (L) and B(R) and their elevations are identical to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



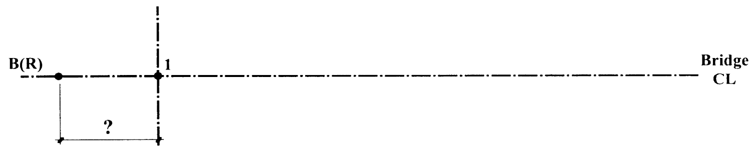
Procedure for Detailed Foundation Layout:

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



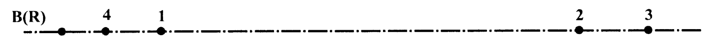


- Mark the front of the tower foundation on the bridge centerline (peg 1) with reference to the axis peg. The distance between the front of the tower foundation and the axis peg is given in the GA.

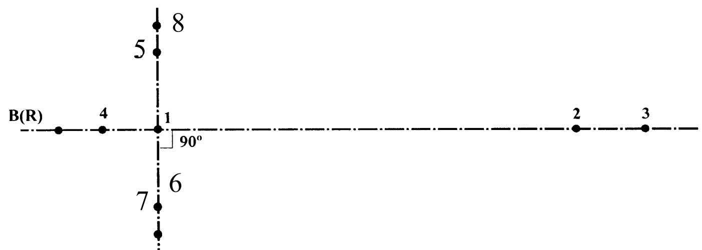


- Check the location of the front of the tower to ensure there is sufficient distance (minimum 3 m for soil slope and 1.5 m for rock slope) from the bank edge.

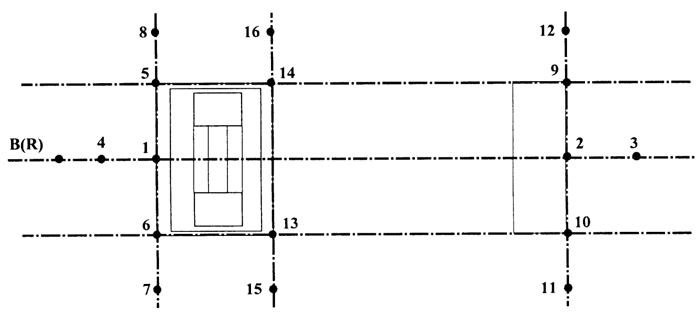
- Measure the length of the foundation from peg 1 and fix peg 2. Set up two additional centerline pegs at a safe distance for the excavation works (pegs 3 and 4).



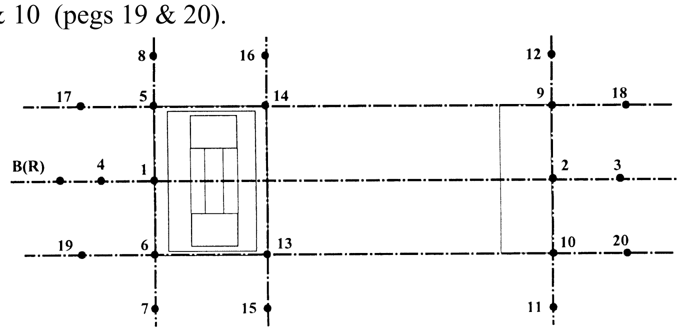
- Draw an offset line (right angle) through peg 1 by the 3-4-5 method . Starting from peg 1, set out pegs 5, 6, 7, and 8 for the reference line of the front edge.



- Draw an offset line through peg 2 for the reference line of the back edge. Starting from peg 2, fix 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 (pegs 19 & 20).

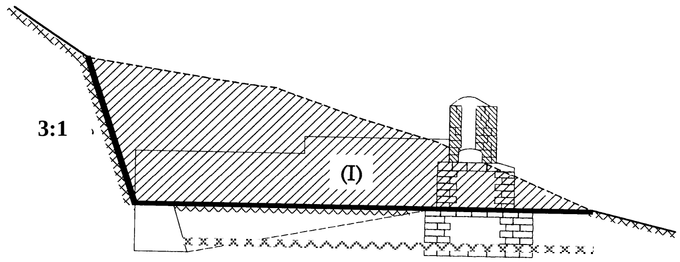


- Fix the elevation line (datum level) and indicate the depth of the excavation work for the tower and the deadman or drum anchorage as per the elevations shown in the GA and Anchorage Block drawings.

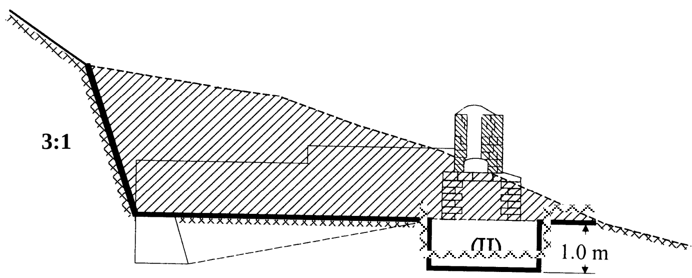
5.3.2.2 Earth Work

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

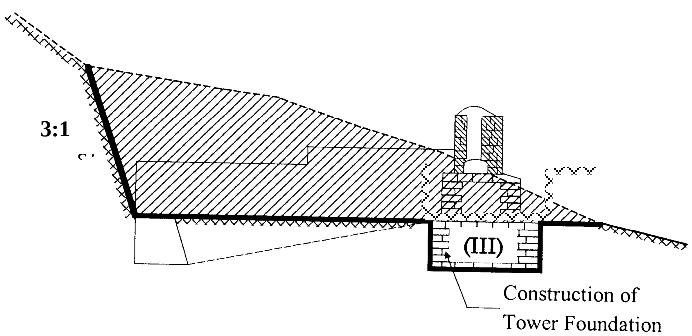
- 1st Stage – All excavation as shown in the sketch below.



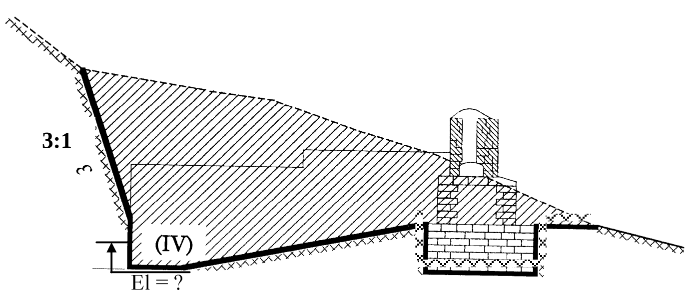
- 2nd Stage – Foundation excavation for tower as shown in the sketch below.



- 3rd Stage – Construction of the tower as per the design.



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

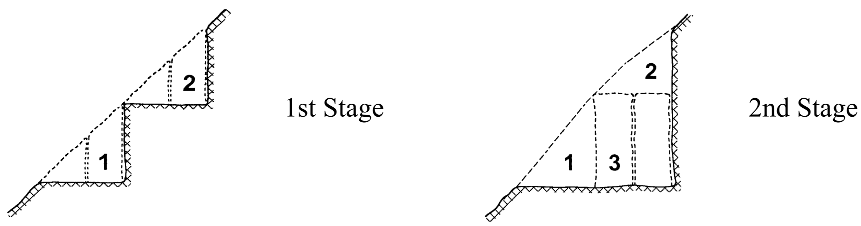


In all of the above excavation stages, the excavation depth should be maintained accurately. For this, establish an elevation line (datum level) and measure the foundation depths with a fixed stick.

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

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

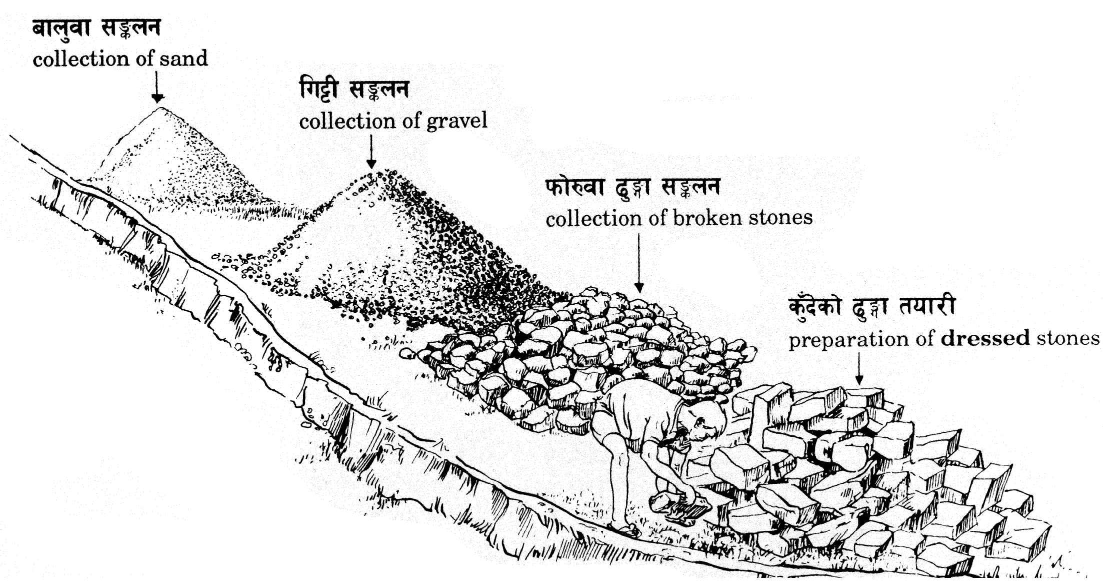
Excavation in rock is done by first drilling holes to weaken the rock and then using crowbars to break up and dig out the rock parts. The cutting can be carried out by forming steps, as shown in the following sketches.



Further details on drum anchorage foundation in rock are given in Chapter…….

5.3.2.3 Local Material Collection

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



- **Stone/Boulders**

The best stone collection is from a rock quarry. The rock should be unweathered, hard and dense with metallic sound.

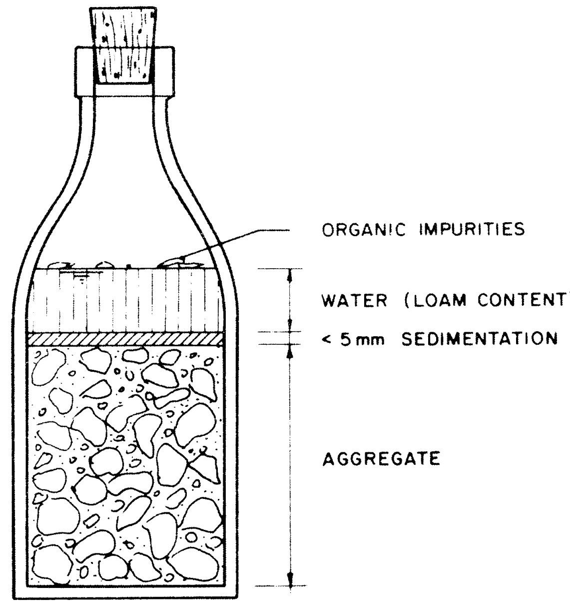
In unavoidable cases, boulders from river deposits can also be collected. However, this can be used only for filling purposes (broken stone filling). In any case, stones from a rock quarry are necessary for masonry works.

The quality requirement for the stone/boulders is further detailed in Chapter …….

- **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 for presence of impurities such as mica, clay, loam, mud organic materials, etc. If such impurities are unavoidable, it is recommended that the sand be washed before use. Sand containing significant quantities 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 5 mm after two hours. And the water above will be only lightly cloudy. The quality requirements for sand are further detailed in other chapters.



- **Gravel**

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

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

Gravel should be of hard rock origin. Gravel of unsuitable rock such as mica, marl and sandstone 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 requirements for gravel are further detailed in forth coming chapters.

5.3.2.4 Masonry and Stone Dressing Work

- **Requirements for Building Stones**

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

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

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

- **Quarrying**

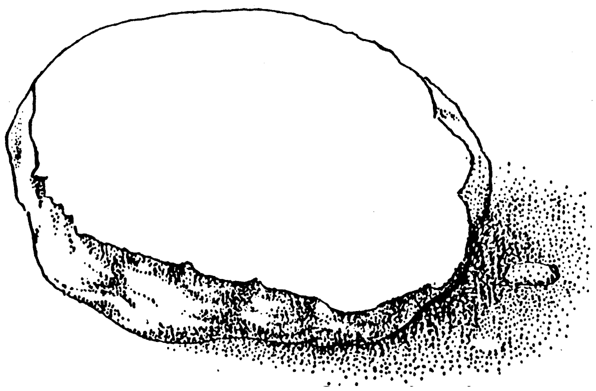
Rocks for stone masonry works should be broken from a quarry by crowbars and wedges. Natural fractures and bedding planes of stratification are the weak features of rock. These natural joints are taken as advantage to break and separate one block from the other.

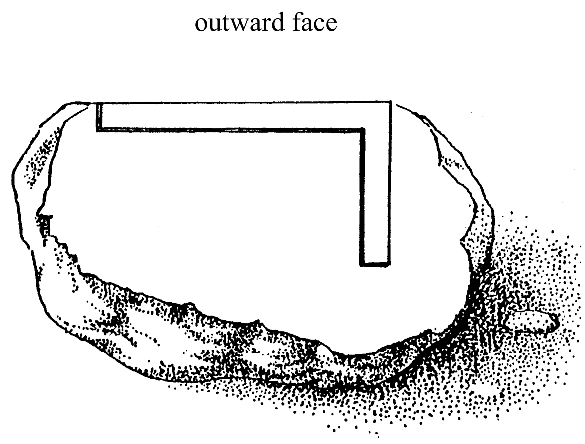
It is advised that only when natural joints do not exist that artificial fissures be made by drilling a line of holes in rows along the desired breaking line. By inserting conical wedges and driving them in succession with a hammer the rock will crack along the face o f the holes.

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.





not suitable for stone dressing.

- **Stone Dressing**

Broken stones from the quarry are to be dressed by hammer or chisel to required sizes. Depending on the **function** of the stone in stone masonry construction the 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

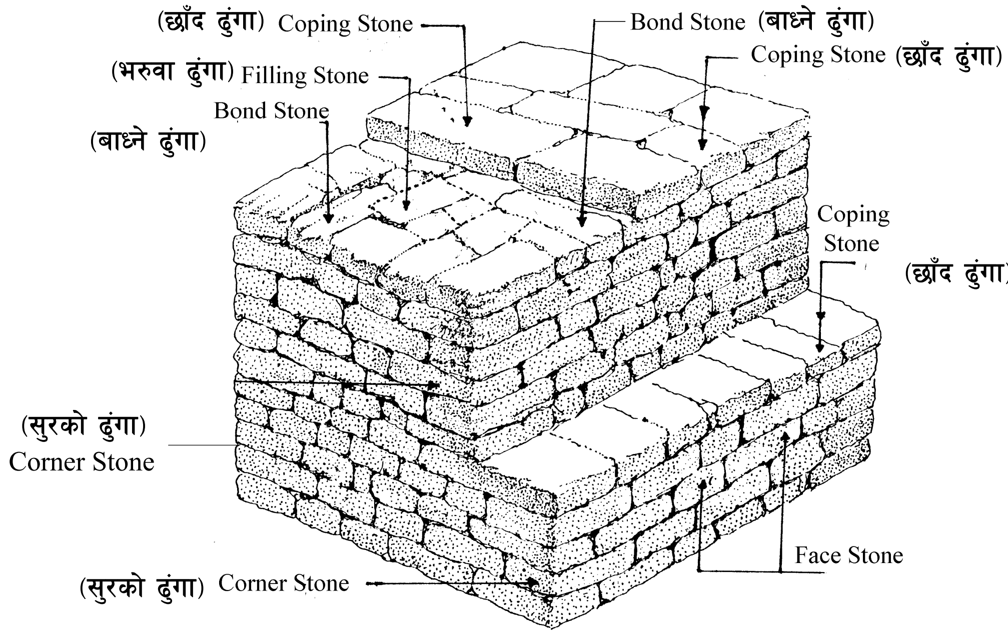
➢ **Bond Stone:** Like the face stone only one face is outside, but the bond stone extends to the interiors of the structure. Bond stones, also called **through stones,** go right through walls of up to 85 cm thick or more. Recommended sizes are:

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.



- **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.

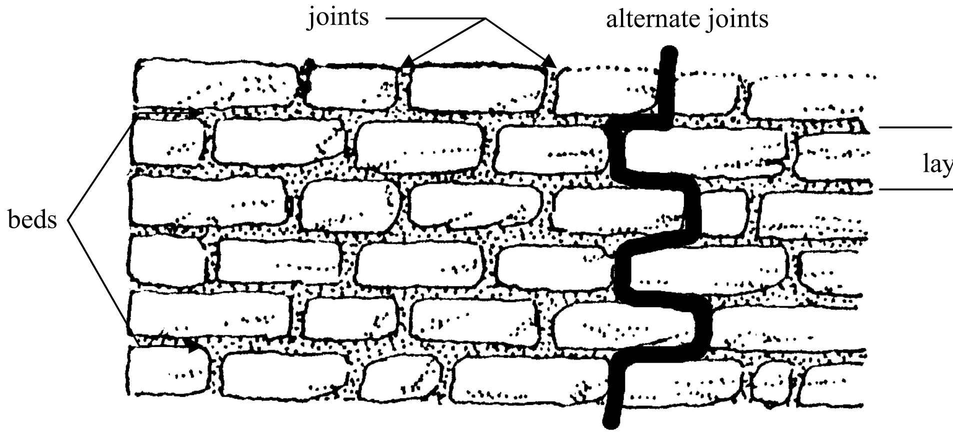
- **Coursed Block Stone Masonry**

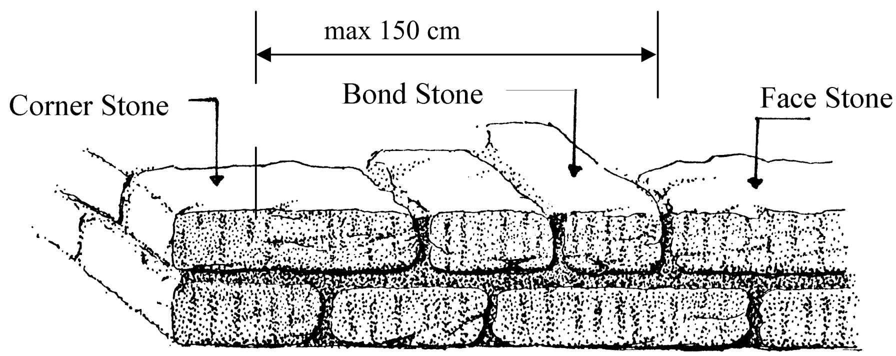
The stones are chisel-dressed at all faces, except the inside face. Joints are dressed at right angles to the face. Gaps between beds and joints should not exceed 6 mm.

