# DIVISION V

# BRIDGE CONSTRUCTION PLANNING

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## CHAPTER 1 GENERAL

### 1.1 Introduction

Construction management can involve the planning, execution, and control of construction operations for any types of construction. Construction planning generally requires determination of scheduling of the work, selection of construction methods and equipment to be used, estimating of construction costs and financing methods.

The construction planning presents general approach to the construction work. Materials and workmanship stipulated in the specifications, financing, and construction cost estimation are not described in this division. The following Specification, manual, and guideline will be referred for details of materials, construction requirement, and workmanship.

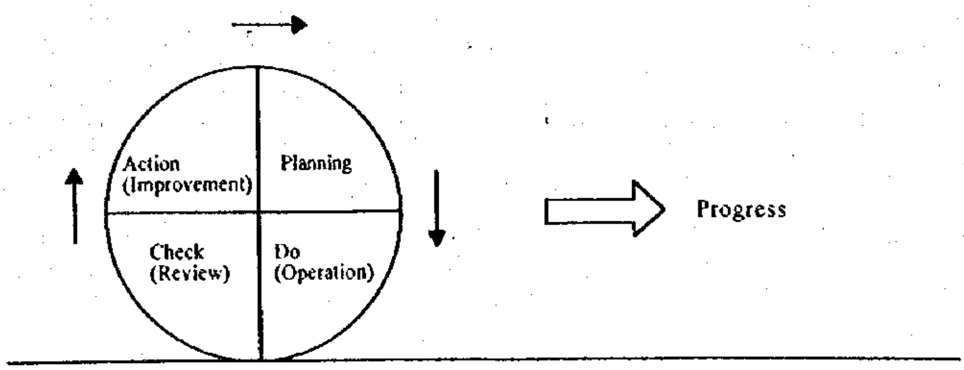
- "Standard Specifications for Highway Bridges Division II Construction" AASHTO
- "Concrete Manual" U. S. Bureau of Reclamation, Government Printing Office, Washington
- "ACI Manual of Concrete" American Concrete Institute (ACI)
- "Manual of Steel Construction" American Institute of Steel Construction (AISC)
- "Detailing for Steel Construction" AISC

### 1.2 Objective of Construction Planning

The construction planning is important and vital to the successful implementation of the works, and suitable construction plan will facilitate the construction.

Prior to starting actual construction, the client or consulting engineers will prepare construction planning mainly work programme, cost estimate and possible problems in order to complete the project in accordance with the Drawings and Specifications within the contract period and with sound engineering practice and government's budget. The contractor is generally requested by the client to prepare construction planning to get approval.

The construction planning should be reviewed from time to time during construction, in accordance with the prevailing circumstances on the site, also if change in the contract or design are required during construction, the construction planning should be modified or corrected to meet the requirement. The cycle of construction planning is illustrated below.




## 1.3 Procedure of Construction Planning

### 1.3.1 Preliminary Investigation

Preliminary investigation for construction planning will be provided taking into account the scope and quantity of works, and site condition including environment.

(1) Scope and Quantity of Works

- Scope of works
- General drawings
- Major quantities

(2) Site Condition and Environment

| | |
|---|---|
| - Topography | Topographic condition<br>Drainage condition |
| - Geology | Geographic condition<br>Soil condition and soil profile<br>Assumed depth of foundation |
| - Climate | Annual rainfall and density<br>Dry and wet season |
| - River | Highest and lowest water level<br>Stream velocity |
| - Environment | Housing, hospital and school around the site<br>Road traffic and railways |
| - Public Utilities | Water, electricity, telephone, sewers, oil and gas |

### 1.3.2 Items of Construction Planning

The following items of construction planning are to be considered.

(1) Materials and Products

- Sources and availability
- Route of delivery

(2) Preliminary Works (Preparatory Works)

- Site office, storage and laboratory---------------- location and size
- Electricity and water supply
- Survey and laboratory equipment

(3) Construction Methods and Work Approach

- Temporary works---------------------------------- Form and falseworks
  Cofferdams
  Temporary water control
  Temporary bridge and road
- Structure excavation and backfill
- Removal of existing structure
- Driving foundation piles--------------------------- Test pile of loading test
  Driving equipment
- Concrete ------------------------------------------ Ready-mixed concrete or site mix
  Transportation and placing
- Prestressing --------------------------------------- Force and elongation of tendons
- Steel structures------------------------------------ Fabrication, Assembly
- Handling and erection of beams-------------------- Erection method
- Miscellaneous works ------------------------------- Bearing
  Handrail
  Expansion joint
  Drainage pipe

(4) Construction Plant and Equipment

- Selection and delivery to the site
- Kinds, numbers, period of use of equipment required
- Layout on the site
- Workshop

(5) Site Organization and Supervision

- Work assignment and their duties
- Nominated or specialist suppliers
- Nominated or specialist sub-contractors
- Committee and communication
- Scheduling of labour requirement

(6) Work Programme

- Sequence of works
- Production rate
- Effect of major public holidays and weather constraints
- Site traffic and traffic pattern

(7) Quality Control

- Technical inspection
- Quality control testing

(8) Construction Safety

- Cofferdams
- Handling and erection of beams
- Falseworks

(9) Public Relations

- Utilities-------------------------------------------Diversion or protection
- Road traffic management
- Railways/highways--------------------------------Over-pass bridge

(10) Cost Control

- Cost estimation
- Budgeting

(11) Environmental Control during Construction

- Noise and vibration
- Air-pollution
- Transportation/handling of hazardous materials
- Water quality and water pollution

### 1.4 The Parties Involved in Construction and Their Roles

The principal parties involved in construction projects are summarized as follows.

(1) Clients

Client may commission work in their own right and, as financiers of the construction project, have a crucial role to play in the establishment of the right conditions for the management of site work. Clients are in a position to exercise considerable control over its conduct although this may vary considerably from one of total control to one where the client relies entirely on his professional advisers.

(2) Professional Advisers

These may include consulting engineer, value engineers and quantity surveyors. One of their main tasks during construction is to ensure that the project is completed by the contractor according to plan in terms of cost, time and quality. Value engineer is to effect economy in the construction cost.

(3) Main Contractor

A main contractor may work on his own, or have a number of sub-contractors working for him, including those nominated by the client. In some circumstances, he may also work in association with other contractors of equal status. The successful main contractor should examine the information supplied by the client's professional advisers and using his experience and expertise, devise an economic construction method.

(4) Design and Build Contractor

A design and build contractor will, in addition to his responsibilities for the construction of the works, have responsibilities associated with the design of the project.

(5) Sub-Contractor

Sub-contractors may be appointed directly by the main contractor and are often contracted to do the actual work because of their specific expertise. The duties and responsibilities of such sub-contractors for their own employees and those under their direct control are the same as those set out for all works contractors. In particular, they must co-operate not only with the contractor who appointed them but also with the main contractor who has overall control of the site.

## CHAPTER 2 GENERAL ITEMS OF CONSTRUCTION PLANNING

### 2.1 Construction Programme

In order to estimate the programme of construction, the quantities of each works should be determined. It will estimated at the probable rate of the work to be performed considering available labour and equipment, allowing for estimated loss in time due to weather conditions, site condition or any other causes. From this information it will be possible to estimate the total time required to complete each works.

The estimated starting date and completion date for each work will be determined. In scheduling the activities it will consider the desirable sequential relationship between the activities. For example, in constructing a concrete foundation, it will be necessary to complete the excavation before concrete is placed, and concrete can not be placed until the forms have been erected and the reinforcing steel has been placed. Work programme will be presented usually in Bar Charts or Program Evaluation & Review Technique (PERT). PERT include progress control (PERT/TIME), manpower control (PERT/MANPOWER) and cost control (PERT/COST).

An example of work programme is shown in Fig. 5.1.