All **Face Stones** tail into the wall twice their height.

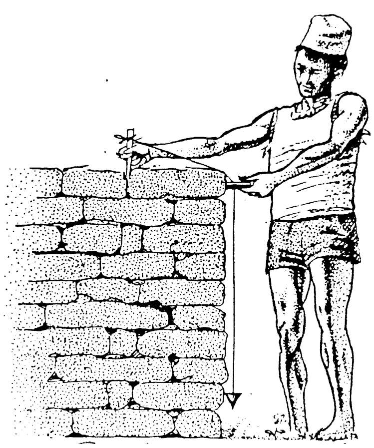
Bond Stones running right through the wall are inserted in each course at least at every 150 cm intervals.

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.





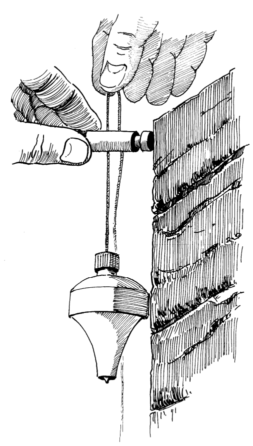
In a reasonably well made stone masonry the inner friction between the beds amounts to approx. 35°. The verification of corners as well as faces has to be checked carefully with the plumb-bob.



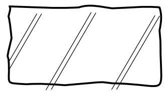
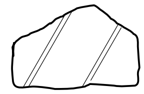
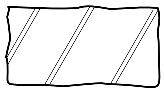
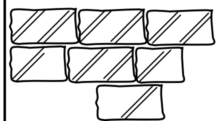
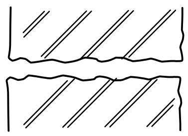
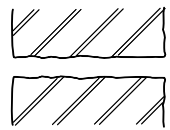
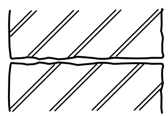
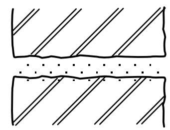
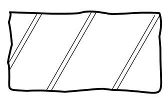
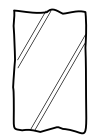
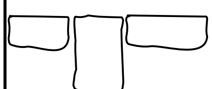
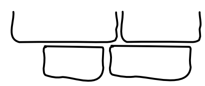
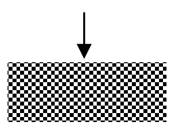
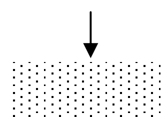
correct use

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

5.3.2.5 Cement Works

A. 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 are given by the mix proportions of their components:

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

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

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

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 Cement : Sand : Gravel	Dry required quantities for **one cubic meter** wet: Cement bags @ 50 kg	kg	Sand [m^3]	Gravel [m^3]	Stones or Boulders [m^3]
Cement Mortars	**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**	**-**	**-**
Cement Plaster (20 mm includes 12% waste)	**1 : 4 -**	**0.18**	**9**	**0.024**	**-**	**-**
	1 : 6 -	**0.12**	**6**	**0.024**	**-**	**-**
Cement Stone Masonries	**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**
Cement Concretes (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**	**-**
"Plum" Concrete	**1 : 3 : 6** 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.

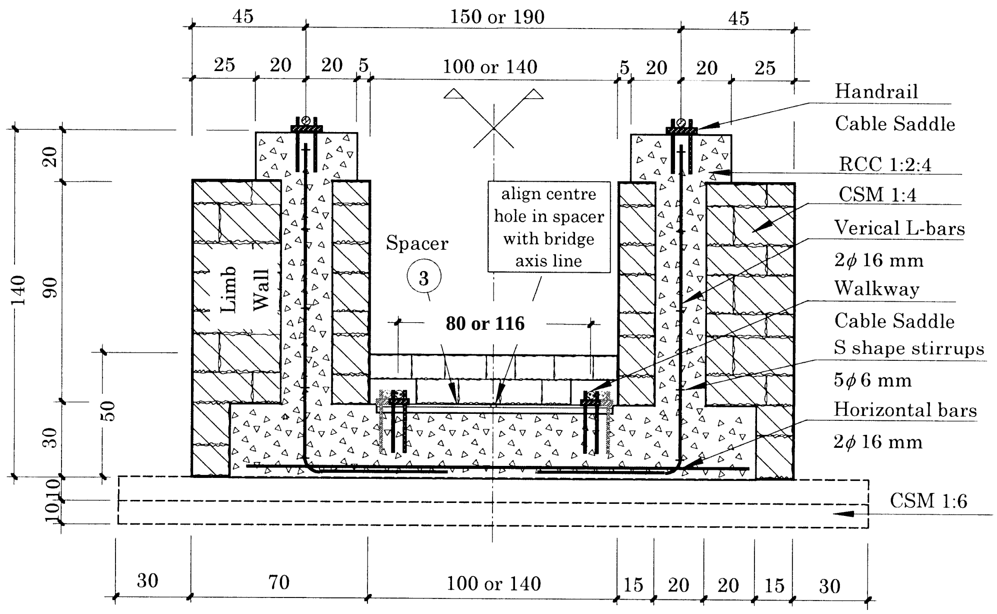
Curing means keeping completed cement works wet until its setting process is completed. If concrete works are not continuously kept wet during its setting process, cement mortars, cement stone masonry work and especially concrete does not develop its full strength. Curing should be done for at least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

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

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

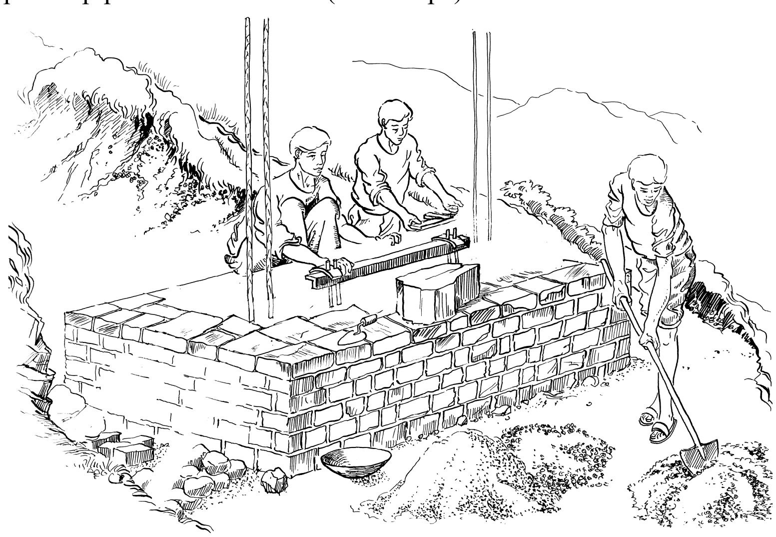
The CSM Towers or Limb Walls are concreted together to form one solid unit (See Drawing Nos. 20Dcon70 & 20Dcon106). The core and the connection of both the towers are made in R.C.C 1:2:4, whereas the limb walls are made in CSM 1:4.

Section through CSM Tower (Bridge Entrance)

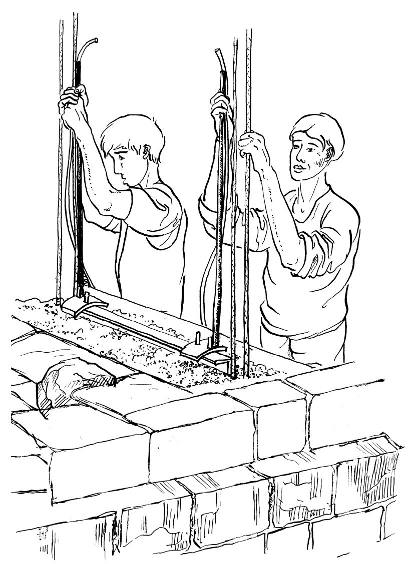


- **Placing the Saddles for the Walkway Cables**

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



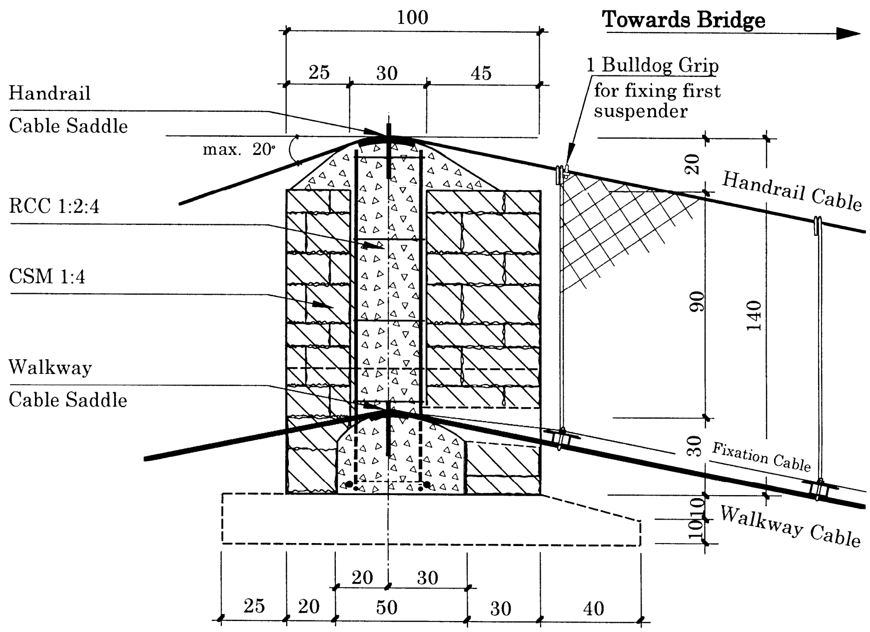
Concreting Work for CSM Tower



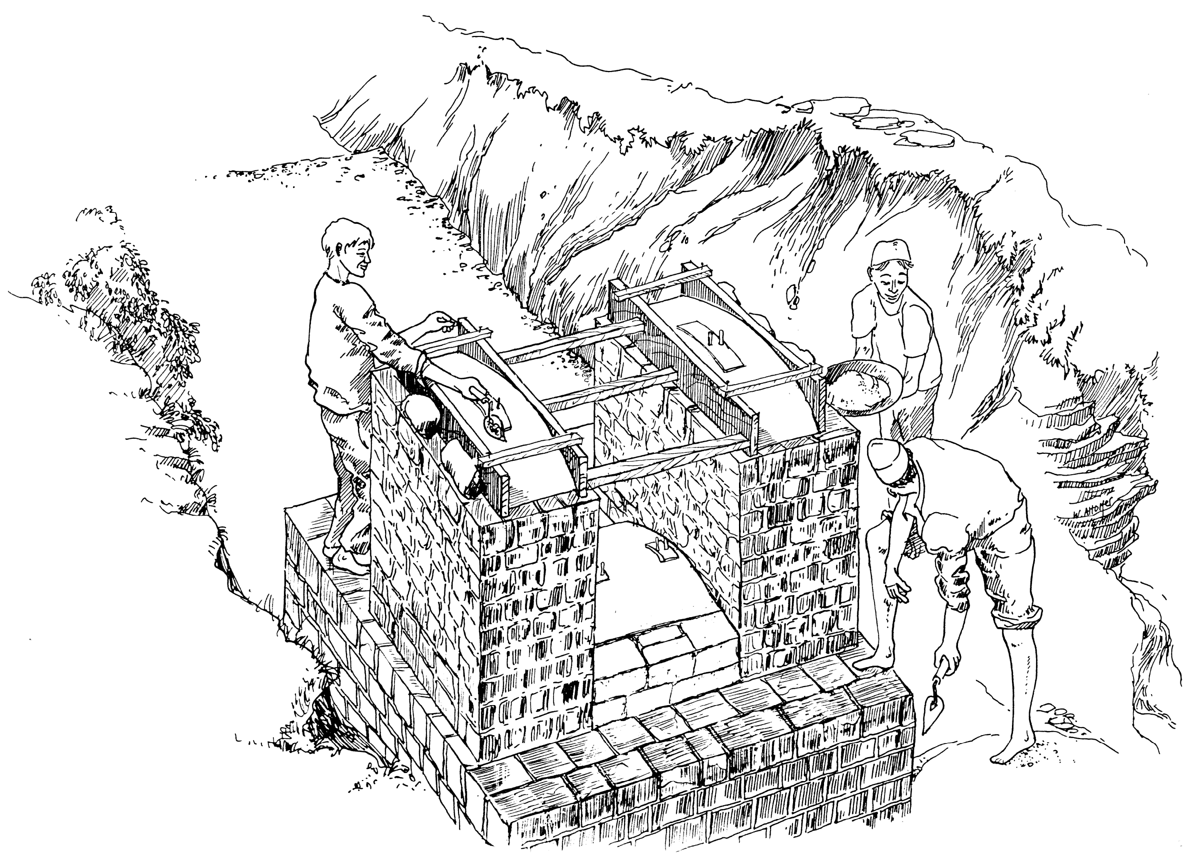
Checking Level of Walkway Cable Saddles

- **Construction of Towers and Placing Saddles for Handrail Cables**

The Towers or Limb walls support the handrail cables. The limb walls are made out of cement stone masonry 1:4 with a R.C.C. core.
The handrail cable saddles are to be placed on top of the "hump" of the limb wall. Make sure that the position and shape of the "hump" is correct so that the handrail cable touches the saddle plate only.



Section View



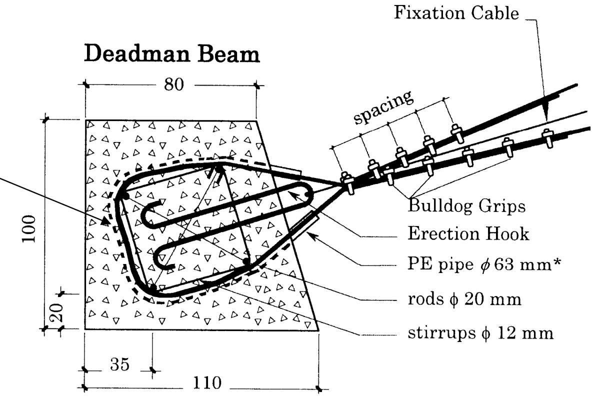
Finishing off the CSM Tower

C. Constructing the Deadman Beam

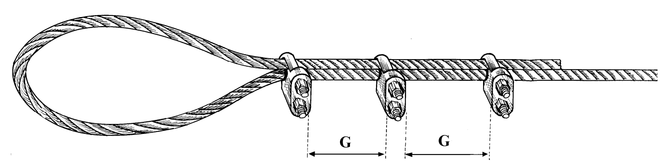
The Deadman Beam is a **soil anchor** cast in reinforced cement concrete R.C.C that lies buried under the gravity structure. The handrail and walkway cables are placed around the reinforcement bars **before** concreting the beam. At one bank the cables are inserted into a polyethylene (PE) pipe, so that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

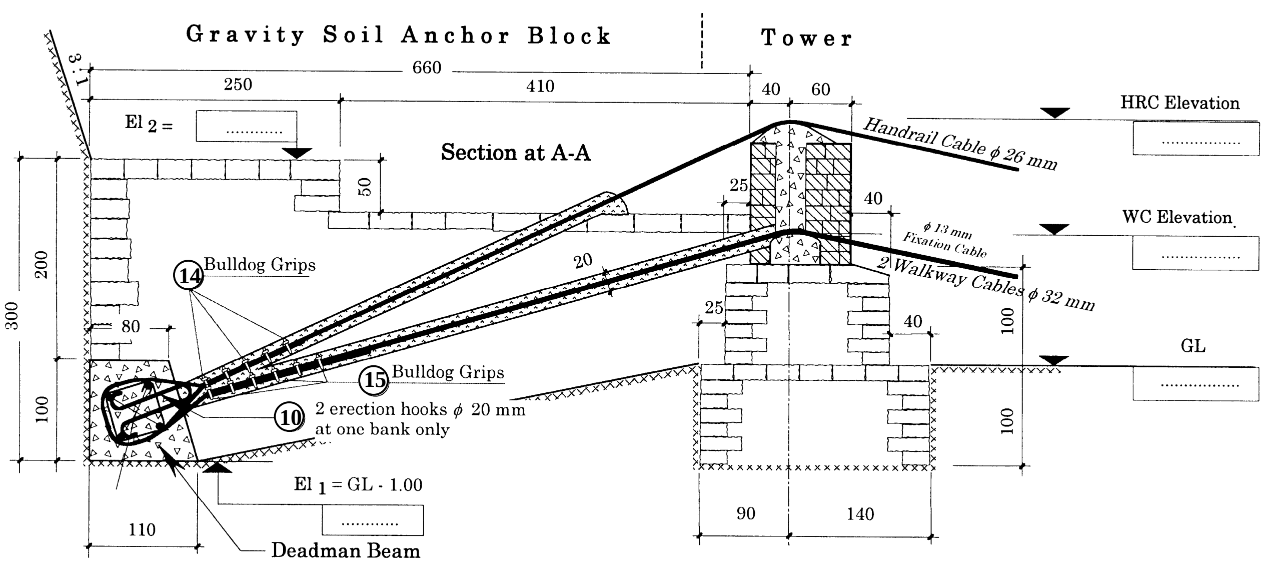
The PE pipe can also be bent by preheating it before bending.



Nos & spacing of Bulldog Grips		
Cable ϕ 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.

D. Constructing Drum Anchorages in Rock

There are two types of Drum Anchorages in Rock:

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

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

Fill the holes with cement mortar 1:1 before the anchor rods are inserted.

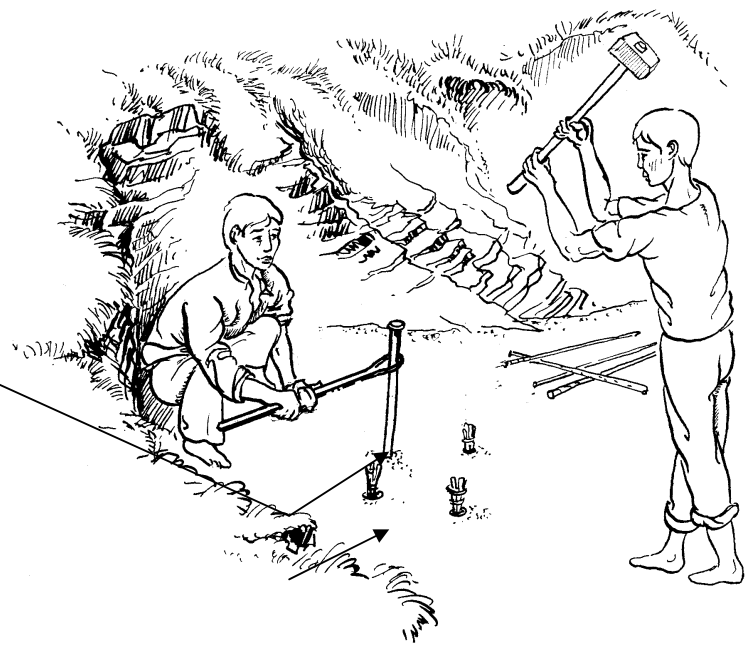
The formwork for the drum is made by a chitra (bamboo mat) or plain G.I. sheet inside lined with a plastic sheet.

Use binding wire around the chitra to prevent the bamboo mat bulging during concreting.

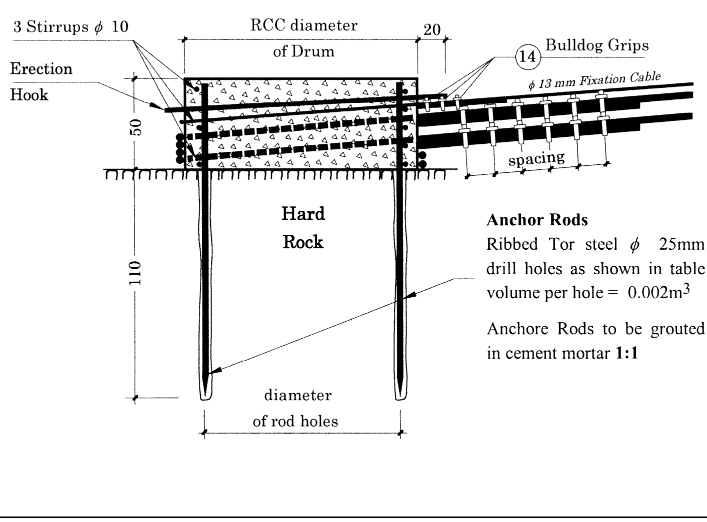
Drilling starter holes (up to 1 foot) for Anchor Rods of a Drum Anchorage in Hard Rock.

Rotate chisel from time to time.

Use crow bar for making holes deeper.

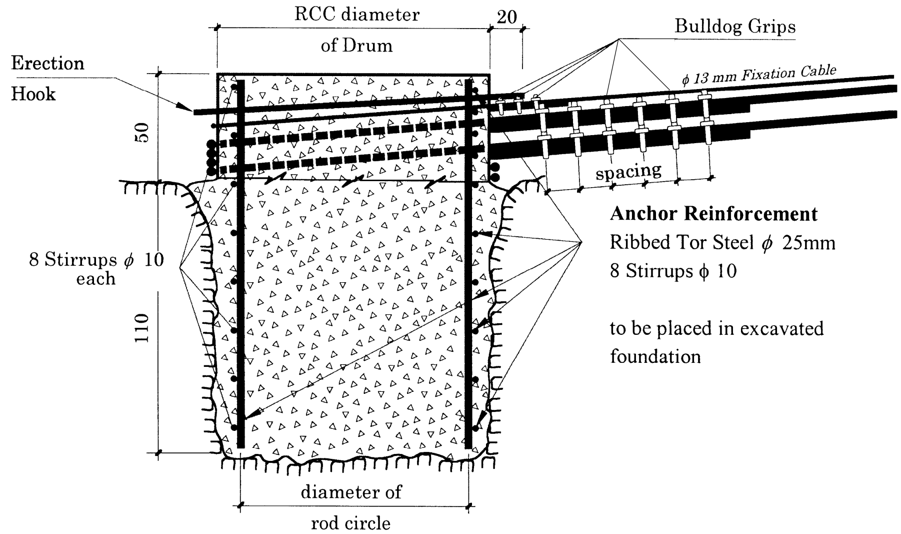


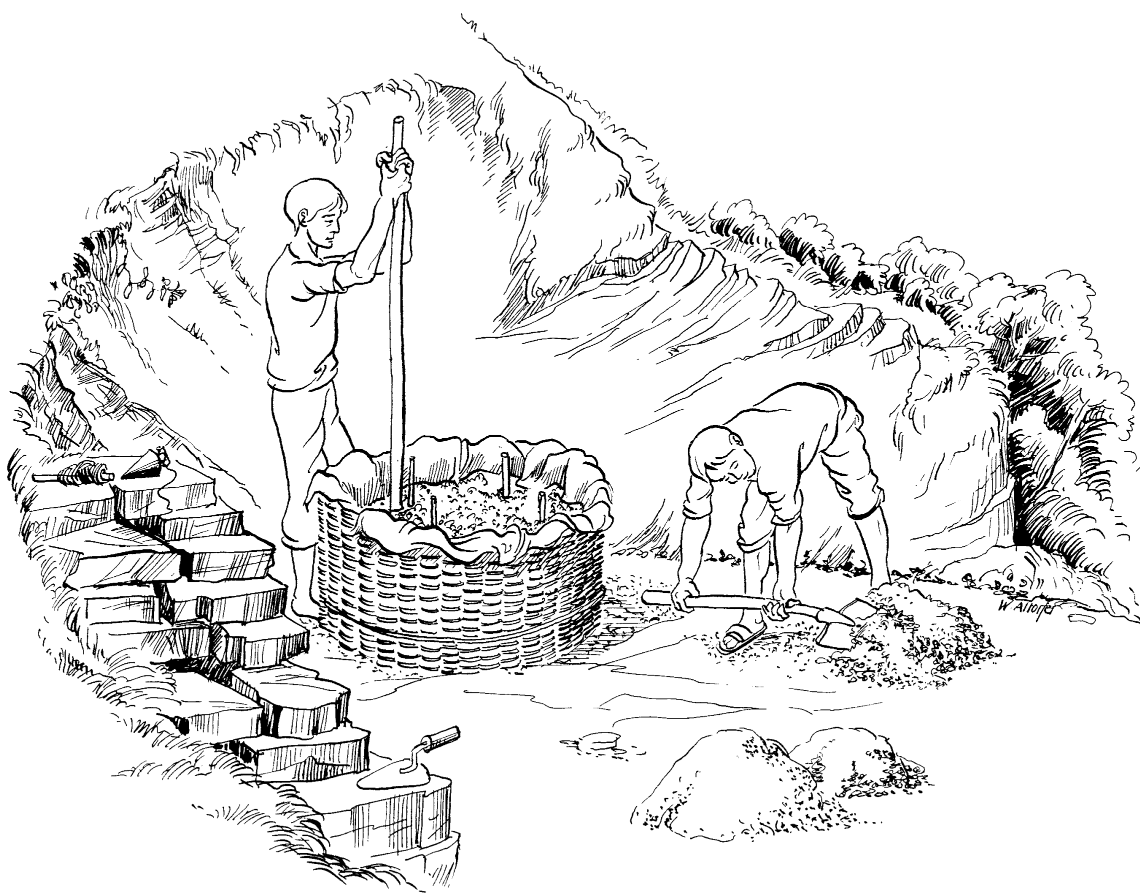
Typical Cross Section of RCC Drum in Hard Rock



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





5.3.2.6 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.

A. Calculation of Hoisting Sag

Before starting any hoisting work, the actual span ℓ from saddle to saddle of the bridge and the actual difference of elevation **h** between the walkway cable saddles have to be measured first and calculate as per following table.

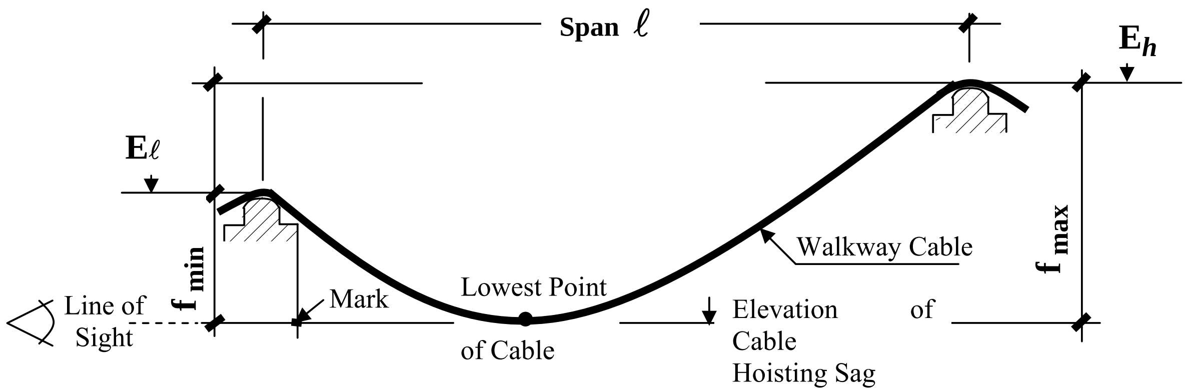


Table for Calculating Elevation of Low Point for Cable Hoisting

1. Actual Span measured in the Field					ℓ =……………m
2. Saddle Elevation of the Walkway Cable on the **higher** side					E_h =……………m
3. Saddle Elevation of the Walkway Cable on the **lower** side					E_ℓ =……………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.

B. Cable Hosting

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

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

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

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

Check also that parallel cables have equal hoisting sag.

5.3.2.7 Finalizing the Cable Anchorage

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

A. Rust Protection for the Cable

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

B. Completing the Gravity Structure

The actual gravity structure on top of the Dead Man Beam or Drum Anchors is constructed according to the respective construction drawing 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 for as possible. (Refer also to chapter 6.4 Masonry and Stone Dressing Work).

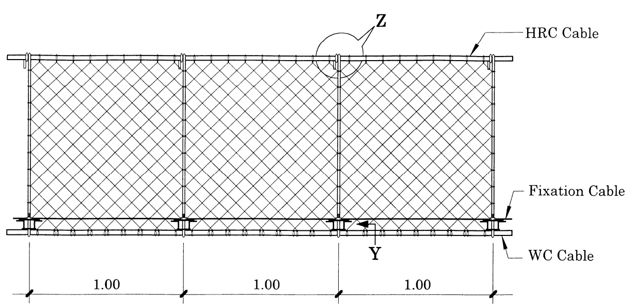
> Only **after** the gravity structure is completed can fitting work for the walkway structure start.

5.3.2.8 Walkway Fitting

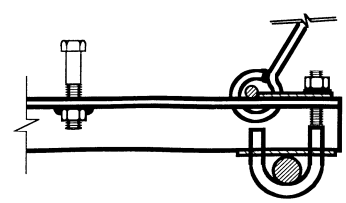
The fitting work for the walkway must only start after the gravity structure of the cable anchorage have been completed. Walkway fitting is simple and self-explanatory. Refer also to the construction Drawings No. **19Dcon70** or **19Dcon106** respectively.

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.



VIEW OF FENCE WEAVING

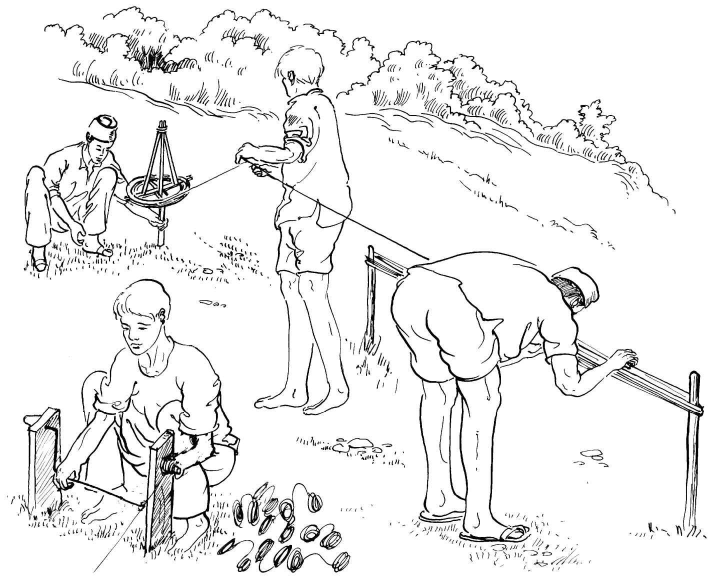


View at - Y

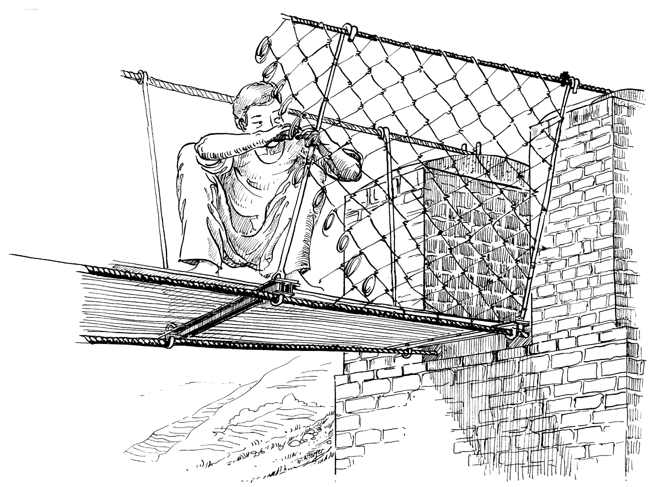
Fencing is woven on the spot with gabion wire (12SWG) between the handrail cable and the fixation cable. First fix the fixation cable by pulling it through the bottom eye of the suspender along either side of the walkway, and then join it with the short piece at the other end of the bridge.

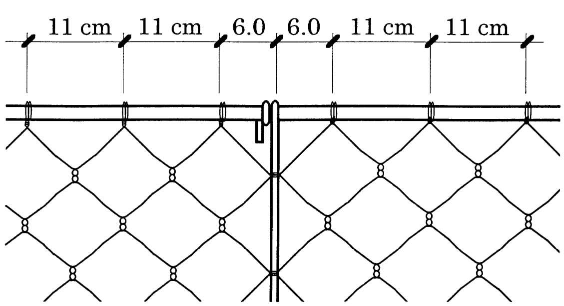
Preparing Coils

Cutting Length is 4.20 Meters



…**for Fence weaving**





Detail at - Z

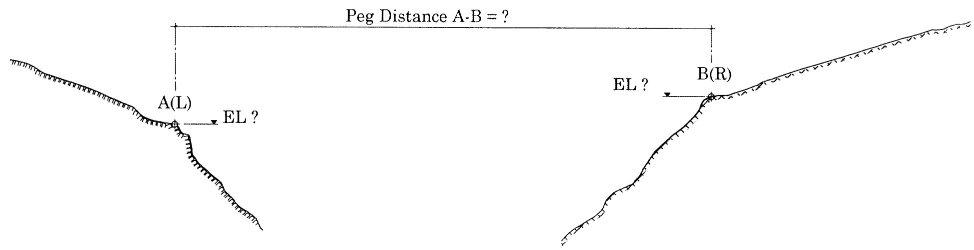
5.3.3 Construction of Suspension Type Bridge

5.3.3.1 Bridge Layout

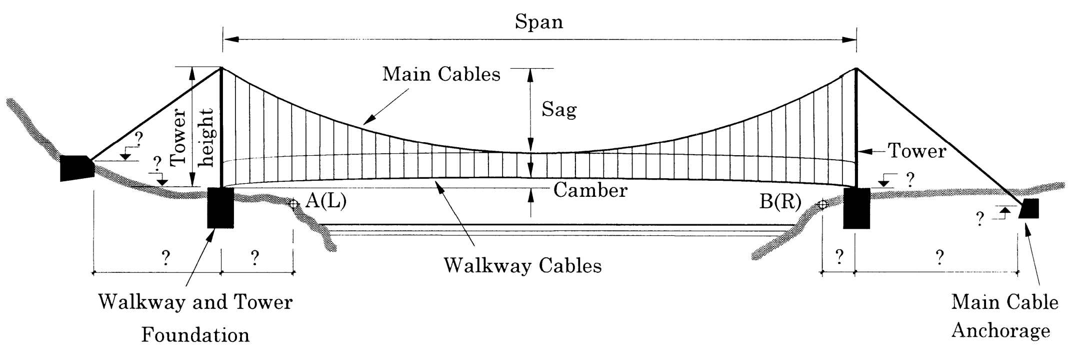
The Bridge Layout is to fix the bridge position and foundations at the site as per the design.