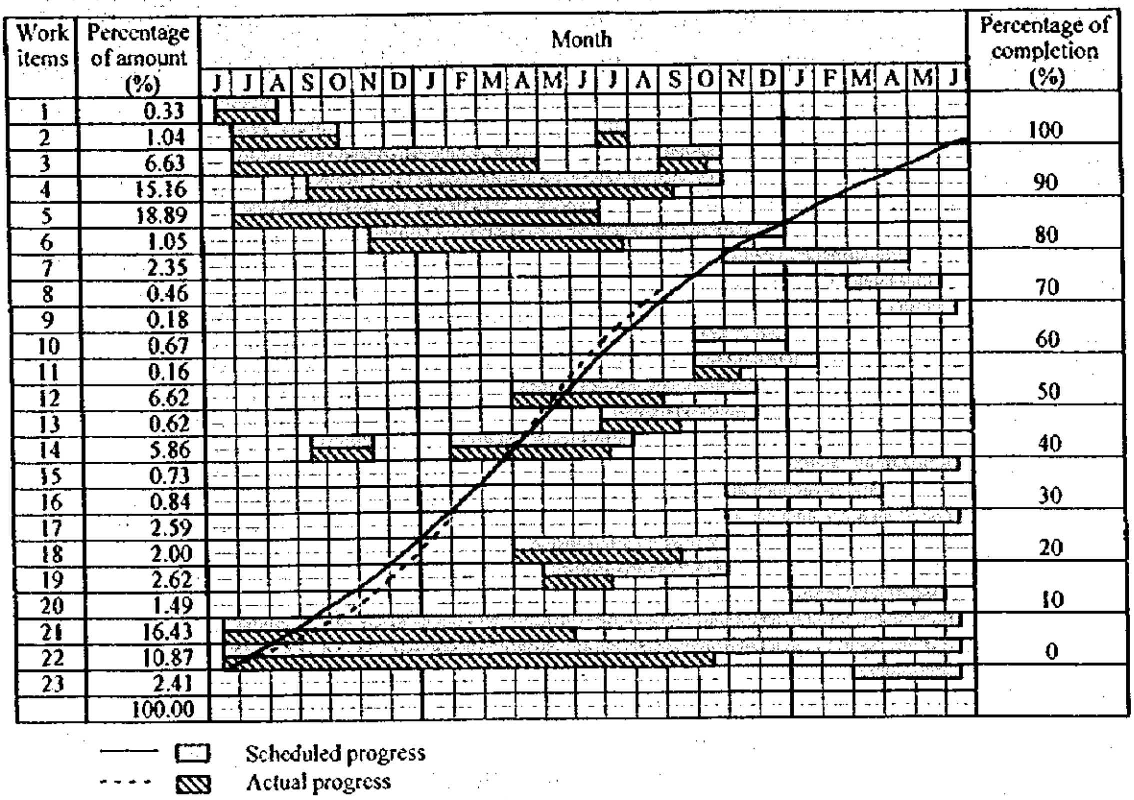



Fig. 5.1 Construction Programme

The schedule control curve which is called S-cures or Bell-curves for road construction was produced by the statistical analysis in the California Division of Highway, USA is shown in Fig. 5.2.

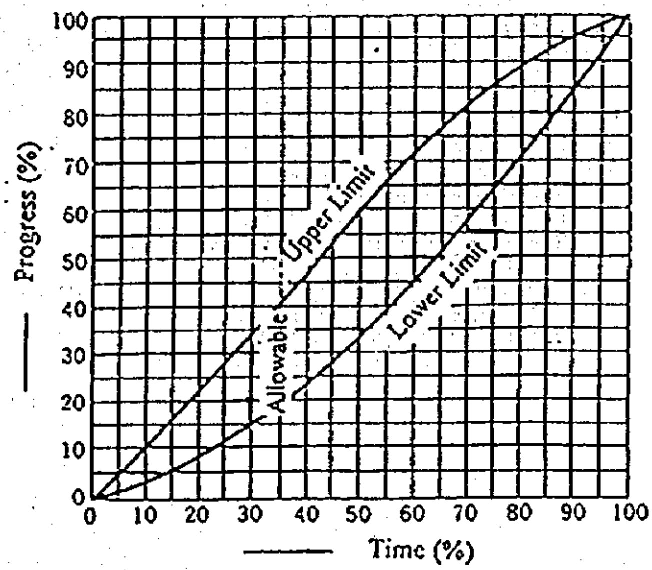



Fig. 5.2 Schedule Control Curve (S-curve)

The lower line in this figure gives allowable progress rate, i.e. at 30 % of time passing, an allowable rate of progress is 16 - 35 %. If the progress of work is under 16 %, it is necessary to take measures to recover from the critical condition, and if the progress is over 35 %, present incorrect work programme is to be reviewed.