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

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

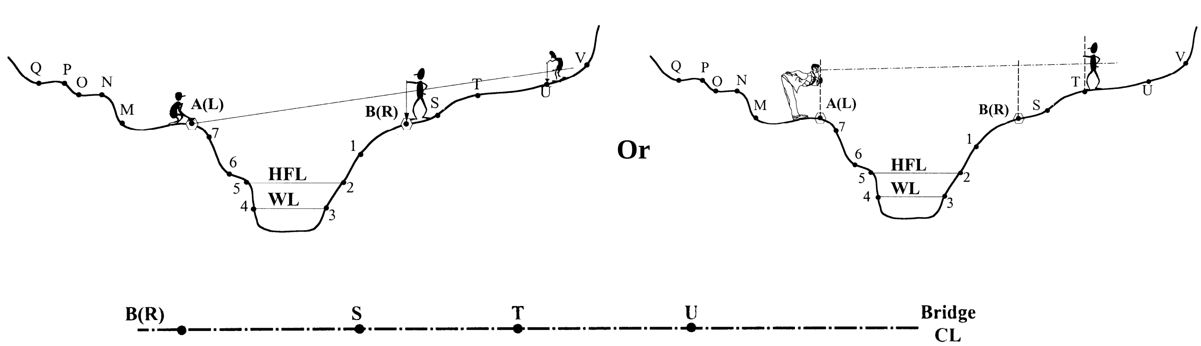


- If the horizontal distance between the axis pegs A (L) and B(R) and their elevations are not similar to the measurements given in the GA, readjust the design according to the actual measurements.
- If the horizontal distance between the axis pegs A (L) and B(R) and their elevations are identical to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



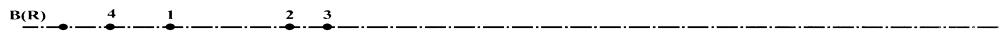
Procedure for Detailed Foundation Layout:

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

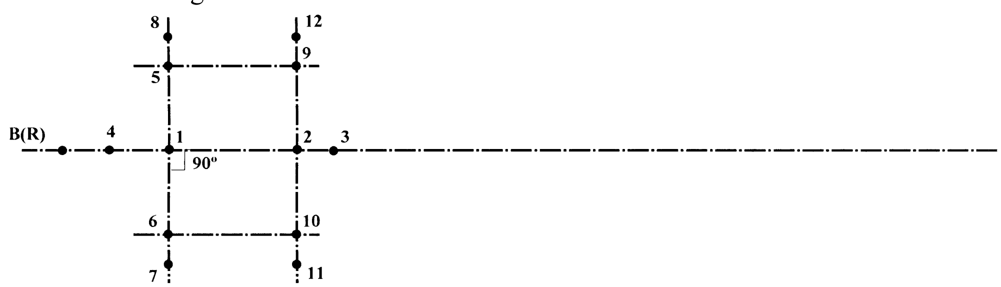


- Mark the front of the tower foundation on the bridge centerline (peg 1) with reference to the axis peg. The distance between the front of the tower foundation and the axis peg is given in the GA.

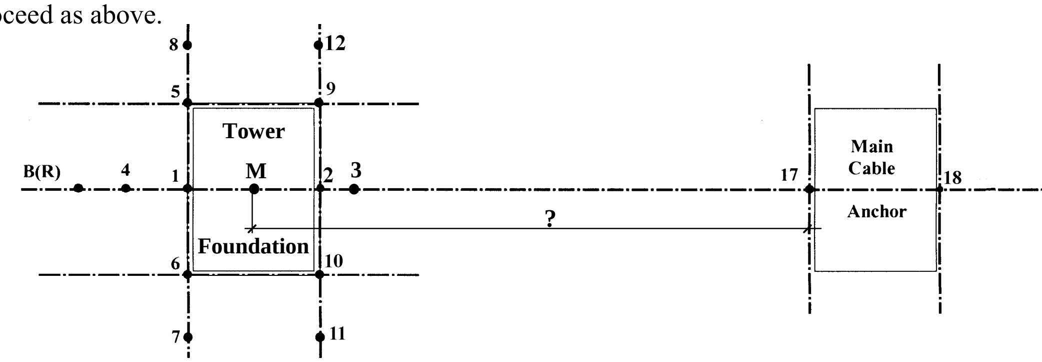
- Check the location of the front of the tower to ensure that it is at a sufficient distance (minimum 3m for soil slope and 1.5m for rock slope) from the bank edge.
- Measure the length of the foundation from peg 1 and fix peg 2. Set up two additional centerline pegs at a safe distance for the excavation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



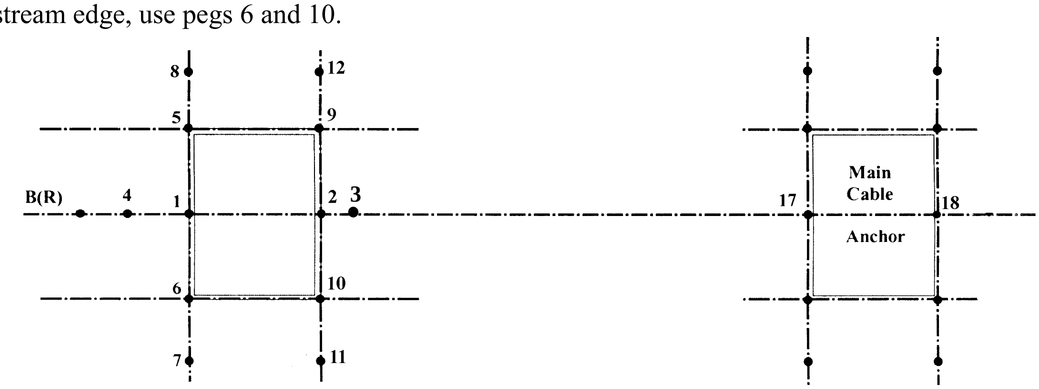
- Draw an offset line (right angle) through pegs 1 and 2 by the 3-4-5 method. Starting from peg 1, set out pegs 5, 6, 7 and 8 for the reference line of the front edge, and from peg 2 for pegs 9, 10, 11 and 12 for the back edge of the tower foundation.



- Determine the center point of the tower foundation and measure the distance between the tower axis and the front of the main cable anchor and fix peg 17. Draw an offset line through peg 17 as a reference line of the front edge. Set up one additional centerline peg at a safe distance behind and proceed as above.



- Determine the reference line at the downstream edge with the help of pegs 5 and 9. For the upstream edge, use pegs 6 and 10.

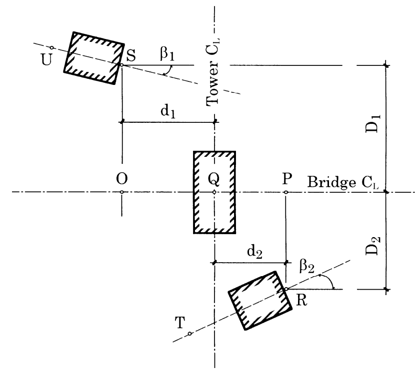


- Fix the elevation line (datum level), and indicate the depth of the excavation work for the tower foundation and the main cable anchor as per the elevations shown in the GA and Anchorage Drawings.

Setting out Windguy Cable Anchorages
(only if applicable)

In the General Arrangement, the location of the windguy cable anchorages is usually given in reference to the tower and bridge centerline: D_1, d_1, D_2, d_2.
The correct direction is given by the angles β_1, β_2.

Plan:



D_1, D_2	=	Distances measured from the bridge axis to the front (centerline) of the windguy cable anchorage block.
d_1 d_2	=	Distances measured from the tower centerline to the front of the windguy cable anchorage block.
β_1, β_2	=	Angle between the windguy cable and the direction of the bridge centerline.

Procedure:

- Measures the distances d_1 and d_2 from point Q along the bridge centerline, peg out points O, P.
- Set up the theodolite at O and P and measure the distances D_1 and D_2 perpendicular to the centerline of the bridge, peg out points R and S.
- Set up the theodolite at R and S and set out reference lines R - T, S - U.

  $\sphericalangle$ PRT $= \beta_2 + 90^o$ $(\beta_2 + 100^9)$
  $\sphericalangle$ OSU $= \beta_1 + 90^o$ $(\beta_1 + 100^9)$

  Peg out points T and U. The reference lines R - T and S - U are the centerlines of the windguy cable anchorages.
- Check if the ground levels at points S, U, R and T correspond approximately to the layout given in the General Arrangement.

  If the ground levels are correct:
- Set out the windguy cable anchorage blocks in the same way as for the Main Anchor Foundation.

Setting out Windguy Cable Anchorages in Case of Obstacles

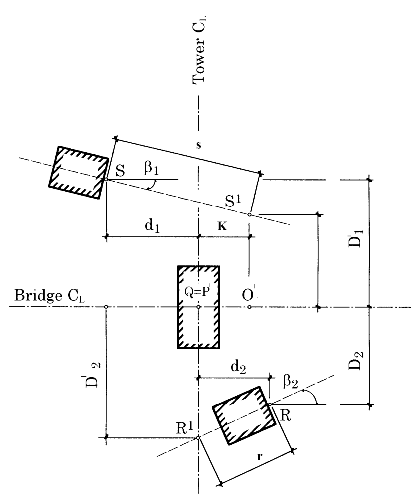
If it is not possible to set out the windguy cable anchorages, according to the above procedure due to obstacles (rock, trees, etc.), it can also be done by using other points like R' and S'.

Plan:

$$D'_1 = D_1 - (d_1 + k) \cdot tg\beta_1$$
$$D_2' = D_2 + d_2 \cdot tg\beta$$

$$s = \frac{d_1 + k}{\cos \beta_1}$$

$$r = \frac{d_2}{\cos \beta_2}$$



Procedure:

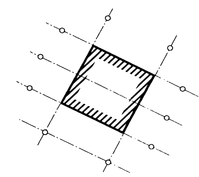
- Choose points P' and O' and measure the distance k from the tower centerline to P' and O'.
- Set up the theodolite at O', and measure the distance D'_1 and D'_2 perpendicular to the centerline of the bridge and determine R' and S'.
- Set up the theodolite at R' and S' and set out reference lines R' - R and S' - S.

Measure the distances r, s and peg out points R, S.

Notes:

- The points O', P' can also be at the river bed if it will facilitate setting out the reference lines.
- Reference lines for the windguy anchorages are to be set out in the same way as employed for the main anchorages.

A bench mark should be set up for checking the elevation.

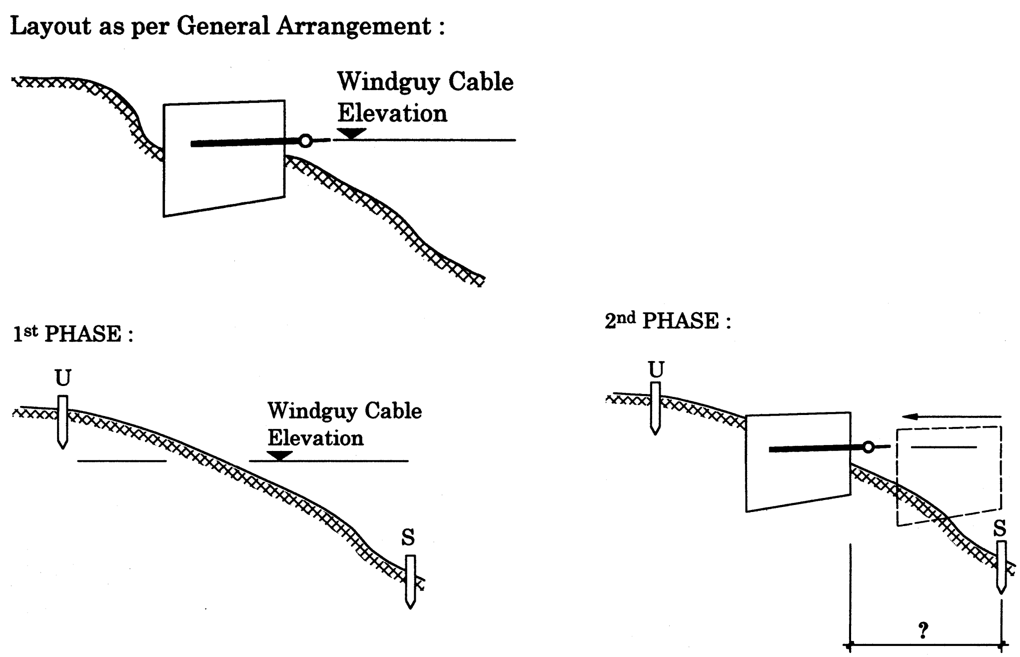


Setting out Windguy Cable Anchorages in Case of Incorrect Survey

In some instances, the elevation of the ground near the windguy anchorages may not coincide with the General Arrangement. In such cases, the layout of the anchorage block position can be revised at the site.

Proceed as follows:

1. Prepare a new profile drawing along the reference lines R - T and S - U and indicate the windguy cable elevation according to the General Arrangement (first phase).
2. Relocate the windguy cable anchorage block in such a way that its position in relation to the ground is similar to the layout given in the General Arrangement (second phase).
3. Draw the new location of the anchorage block in the profile drawing and transmit the data to the design office which will prepare a revised design.
4. Make sure that the windguy cable is still long enough.



5.3.3.2 Foundation Excavation

In Soil:

The foundations should be excavated with slopes to provide stability in the cut slope. The cut slope in soil should generally not exceed 3:1 (V:H). The foundations should be excavated stagewise. Trenches should be excavated vertically with sheeting, or must be banked with slopes which afford the necessary stability.

All safety requirements for the protection of personnel during excavation must be met.

Slope Pitch

in well consolidated stable ground, maximum slope pitch 3:1 (3m vertical, 1m horizontal)

in moderately consolidated but stable soil, maximum slope pitch 2:1 (2m vertical, 1m horizontal)

in non-cohesive ground, maximum slope pitch 1:1 (1m vertical, 1m horizontal)

If slope stability is impaired by unfavorable strata morphology, artesian water, intermediate friction layers, vibration, etc. the slope pitch must be reduced.

> The most important point to be borne in mind during excavation is the fact that almost every bridge foundation bed is inclined. It is not allowed to excavate horizontally and form the incline with fill material!

To ensure that the foundation bed is clean and undisturbed, the bottom 10cm should be excavated only shortly before the concrete is poured.

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

All the excavated soil should be safely disposed of without damaging the existing vegetation down hill, thus not affecting the environment.

In Rock:

Refer to Chapter 5.3.2.2

5.3.3.3 Local Material Collection

Refer to Chapter 5.3.2.3.

5.3.3.4 Masonry and Stone Dressing Work

Refer to Chapter 5.3.2.4

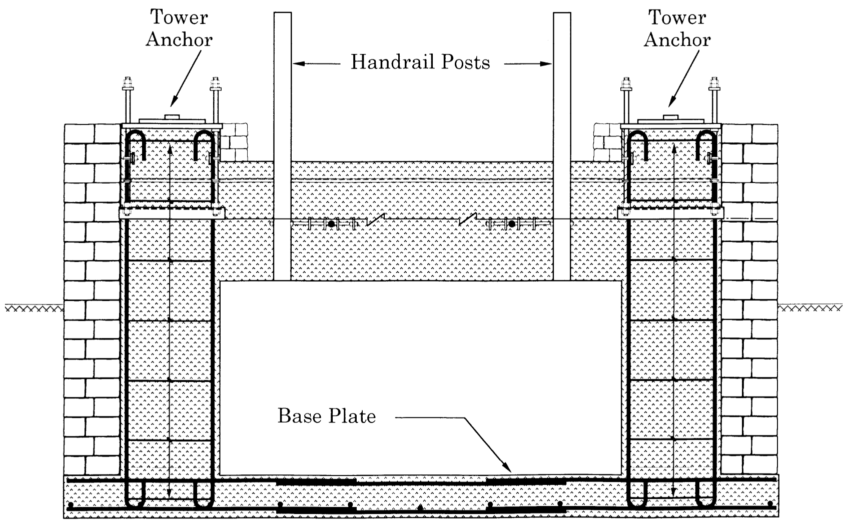
5.3.3.5 Cement Works

A. Composition And Mixtures

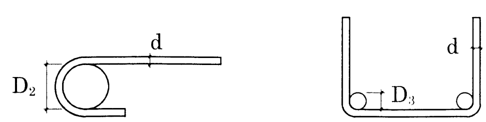
Refer to Chapter 5.3.2.5 A

B. Tower and Walkway Foundations

The tower and walkway foundations are built for providing a safe base for the towers and for the firm anchoring of the spanning cables, fixation cables and handrail cables. This structure also stands for the bridge entrance.



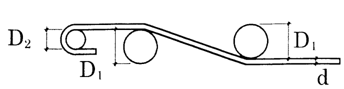
For this structure, the proper and precise placing of the reinforcement bars is very important. The bars usually come pre-bent from the workshop, but can also be bent at the site if required.

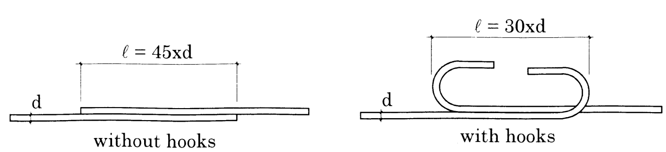


D_1 = 15 x d

D_2 = 6 x d, for rod ø ≤ 20mm
8 x d, for rod ø > 20mm

D_3 = 4 x d, for rod ø ≤ 16mm





Reinforcement steel is fixed with binding wire, so that no displacement can happen during concreting.

C. Cable Anchors in Soil

Cable Anchors in Soil or Soil Anchors are constructed either as:

- **Deadman Anchor or**
- **Gravity Block Anchor**

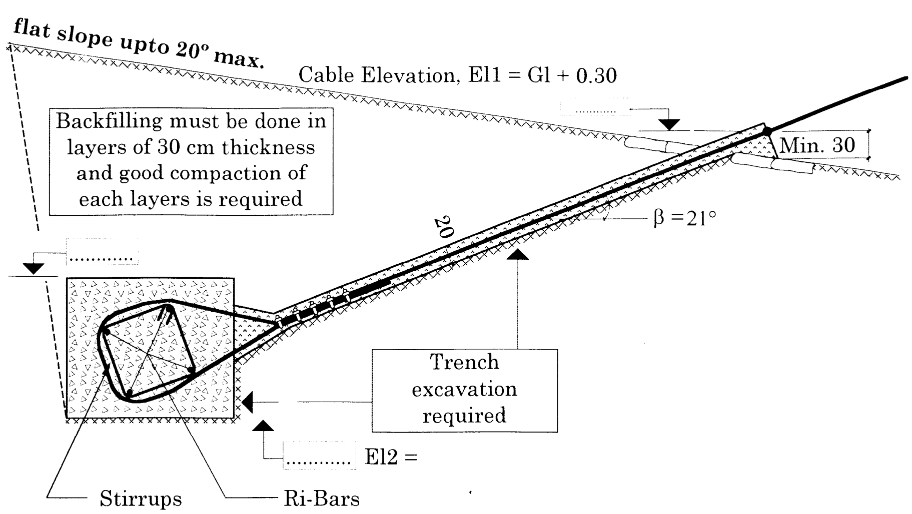
For both Soil Anchor Types (Deadman and Block Anchors), ready-made design drawings are provided for Anchors *with Turnbuckles* or Anchors with *Direct Cable Connection*. One Cable Anchor should always have a Turnbuckle which allows fine adjustment of the cables during erection time. For economic reasons, the cable anchor on the other bank should always have a direct cable connection.

Always choose the more convenient bank for the Main Cable Anchor with Turnbuckle.

For the Main Cable Anchor with Direct Cable Connection the Main Cables have to be fixed during the construction of the particular Anchor Type. The Main Cables, therefore have to be ready during the time of construction. Make sure that the Main Cables are deposited at a safe distance from the bank of the river during construction time.

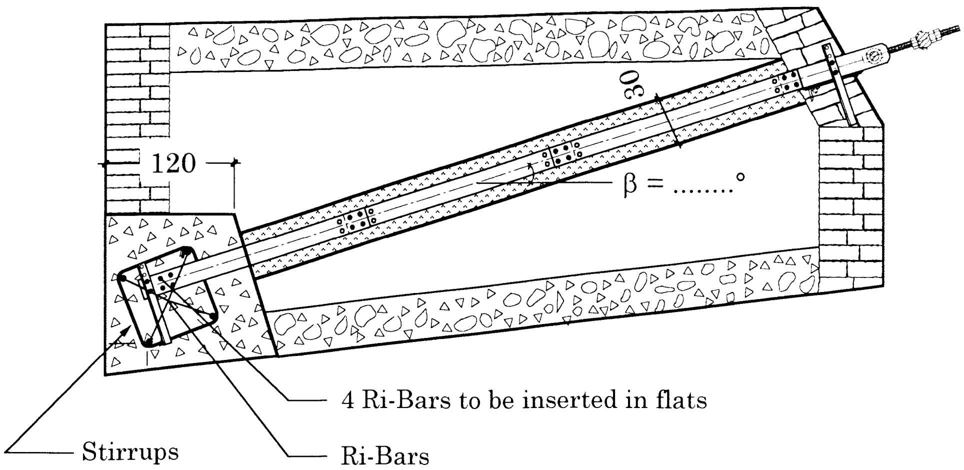
For both the Soil - Anchor Types (Deadman and Block Anchor), ready-made design drawings are provided for Anchor with Turnbuckles or Anchors with direct cable connections. For details, refer to Volume III, Steel & Construction Drawings. These drawings contain all the information about assembly and location of each steel part.

Example of a Deadman Anchor without Turnbuckle:



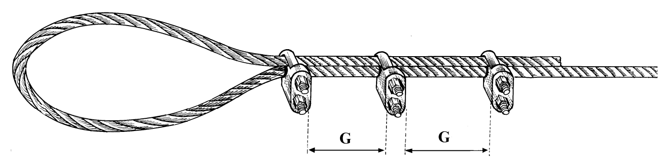
Section of a Deadman Anchor with direct cable connection.
The cables for soil anchors are placed around the Ri-Bars before concreting.

Example of a Gravity Block Anchor with Turnbuckle:



In the Turnbuckle case, steel flats are joined till the rear (back) of the gravity block where a solid reinforced cement concrete (RCC) beam is constructed. The ends of the flats are anchored by 4 Ri-Bars which have to be ***inserted*** through the 4 holes provided at the end of the flats.

Nos. & Spacing of Bulldog Grips		
Cable ϕ mm	**Nos.**	**G**
13	**3**	**10 cm**
26	**5**	**15 cm**
32	**6**	**20 cm**



D. Constructing Drum Anchorages in Rock

There are two types of Drum Anchorages in Rock:

- **Drum Anchor in Hard Rock**
- **Drum Anchor in Soft or Highly Fractured Rock**

For detail refer to Chapter 6.3.2.5 D.

5.3.3.6 Water Management and Backfilling

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

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

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

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

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

D o B a c k F i l l ! ! !

5.3.3.7 Finishing Work

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

Never do cement pointing or other non-functional works.

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

5.3.3.8 Bridge Erection

As soon as the anchor blocks and tower foundations are completed, the bridge erection works can be started. Bridge erection and fitting works are somewhat difficult and dangerous, and require especially skilled laborers who will not suffer from giddiness. Because of this somewhat risky work, the necessary safety precautions should strictly be followed and the respective responsibilities should be clarified before starting the work.

A. Erection of Towers

The towers must be temporarily fixed during erection, because they rest as a line load on the base plate which acts like a hinge. In order to avoid serious accidents during erection, the towers must be temporarily fixed at their base. For this purpose, temporary side struts have been provided at the tower and walkway foundation with an additional 8 angles for each tower (see position B-5 of Base Element Drawing No. 100N). The angles are supplied with holes at one end only, the exact position of the required hole at the other end must be marked at the site when erecting the base element.

First fix both the Base Elements at the bottom and put them in an exactly vertical position. Fix the temporary angles at the bottom of each side, then mark the required position of the hole at the other end of the angle. Also give a position number to each angle so that they won't get mixed up. Have one hole of
ø 17mm drilled at the site or at the nearest workshop.

For tower erection, refer to the respective Assembly and Layout Drawings.

- Check Steel parts for labels and numbers put by the manufacturer.
- Use steel-cones for easy fitting works and tighten the nuts and bolts fully only after the next diagonal bracing has been put in place.

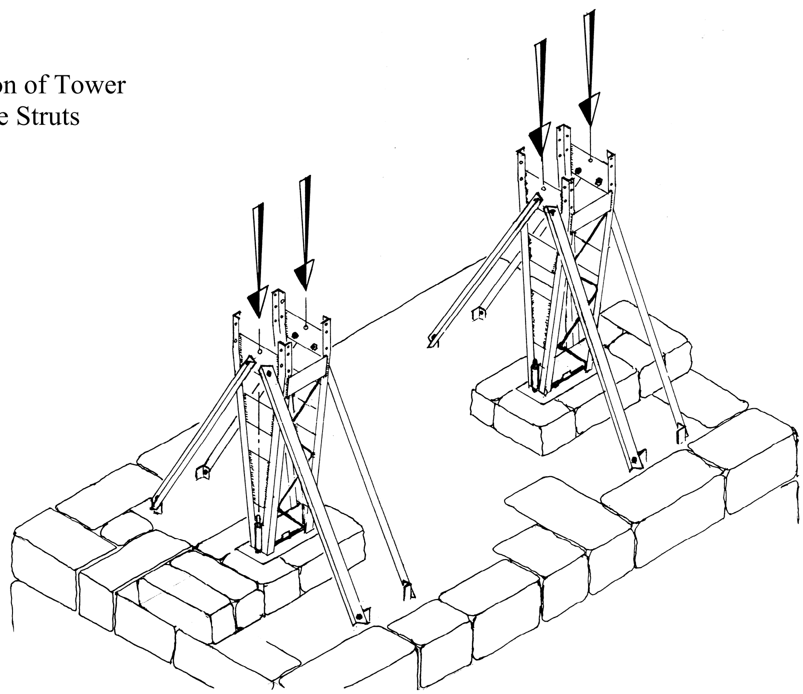
Each tower consists of the following parts :

Type of element	Part Nos. in Steel Drawing
Base Element	**B**
Intermediate Element	**I**
Top Element	**T**
Saddle	**S**

Retighten all Nuts and Bolts firmly after fixing the Elements.

After the bridge has been erected, the cable clamps on the top of the pylon must be firmly tightened, and then all the side struts (angles) must be removed.

Temporary fixation of Tower Base with side Struts



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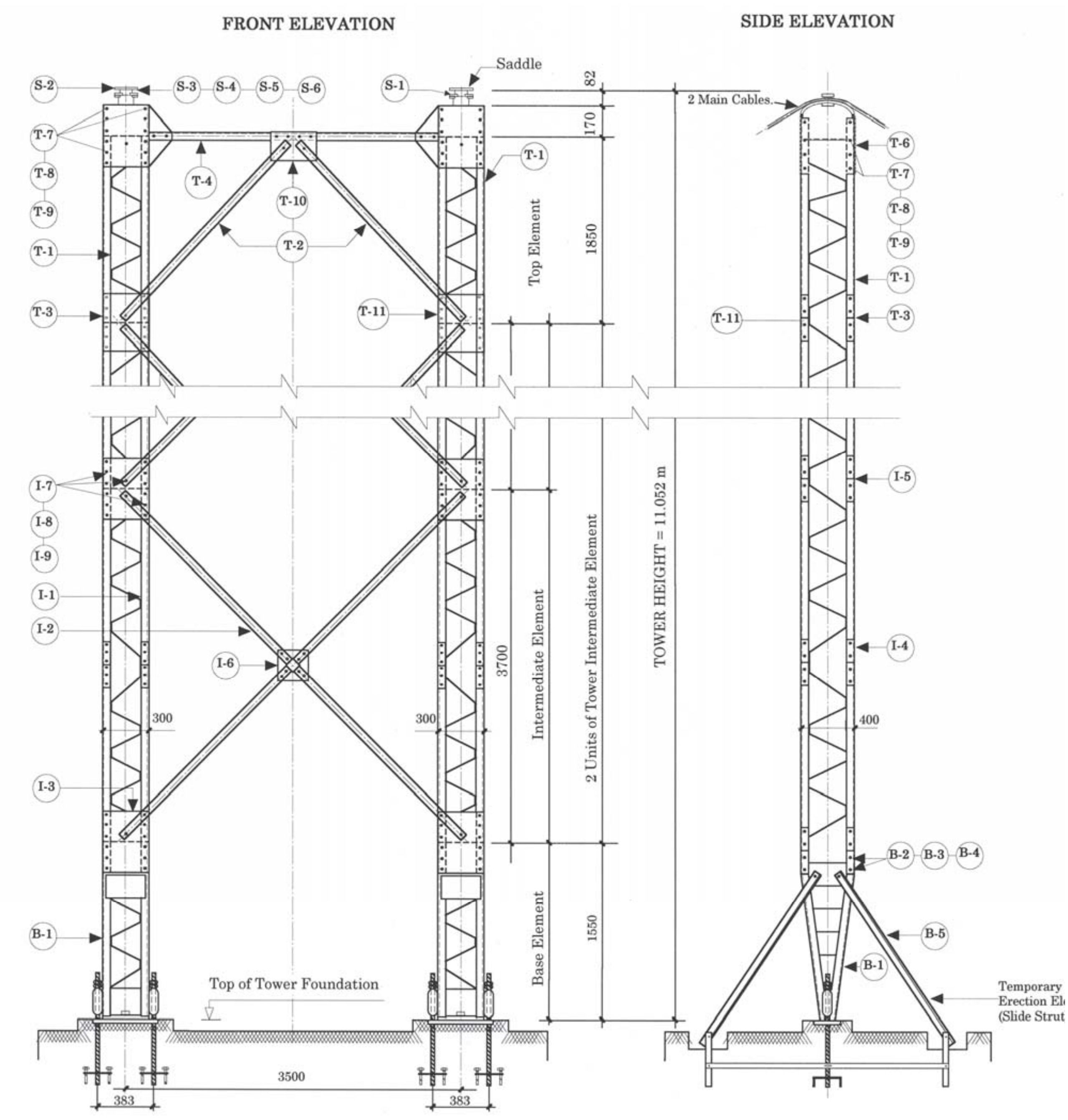
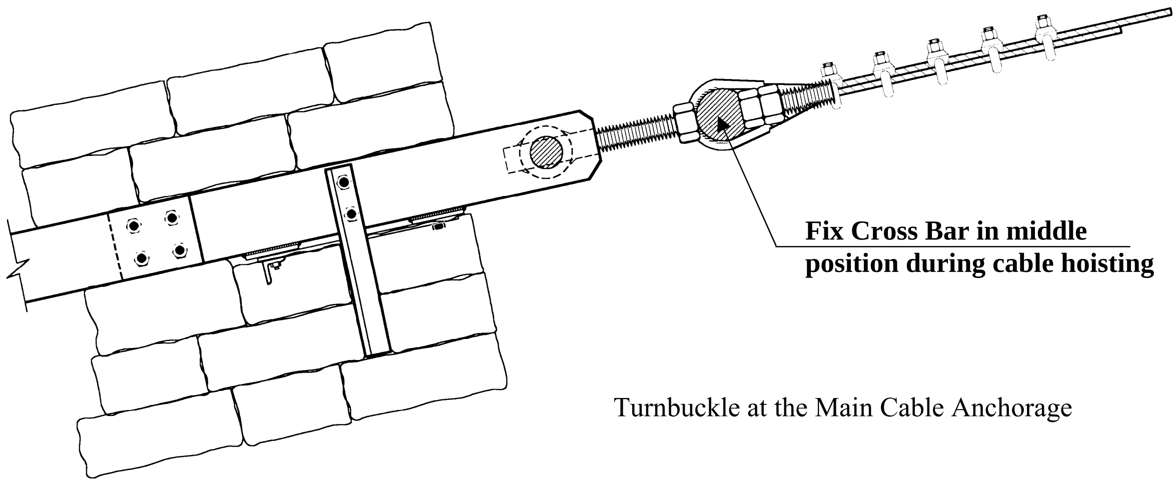


Assembly and Layout of Tower No. 4

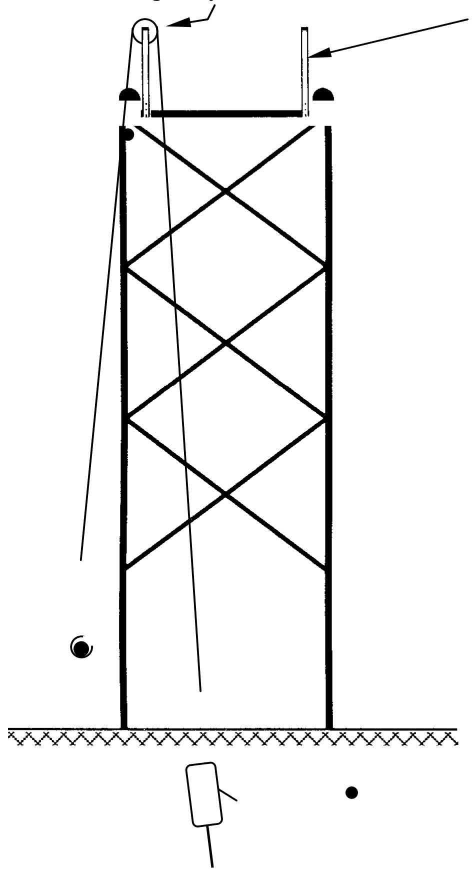
B. Hoisting of Main Cables and Sag Setting

Usually, the main cables are pulled across the river with the help of nylon ropes. In case of a deep or turbulent river, attach an empty airtight plastic can (jerry can) at the end of the cable. This will prevent the cable-end from getting stuck between stones and rocks lying on the riverbed.

Make sure that the respective Main Cables are pulled on either side of the Tower and Walkway Foundations. Fix them temporarily at the respective Turnbuckle at the Main Cable Anchor.



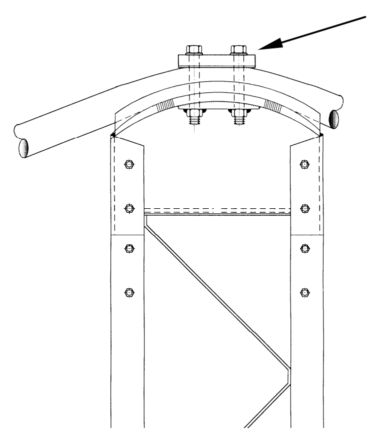
Turnbuckle at the Main Cable Anchorage



Temporary device for lifting the main cables (supplied with Top Element)

Lift the cables one by one, first the inner then the outer cables.

Once the cables are in the saddle groove, immediately secure them with the saddle cover plate, but do not tighten the bolts so that the cables can still slide during erection time.