### 2.2 Quality Control

The objective of quality control is to ensure and verify the quality of the materials and the execution of works shall be in accordance with the contract documents and conforms good workmanship.

Two functions of quality control for materials and workmanship are as follows:

- Technical inspection
- Quality control testing

The technical inspection and quality control testing to be performed appropriately by suitably experienced engineers, inspectors and technicians, and thoroughly familiar with the relevant standards and corrected technical procedures. The construction quality control is a system which involves the joint but independent efforts on the Government, the Contractor and Manufacturer to achieve the level of quality in accordance with the Specifications. When the quality of completed structure does not meet required quality, the structure should be replaced and reconstructed. That is very uneconomical and brings loss not only to the Contractor but also to the Government.

In the generality of cases, quality and cost or progress is disagreed to each other as shown in Fig. 5.3. However, quality control is the most important matter than others.

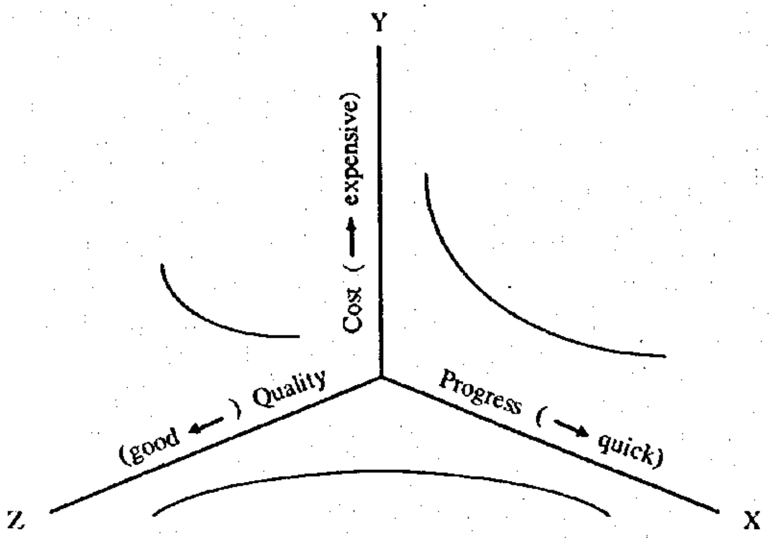



Fig. 5.3 Relationship between Quality, Cost and Progress

Quality Control Checks

An example of quality control checks for tensioning works and grouting works for post-tensioned beams are as follows:

(1) Tensioning Works

(a) Materials

- Identification of the steel and checking and filing of the documents (test reports, dispatch notes) sent by the supplier

- Checking anchorages and accessories
  Condition of the ducts.
  Geometric tolerances of anchorages and accessories.

(b) Before Tensioning Stage

- Placing the formwork
  Checking the condition of the tendons after storage and handling.

Checking to ensure that the positioning tolerances have been complied with.
Checking the number and rigidity of fasteners.

- Availability of full instructions issued by the designer
  Sequence of tensioning the tendons.
  Tensioning procedure (from one end or both ends, increments in the tensioning force to be applied, maximum pressure at the jack, corresponding theoretical tendon extension, tolerances on such extension).

- Availability and proper condition of the necessary equipment
  Calibration of the acks.

- Quality of the concrete (information check test results) and other materials concerned, (e.g. jointing materials)

- Degree of freedom
  To enable the prestressed concrete member to deform when the prestress is applied.
  To enable the cables to move in their ducts.

(c) Tensioning Stage

- Measurements for determining transmission coefficients, if necessary.

- Records of the forces and extensions corresponding to each increment of the tensioning force. (plotted in a diagram).

- Supervision of any re-tensioning operations and of the installation of anchorages and accessories.

- Measurements of slip of cable in relation to the anchorages.

(d) After Tensioning

- Visual inspection of the concrete of the structure.