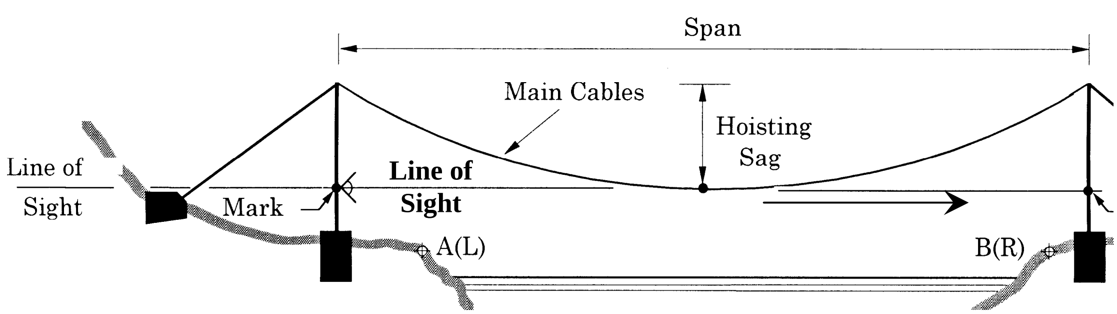
Keep saddle cover plate loose during bridge erection time, but tighten it firmly before removing the temporary side struts at the bottom of the tower.

The hoisting sag setting of the Main Cables is one of the most important tasks during the erection of the bridge.

The towers should stand exactly vertical, the saddle cover plates are loose, and the temporary side struts are fixed. With this arrangement, the main cables can slide over the saddles when the bridge is being erected and the cables become longer; and the towers remain in vertical position in dead load.

With a leveling instrument, the exact hoisting sag is fixed in the following way:

- Mark the elevation of the hoisting sag on both the towers with permanent paint.
- Now set up the leveling instrument on the tower foundation so that its line of sight matches with the mark on the tower across the river. Setting up the leveling instrument at the prescribed hoisting sag elevation has to be done by trial and error, and may require several attempts. Make use of the three adjustment wheels of the leveling instrument when the eyesight is close to the mark.
- Pull the Main Cables until they reach a level of about 20 cm higher than the hoisting sag.
- Clamp the cables around the thimbles at the cross bar of the Turnbuckle of the main cable anchorage. Make sure that the crossbar is **in the middle position** of the threaded anchor bars when clamping the main cables, secured with two nuts in the front and one in the back.
- The Main Cables should be left in this "over pulled" position for at least 12 hours so that some relaxation can take place.
- Now move the Turnbuckles to achieve the exact sag setting. For compensating elongations due to change in air temperature, recheck the hoisting sag at different times of the day and make the necessary adjustments. It is recommended to adjust the final sag setting during the hot day after noon, when the cables have accumulated maximum heat, i.e., during maximum elongation condition.
- The hoisting sags of all the Main Cables must be identical at any point of time.



Also check the sags from time to time when the fitting works are going on. Different elongations may take place due to dissimilar hidden cable relaxations when the tension increases. Adjust possible sag differences with the help of the turnbuckles at the main cable anchor so that the Main Cables are always parallel and compare the dead load sag with the pre-calculated values.

B1. Hoisting of Spanning Cables

Fix the Spanning Cables at the Turnbuckles of the Tower and Walkway Anchorage on one river bank. Make sure that the crossbar of the turnbuckles are at the **outermost position** secured with two nuts each so that more tension can be applied when all the fitting work is completed.
Pull the cables across the river and secure them at the corresponding turnbuckles on the other bank (crossbar at the outermost position).

It is not necessary to achieve the sag corresponding to the required dead load camber, since this requires very high pulling forces. Just make sure that both the Spanning Cables are hanging approximately parallel and are high enough over the highest water-level of the river.

It is much easier to adjust the spanning cables when the suspender is being fitted (see Sub-chapter B2).

C. Fitting Suspenders and Center Row of Steel Deck

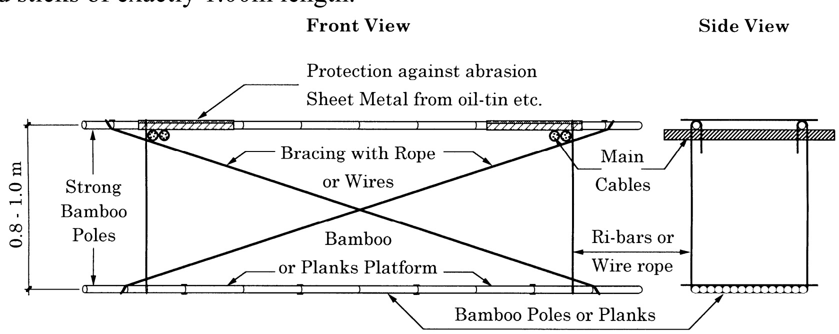
Fitting the suspenders and walkway elements is the most difficult and daring job.
As mentioned already in the beginning of this Chapter 6.7, adequate safety precautions should be strictly followed and the respective responsibilities should be clarified.

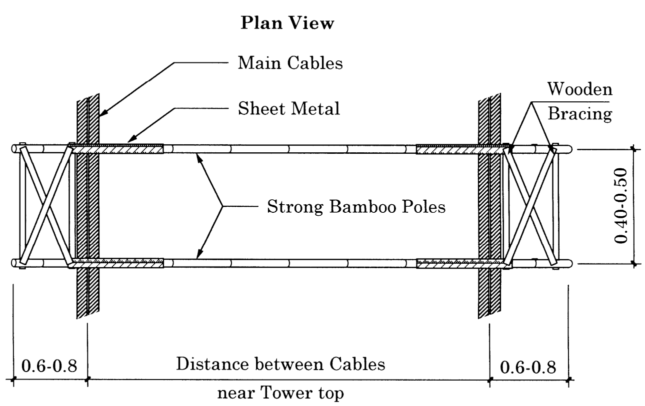
The suspender fitting work should start from **both** the towers and proceed towards the center of the bridge. This procedure is easier and has more advantages than starting the fitting work from the center. However, in order to achieve a proper symmetry of the suspenders, the **central suspender** must be fitted first.

The only disadvantage will arise when finishing the fitting works at the middle of the bridge. Due to inaccuracies, the remaining spacing at the center of the bridge might be either too long or too short. For minimizing this imprecision, the required distances to the towers and the center have to be rechecked after fitting 10 suspenders.

Preparation for Suspender Fitting Works:

- Lay out all the suspenders in sequence on the ground.
- Prepare all crossbeams, J-hooks and steel deck.
- Prepare two fitter platforms, one for the main cables and one for the spanning cables, and two gauged sticks of exactly 1.00m length.



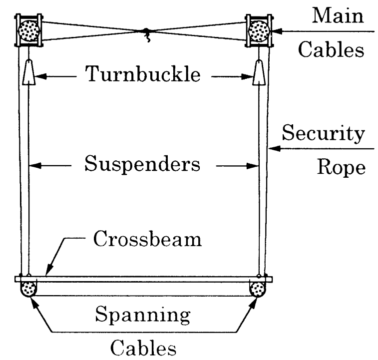


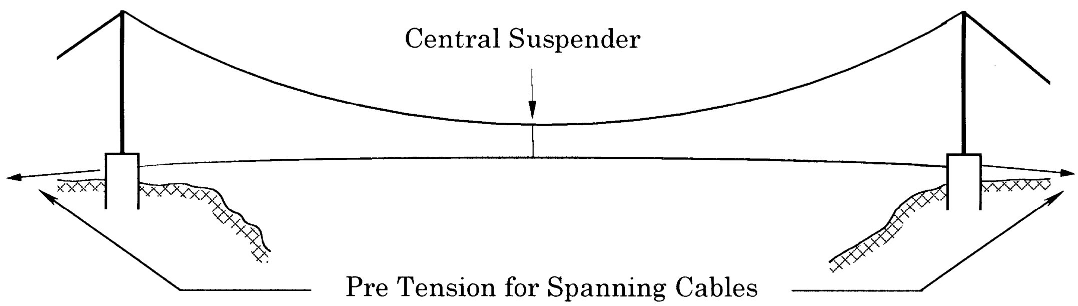
Assembly:
First fit the top portion on the main cables, then hang the platform under this by using either steel bars or cables.

C1. Fitting the Central Suspender :

With the help of the fitting platform, the suspender in the center has to fitted first. Determine and reconfirm the center with a tape and level instrument, then fit the first suspender-pair at the center of the bridge. To avoid excessive load on the center suspender during erection time, bind all cables (spanning and main cables) together as shown in the sketch below with a security rope.

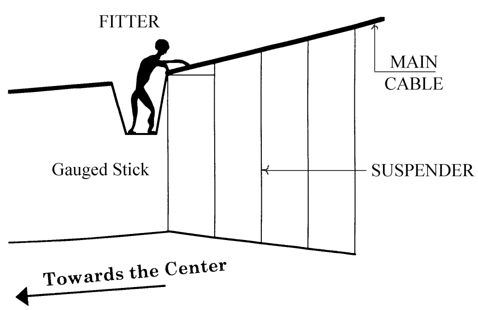
The **security rope** supports the suspender in the middle during erection work.

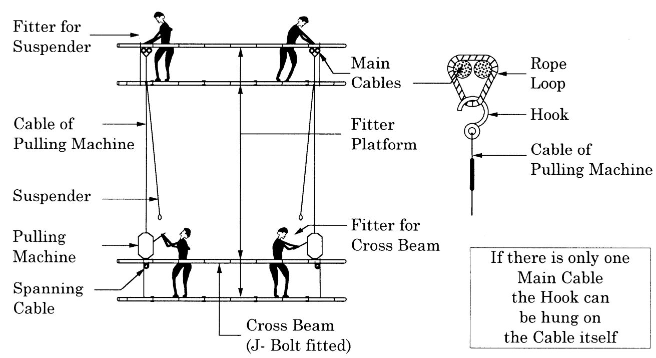




Tighten the spanning cable to some extent; now the cables are ready to be fixed to the suspenders.

Sketches and Procedures for Fitting Operations:





- Start the fitting work from both sides of the bridge and work towards the center of the bridge;
- Fix one cable car on top of the main cables and one on top of the spanning cables;
- Fix the first two suspenders to the main cables at the prescribed distance from the tower;
- Lift the spanning cable until the suspenders can be connected with the threaded rod of the walkway crossbeam.

Note: The first crossbeam at the bridge entrance is fitted without a suspender (see Drw. No. 19Ncon).

- In order that the suspenders are fixed exactly 1m apart, use gauged sticks for exact fitting;
- Re-adjust the spanning cables from both the banks as the suspenders are being fitted;

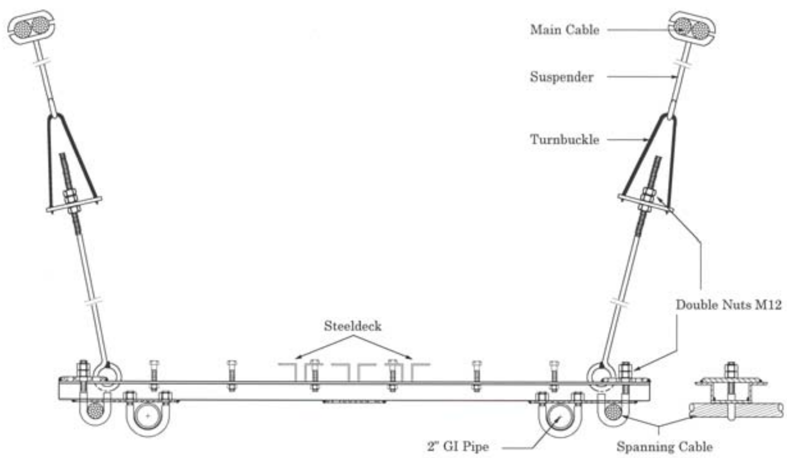
- After fitting ten pairs of suspenders, check the distances to the tower and to the center;
- Adjust only inaccuracies by moving the crossbeams;
- Gradually start fitting the **center row only** with standard steel deck panels as shown in Drawing No. 19 Ncon.

When the center is reached, there will be some extra length of spanning cable. For adjusting this, pull the spanning cables from both the banks with the tirefor machine through the loose J-hooks. Make sure that the middle row of the steel deck is fitted when doing this work.

- When all the suspenders have been fixed, tighten the spanning cables with the cable pulling machine as much as possible before fitting the 2" G.I. pipes below the crossbeams and before fitting the rest of the steel deck panels.
- Fix the handrail cables by pulling them through the suspender-rings just above the suspender turnbuckle, and secure them to the handrail posts by winding the cable end twice around the post.

Fitting the 2" G.I. Pipes :

Two 2" G.I. pipes have to be mounted from below to the steel deck cross beams. This provides additional vertical but also lateral stability to the entire walkway. These pipes can also be used for transferring water across the river as per local requirement.



The G.I. pipes have to be fitted before the outer rows of the steel decks are mounted in the following way:

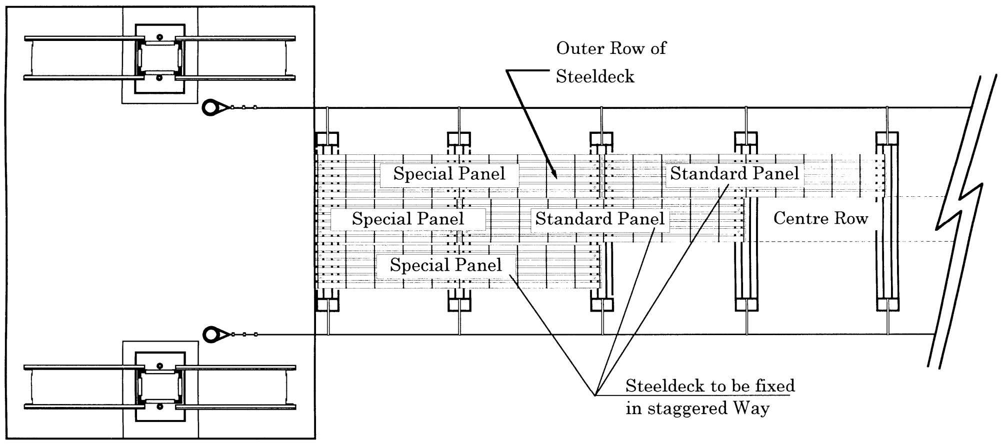
- Lay two pipes of 6m length end to end on the ground and join them together firmly. Use a 2" die set and jute threads to make the joint water tight.
- In the same way, also fix half of the "union" at each end of the 12m piece.
- Now carry the 12m pipe to the bridge, pass it through the suspenders by securing it with nylon ropes until the entire 12m piece is on the outside of the suspenders.
- Now bring the pipe into proper position underneath the walkway, and secure it immediately with the U-clamps and join it with the "union".
- In case a union coincides with a crossbeam, cut the pipe and make a new thread with the die set.

This work requires special attention. While passing the pipe outside the suspenders, several workers are necessary and sufficient ropes are required to secure the pipe at all times.

D. Finishing the Walkway Steel Deck

Now the remaining steel deck panels can be fitted. Fit them in a staggered way as shown below. Adjust the end of the walkway with "Special Panels"; and cut off any extra length with a hacksaw as required.

- If wood is used for the bridge deck, the planks should be 2 meters long and at least 4 cm thick. They should also be fitted in a staggered way. Use washers below the Bolt Heads. The distance between the Crossbeams is 1 meter.

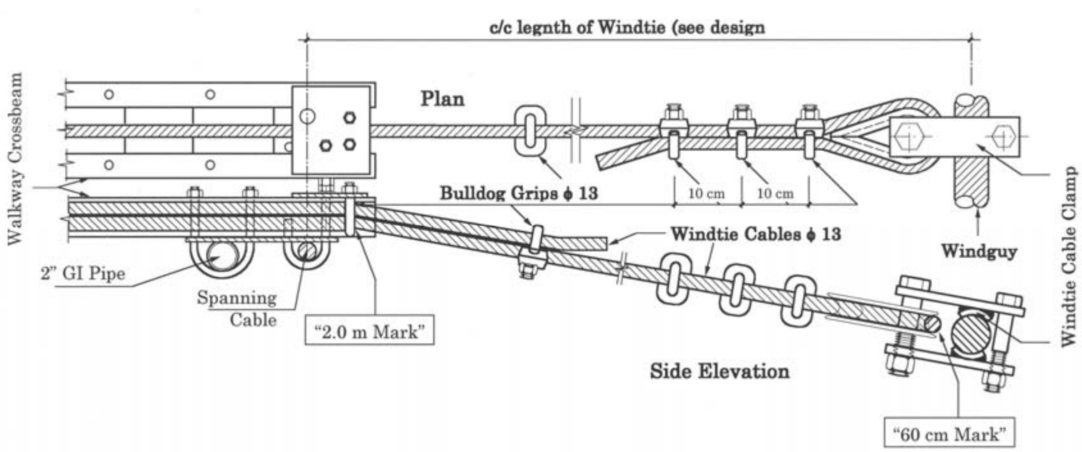


Note: ***Make sure that all U-clamps which hold the G.I. pipes have been tightened firmly before fitting the steel deck.***

E. Fitting Wind Bracings

Wind bracings might be required to protect the superstructure from excessive wind forces.

- Cut the windtie cable according to the calculations resulting from the design form;
- Mark each cable at 60 cm from the end;
- Fit a thimble and bulldog grips so that the "60 cm mark" is at the top of the thimble;



- Now mark each windtie cable at 2.0 meter from the other cable end.

The windtie cables are now ready to be fixed to the windguy cable. For this, fix the cut windtie cables at intervals of 5.0 m to the windguy cable; take starting measurements from the design form or the general arrangement.

Make sure that the windtie cable clamps and bulldog grips are firmly tight, and that the nuts are locked against the threaded plates of the windtie cable clamp, because these connections are no more accessible after hoisting.

Hoisting Windguy Cables :

- Place the windguy cable in position along the bridge deck outside the suspenders;
- Pass the respective windties through the walkway beam and clamp them loosely at the "2.0m Mark" as shown in the above sketch;

Note: The steel deck in the center row at this location must be removed for this purpose.

- Fix one bulldog grip with the windtie from the other side just outside the crossbeam;
- After fixing all the windties, attach both cable-ends of the windguy cable to the respective windguy anchors (crossbar at the outermost position). Simultaneously apply tension to both the windguy cables to avoid any unsymmetrical lateral load to the bridge, then tighten all clamps at the "2.0m Mark".

Adjusting the Windguy / Tie - Cables :

- The windties can be adjusted by loosening the bulldog grips at both sides of the crossbeam;
- Loosen also one bulldog grip outside the crossbeam, but make sure that the grip on the other side is tight !
- Now allow the first windtie - pair to balance off any unsystematic forces;
- Then grasp the cable under tension (only one cable) from the middle of the crossbeam and lift it as required. (Use a crowbar and wooden logs as shown in the picture below);

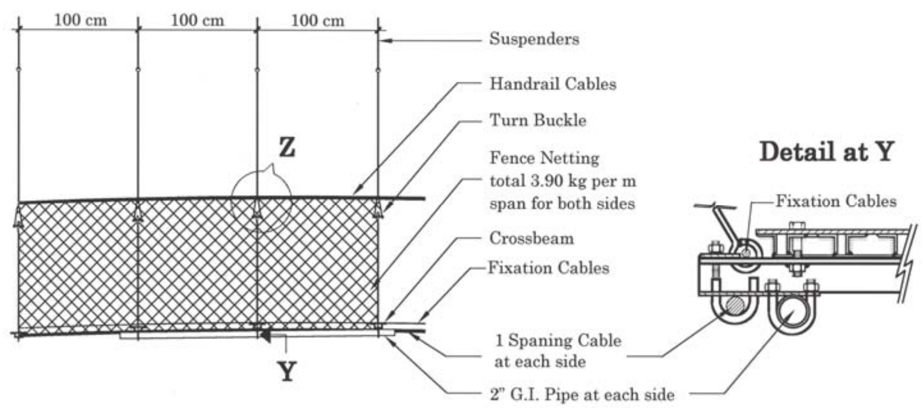
- Use a crowbar and wooden logs to hold this position.
- Now push the loose cable-end of the second windtie through the loose bulldog grip outside the crossbeam and clamp it to the cable under tension;
- Now do the same with the other end, and finally again clamp both the cables to the crossbeam.

This procedure should be repeated until all the windties are tight. The adjustment length is not limited and can also be done again at a later stage.

F. Finishing Erection Works

Now there remains the fitting of the fixation cable, the wire mesh and some final adjustments (See also Drawing No. 19Ncon, Volume III, SSTB Suspension Type Manual).

Like the handrail cable, the fixation cable is to be passed through the rings at the bottom of the suspenders. Anchor the fixation cables to the spanning cable anchor.

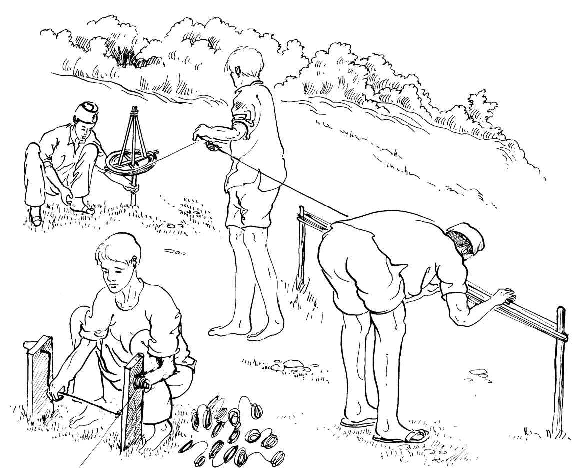


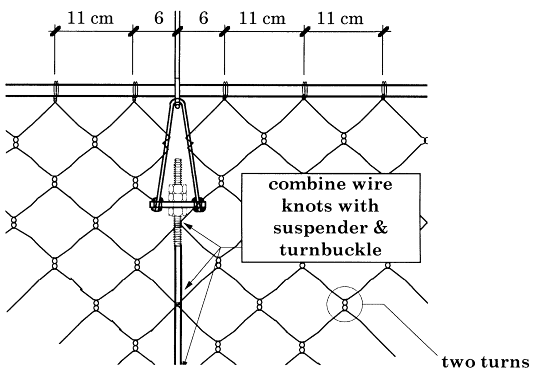
The fencing is woven on the spot between the handrail and the fixation cables with gabion wire (12 SWG $\triangleq$ ø 2.64 mm)

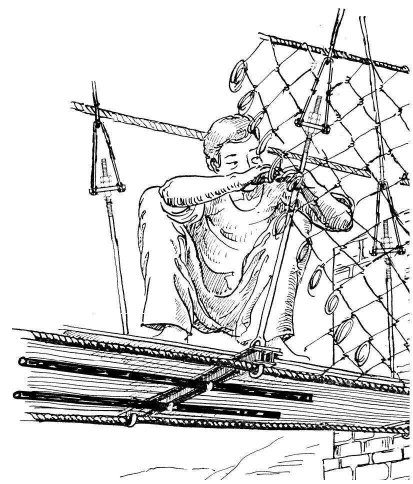
Preparing Coils …..

Cutting Length is 4.20 Meters

…for fence weaving







Finally the whole bridge should be aligned with the help of the turnbuckles at the suspenders so that the walkway forms a smooth parabola.

If a wind bracing system (windguys and windties) is in place, recheck whether all the cables are tight and align the walkway so that it is perfectly straight.

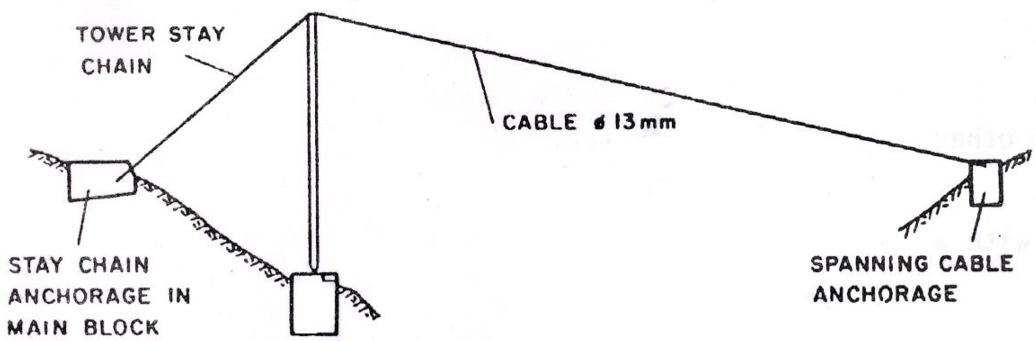
5.3.4 Construction of LSTB Bridge

Construction of LSTB bridges is more or less similar to SSTB bridges except those elements, which are described in the following chapters.

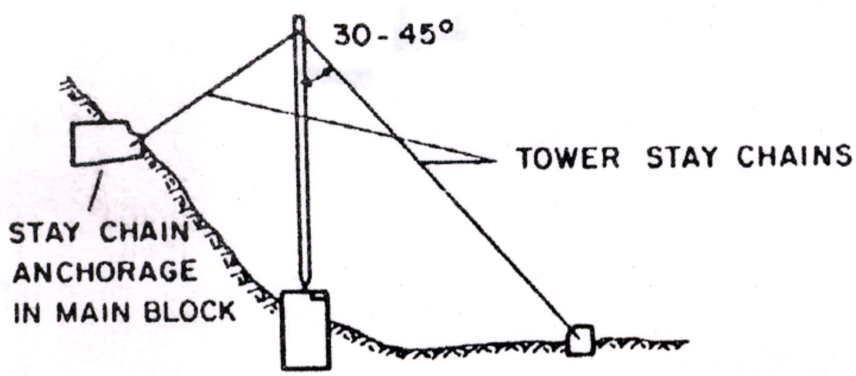
5.3.4.1 Tower Erection

The erection of towers is quite difficult and has to be carried out carefully. When the towers are hinged the difficulty is more aggravated. During erection towers have to be fixed with the help of temporary stay cables. They are usually in the shape of tower stay chains, which are fixed at the front as well as at the back of the tower. The stay chain at the back is fixed to the main anchorage block and in the front to special anchorage blocks provided for this purpose. To guarantee a good fixture to the tower the forestay and backstay chains should always be in tension.

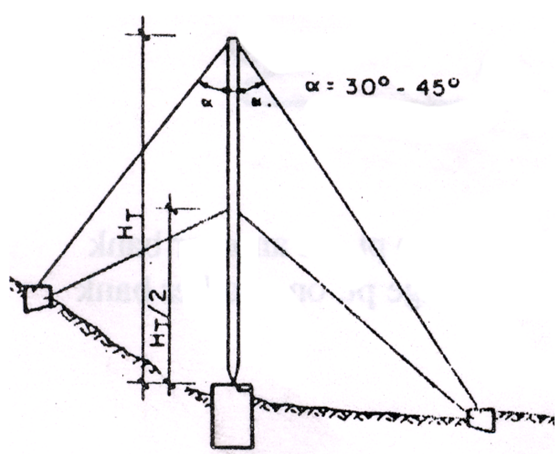
The following sketches are helpful guidance for tower erection. They show how the towers are temporarily being fixed.



Temporary tower fixation for small span bridges



Temporary tower fixation for tower height up to 25 m

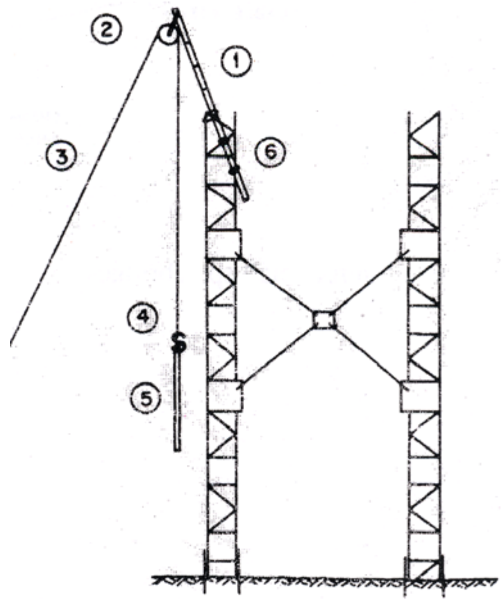


Temporary tower fixation for tower height above 25 m

Scaffolding
The scaffolding serves only to facilitate the work of the fitters and not to support the tower during erection. The scaffolding and the tower should, therefore, be fixed separately. Instead of scaffolding a suspended platform can be used.

Hoisting of the Parts
A derrick made either of wood or bamboo may be used to hoist the part for tower erection as shown in the following sketch:

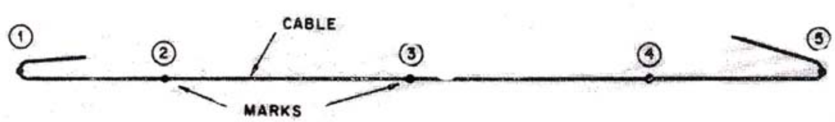
1. A piece of bamboo or other wood, about 5 m long.
2. Pulley block, fixed with a rope.
3. Hoisting rope.
4. Hook (bent piece of a reinforcement steel bar)
5. Tower part to be hoisted.
6. Strings to attach the derrick-pole to the tower already erected.



Tower hoisting

5.3.4.2 Cable Hoisting of LSTB Suspension Type Bridge
This is one of the most important as well as most difficult operations. But, if carefully executed according to the following procedures, it is done easily with safety and accuracy.

- Making: Before the cables are taken across the river they should be marked with some of the important points for hoisting.



Pt. 1 – Anchorage pt. on one bank
Pt. 2 – Tower top pt. on one bank
Pt. 3 – Centre pt. on the cable
Pt. 4 – Tower top pt. on another bank
Pt. 5 – Anchorage pt. on another bank

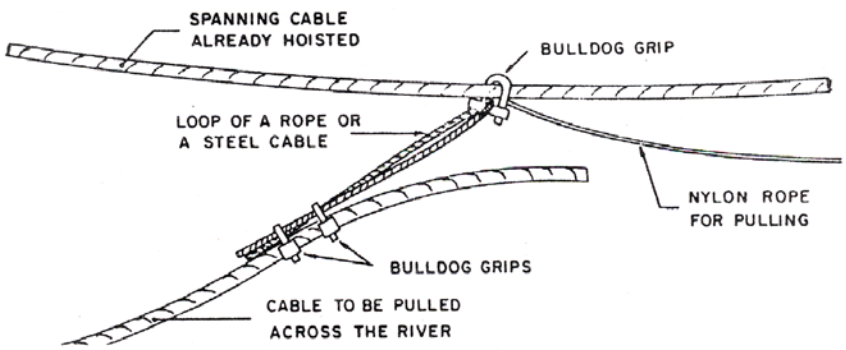
Cable marking
The lengths between 1 & 2 (4 & 5) are hypotenuses of the triangles formed by backstay distance (D) and the difference in elevation (h) between the saddle elevation and the elevation of cable at anchorage.

Length 23 = 34 = ½ of 24
Similarly the length between 2 & 4 is derived from the following relation:

$L = l + \frac{8.f_h^2}{3.1}$ where, l = span; f_h = hoisting sag

The cables can be taken across the river in two different ways:

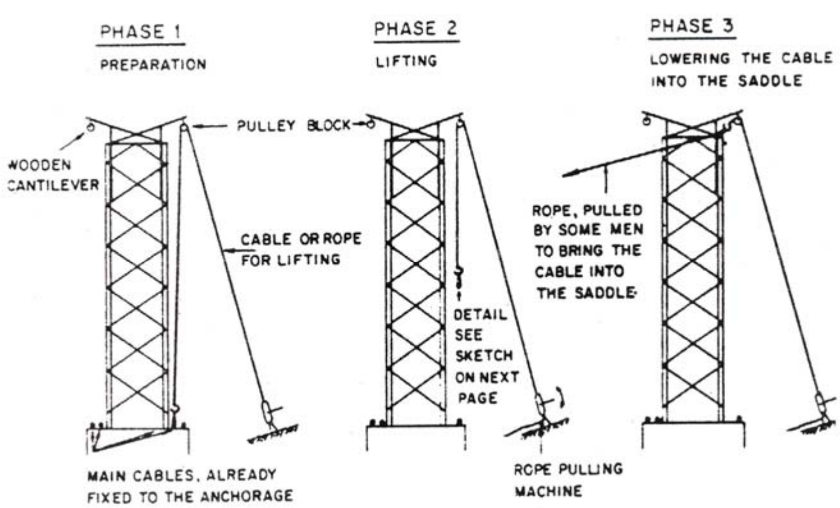
- Pulling the Main Cables along another hoisted cable: Initially a rope is ferried or pulled across the river. Along it a cable of smaller diameter is pulled and fixed on an anchorage (spanning cable). Then along this cable the main cables can be pulled easily by manpower as shown in the sketch below :



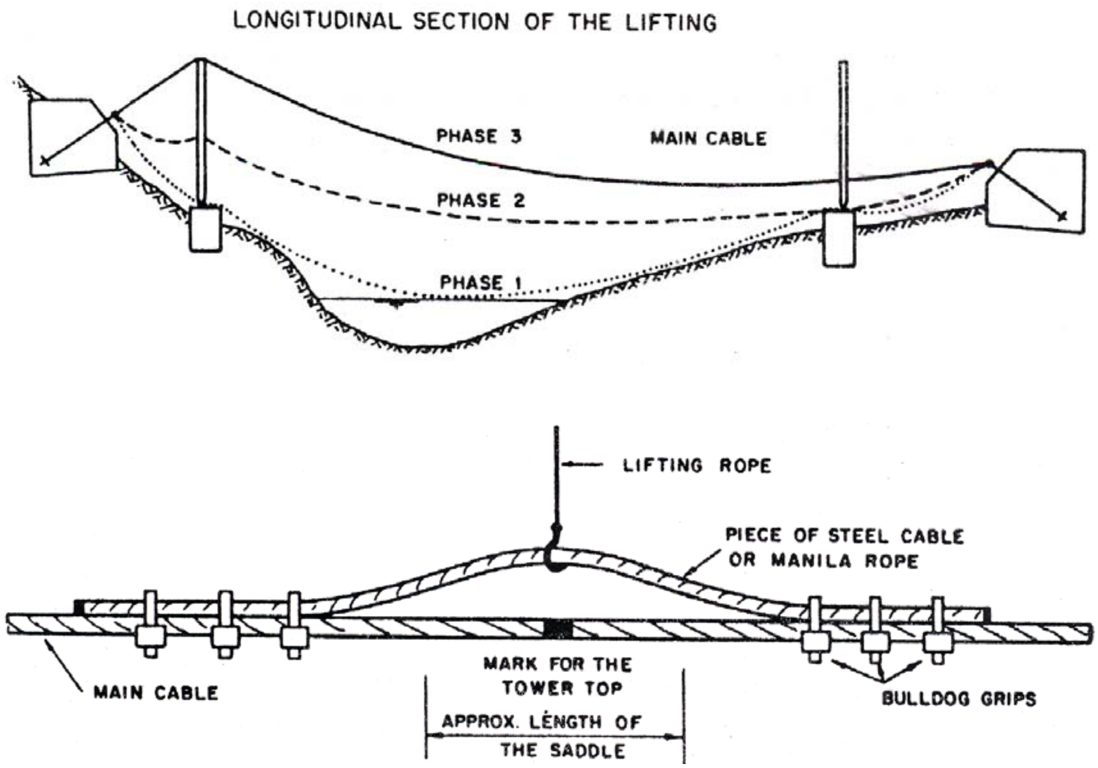
Detail cable pulling

- Carrying the Main Cable across the river: This method is an easy one as long as the cables can be carried across the river or across a temporary bridge. If there is no bridge, a rope hitched to the cable has to be ferried across the river, the cable is then pulled through the river bed. Difficulty arises when the fixture between the rope and the cable gets stuck between stones. To avoid this a second rope can be tied to the cable end which can be lifted a little above the surface by pulling from a ferry boat or from another