(2) Grouting Works

(a) Before Grouting Stage

- Results of preliminary and suitability tests.

- Continuity of the ducts (no breaks in them), liquid-tightness of couplings, availability of unobstructed bent holes and weep holes.

- Making the grout (mix proportions and tolerances in the proportions, sequence of adding the constituents, mixing time, speed of the agitator, etc.).

- Grouting (adapted to the climatic conditions, blowing through with compressed air or flushing the ducts and tendons with water, grouting pressures, closure of bent holes).

(b) Grouting Stage

- Observing the pressure and detection of any leakage.

- Checking the volumes: quantity of grout and time that elapses before it emerges from the bent holes.

- Taking samples for quality control check.

(c) After Grouting Stage

- Checking that all bent holes and other openings have been properly sealed and that the permanent anchorages are suitably protected.

Quality control shall obtain the level of quality desired by the Specifications. Flow chart of quality control is shown in Fig. 5.4.

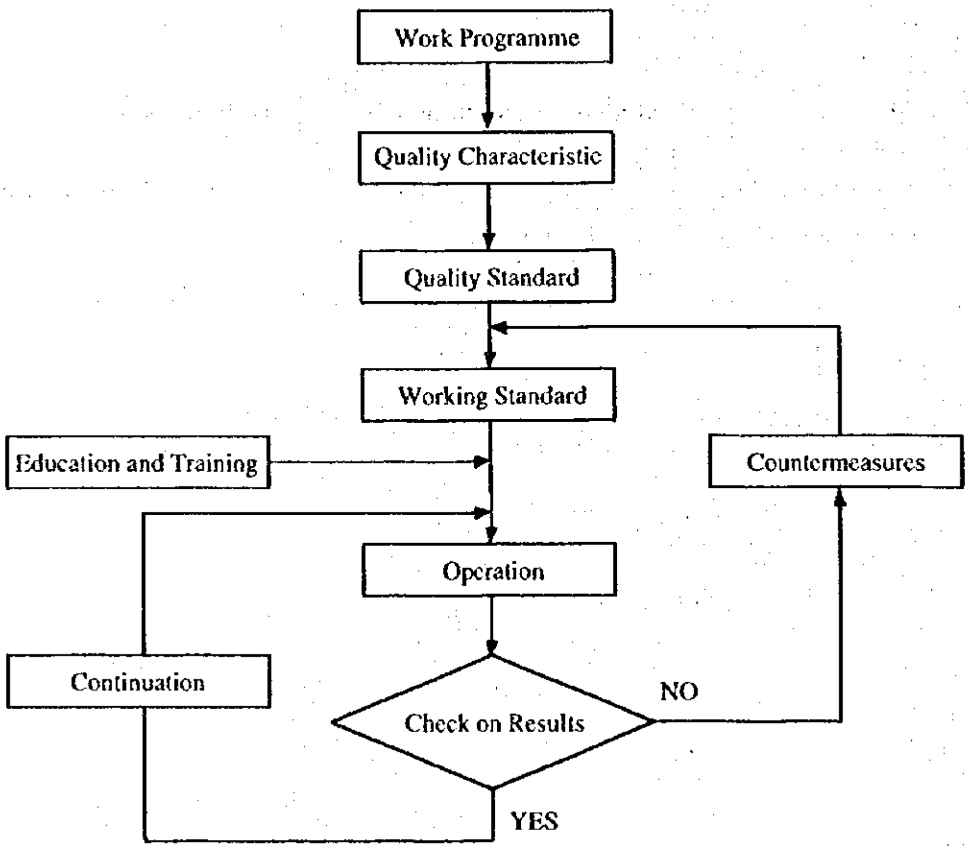



Fig. 5.4 Flow Chart of Quality Control

### 2.3. Public Relations

Cooperation should be obtained from the government concerned and private agencies whose utilities or facilities affect the works, and also the inconvenience and danger to the public are to be avoided.

(1) Utilities

Involved utilities are water, electricity, telephone, sewers and oil/gas pipelines. These utilities are usually required diversion or protection by the government concerned or authorities and any damage to the utilities are to be avoided.