- Hoisting the Cable into the Tower:
  From the side: This method is applied for shorter towers.
  * Cables are taken across the river and anchored to respective anchorages.
  * Cables are lifted one by one, first the inner and then the outer.
  * As soon as the cable is a little higher than the saddle, they are pulled into the saddle by an auxiliary rope

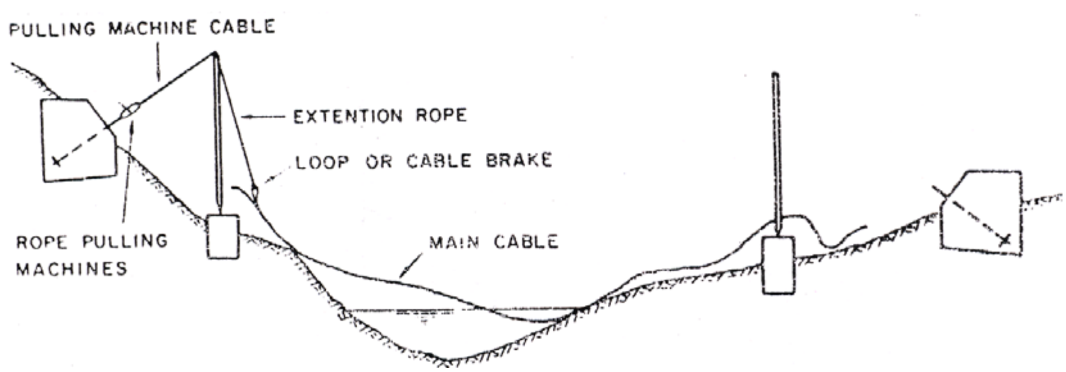


Cables hoisting from the side for shorter span bridges

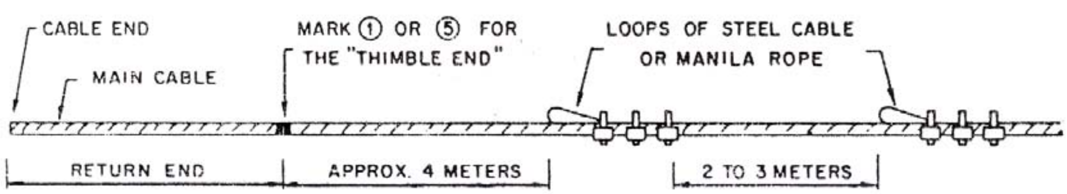


Longitudinal section of the lifting

From the Tower front: For this method, two pulling machines are required. Loops are fixed at two places of the cable end as shown in the sketch below.



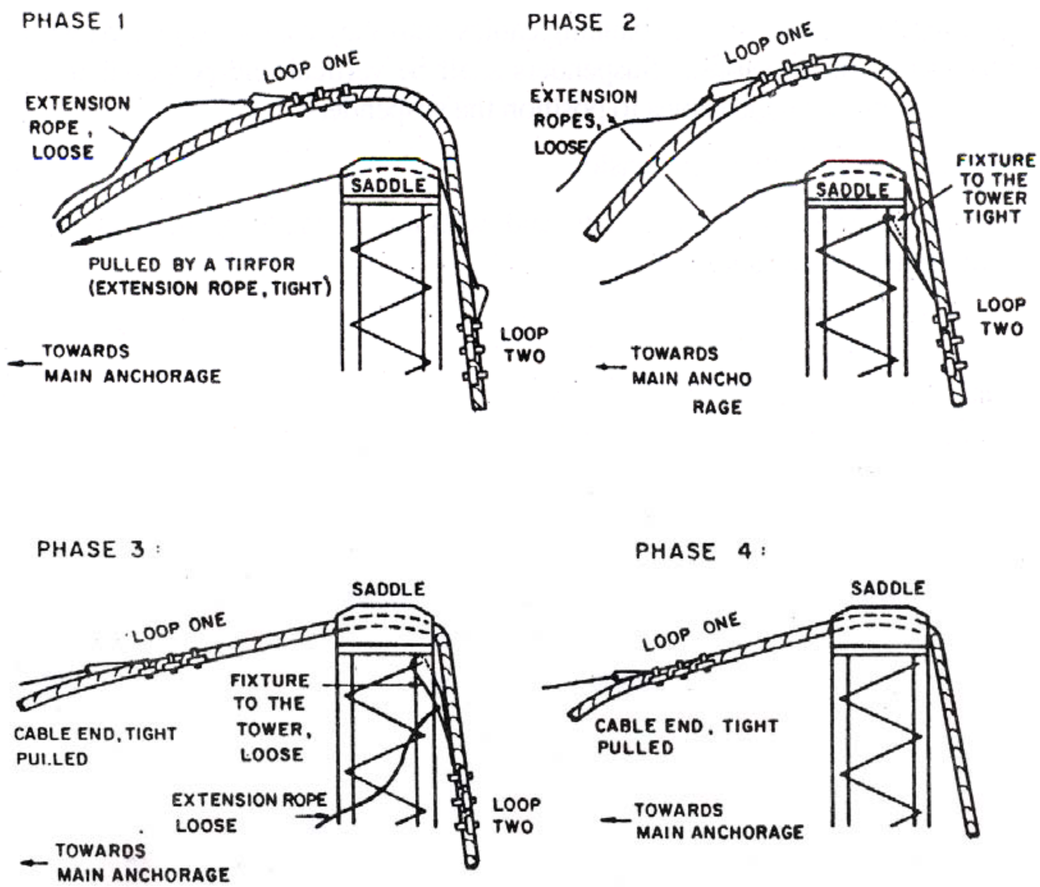
For this method two cable pulling machines are needed. Fix a loop in two places to the cable end. Preparation of the cable for this hoisting method is shown below.



Cables hoisting from tower front for longer span bridges

Pulling machines are anchored to the hooks provided for it at the main cable anchorage blocks. The following procedure is recommended as shown below:

* When the cable end comes close to the tower top, pull on the second loop, until the first loop has passed the saddle.
* With the second loop tightly bound to the tower, loosen the second pulling machine.
* Put the cable end into the saddle and pull with loop one.
* Take away the second loop as soon as its connection is loose. Continue pulling on the loop with extension rope tied to pulling machine until the required geometry is achieved.
* Keep the friction forces between saddle and cables to a minimum by using lubricants.



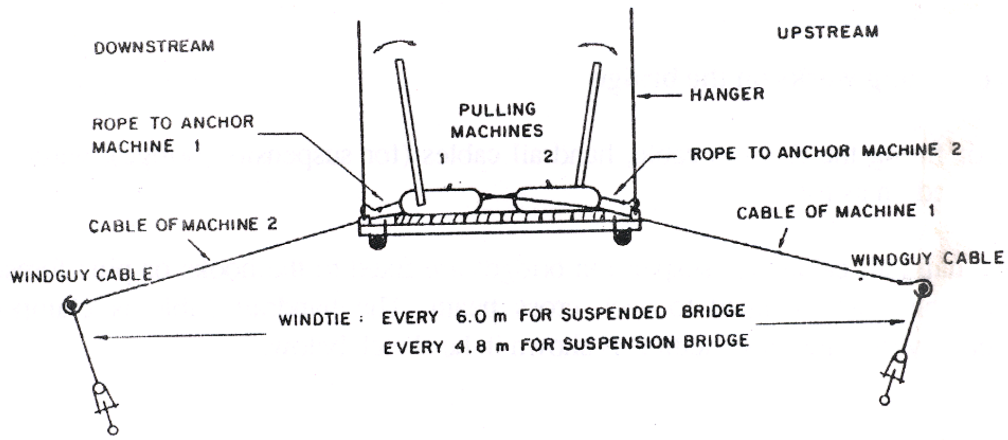
Cables pulling over tower saddle

- Fixing the Hoisting Sag: The required hoisting sag and the elevation of lowest point of the bridge parabola are given in the design. The exact hoisting sag can be fixed with the leveling instruments in the following way:

  * Align the towers with the given vertical deviation as specified in the design with the help of turn-buckles of stay chains. Measurements are taken with theodolite and tape.
  * Mark the level calculated for lowest point of the cable on the tower.
  * Adjust the leveling instruments that its line of sight is at the level of the mark.
  * Pull the cable until it reaches a level of about 20 cm higher than the mark.
  * Clamp the cable around the thimbles in the cross beam of the cable anchor.
  * Loosen the rope pulling machine.
  * Bridge the cables to required level by adjusting movable anchor cross beam.
  * Make sure that all cables are properly gripped and the clamp plates at the saddle are tight before loosening the tower stay chains.

5.3.4.3 Fitting of Wind Bracing of LSTB Bridge

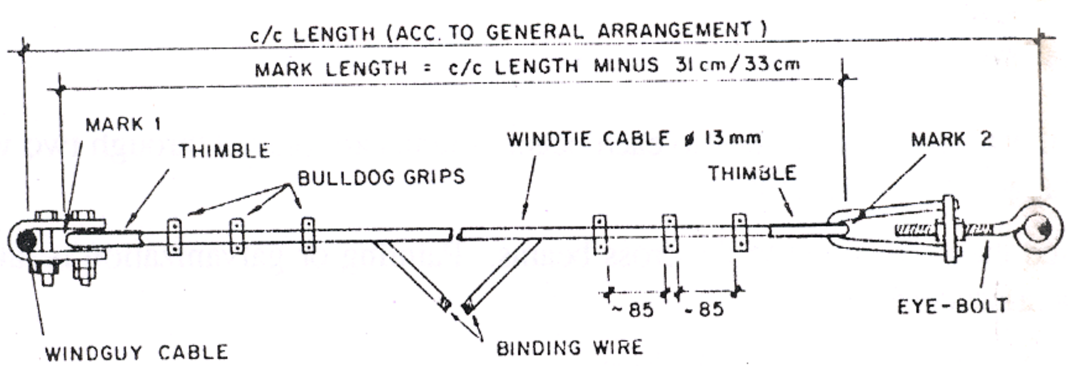
- Preparation of Windties:
  * Cut the windtie cables to the correct length according to design.
  * Measure the length of the return end of the outer side and mark point 1. Measure the required length c/c and mark point 2.
  * Fit thimbles and bulldog grips on both ends.
  * Fit the eye bolts.



Windtie preparation

- Hoisting: There are two ways to hoist the windguy cable and connect the windties to the bridge. One is to fit the windguy cable first and then the windties (A) and another is to fit the windties first and then the windguy cable to the anchorage blocks (B).

  (A) The windties are fitted to the windguy cables in the design positions. Cables are taken across the river along the walkway and anchored to the respective blocks. Cables hang directly from one anchorage block to another. After the walkway has been fitted windties are connected to walkway beams. This is started in the bridge centre. To keep the bridge straight the windguy cables both upstream and downstream are pulled with two machines simultaneously. Continue to connect the windties to the walkway. Reposition the pulling machines for every windtie. Always pull symmetrically and check the alignment of the bridge.



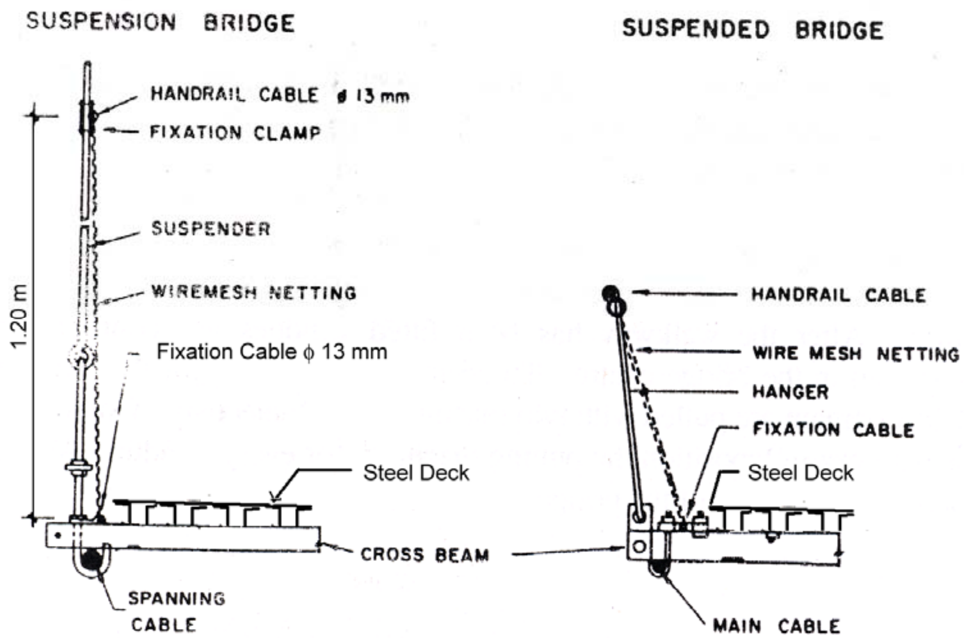
Wind bracing fixation

(B) The windguy cable is marked and windties are fitted as above. The windguy cable is brought in position along the bridge outside the suspenders. Windties are fixed to cross beams. The windguy cable is anchored to the respective anchorages. The required pretension in the windguy cable is obtained by pulling the windguy cable simultaneously from both ends to avoid unsymmetrical load on the bridge.

5.3.4.4 Finishing Works of LSTB Bridge

Finishing off the remaining works on the bridge

The remaining job of fitting the fixation cable, handrail cables (for suspension bridge), wiremesh and walkway deck is carried on as follows:



Detail walkway fitting

- Steel decks are bolted to the cross beams.
- Retensioning of cables, if necessary, has to be done.
- The whole bridge is aligned with the help of turnbuckles on suspenders and wind ties so that the walkway is exactly straight and horizontal in the direction perpendicular to the bridge axis, of parabolic from in side elevation and the windguy cable forming a continuous curve.
- All nuts and lock nuts of the whole construction are retightened.
- Special attention is given to the nuts of the bulldog grip. All pins are secured.
- All non-galvanized threads are protected

5.4 QUALITY CONTROL AND MONITORING

For warranting the designed safety of the bridge, a proper quality control and monitoring system must be set. The TBS (Trail Bridge Section of DoLIDAR) has worked out a Quality Control Scheme, based on its long experience. This scheme is strictly designed for trail bridge construction for both centralized and decentralized management.

The scheme explains:

- Accountability / Responsibility
- Manpower Planning
- Field of Quality Control
- Quality Control by Office
- Built in Quality Assurance
- Budget of Quality Control

The scheme has developed various Inspection Forms for Final Inspections. The methodology of Field Inspections, Recording, Reporting, Schedules, Photo Recording, Test Certificates, Load Testing and Work Completion Reports are fixed.

The scheme is worked out both for new construction and major maintenance.

For routine maintenance too, there are specific job description, routine inspection and responsibility distribution systems.

For Details refer to the "Quality Control Scheme, TBS/DoLIDAR"

Similar schemes have also been worked out for construction and maintenance of bridges done with community approach.

It should be kept in mind that quality work is achieved when there is a proper scheme applied from the beginning to the end. The guarantee of a bridge depends on 1) survey, and design work, 2) procurement and fabrication of bridge parts and 3) construction to 4) finishing work.

Regular supervision is a must, whether it is fabrication and galvanization or construction work. The supervision must be done when the work is under progress. Certain works need timely inspection. The final inspection after the work is completed cannot rectify certain works. That should be kept in mind.

For further details refer to chapter-7.

6. TRAIL BRIDGE MAINTENANCE

6.1 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 on 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.

6.2 ROUTINE MAINTENANCE

Routine maintenance is a preventive type of maintenance and should be done regularly. It is important to protect the bridges from developing big and irreparable damage and assure long term use by keeping them in a serviceable condition. After completion of the bridge construction, routine maintenance should be carried out on a regular basis. In general, the work involved in routine maintenance is simple in nature.

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 the 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 have become loose.

3. **Repairing the walkway deck**

   Re-tightening of loose nuts and bolts of the 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 to seek their necessary support in case of big landslides, bank erosion, etc. which may damage the bridge foundations and structures, or even cause the bridge to collapse.

Routine maintenance work can be carried out either by forming a Bridge Maintenance Committee (BMC) or by appointing a bridge warden. In both the cases, one trained person must be assigned to inspect the bridge regularly. 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 support the VDCs in cases beyond their capacity.

6.3 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.

Major maintenance work includes the following tasks:

6. **Replacing rotten wooden planks with galvanized steel decks.**
7. **Replacing rotten wooden crossbeams with galvanized steel beams.**
8. **Repairing of windguy arrangements/system.**
9. **Repair, adjustment or replacement of suspenders including adjustment of camber of suspension bridges.**
10. **Re-painting of all non-galvanized steel parts.**
11. **Re-tensioning of all loose cables and adjusting bridge alignment.**
12. **Coaltar treatment of all non-galvanized threads.**
13. **River bank and slope protection works.**

The existing bridges which were constructed in the past with wooden walkway decks and non-galvanized steel need major maintenance work in the first instance. 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 major maintenance works and are responsible for independent execution 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, BBLL, Kathmandu.