(2) Road Traffic

Where temporary diversion bridge or half-width construction is required, they shall be made in safe and suitable, and also traffic management, during that period, is very important so as to minimize inconvenience to the public.

(3) Railway

Special care needs to be taken at intersections with railway tracks, or at any locations where work has to be undertaken close to railway tracks. It is essential that very close cooperation with the railway authority and its regulations are strictly taken and observed. Construction operation method and schedule shall be carefully planned, especially for lifting and erecting operations of prestressed concrete beams and steel girders.

### 2.4 Environmental Control

The construction works should be carried out in the manner which ensures acceptable levels of noise/vibration and other forms of environmental pollution are not exceeded. The client reserves the right to prohibit any work which causes such standards to be exceeded in commercial and residential areas, and near livestock. Environmental pollutions are generally as follows:

- Noise and vibration
- Air pollution
- Transportation/handling of hazardous materials
- Water quality and water pollution
- Damage to surroundings

Noise levels of construction equipment are shown in Fig. 5.5.

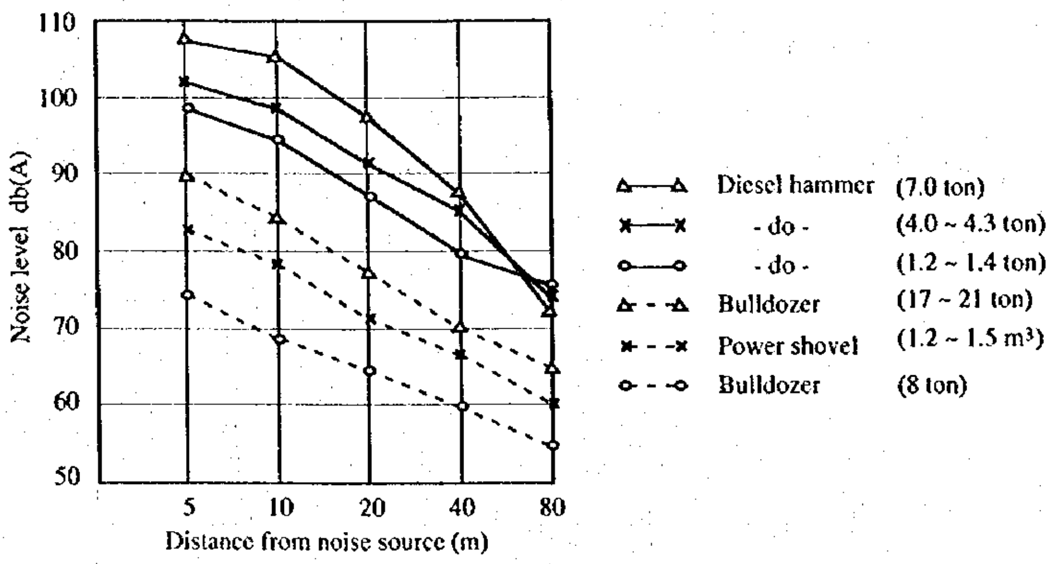



Fig. 5.5 Noise Level of Construction Equipments

# CHAPTER 3 CONSTRUCTION REQUIREMENT OF MAJOR WORKS

## 3.1 Prestressing Works

### 3.1.1 Site Tensioning Operations

The tensioning operation will be carried out by suitably experienced supervisors and operators (specialist sub-contractor).

The instructions controlling the tensioning operations are based on the design of the bridges and may be modified by the engineer as a result of the information obtained from site tensioning records.

The instructions are as follows:

- Minimum concrete strength at the time of tensioning
- Whether tendon is stressed from one or both sides
- Tensioning sequence
- Tensioning forces and elongation

Tensioning of tendon should be done in sequence to introduce a minimum eccentric force in the beam section. In calculation of anticipated elongation of each tendons, cable friction, jack and anchorage friction and elastic deformation of the concrete beam are to be taken into account.

Prior to the tensioning operation, a specialist shall ensure the following matters.

(1) Understanding on Design Calculations

The relation between design and construction work of the prestressed concrete is much close than that of other ordinary reinforced concrete. And particularly, with respect to the design requirements and working drawings, prestressed concrete beams are to be stressed. The basic design contents shall be fully understood.

(2) Equipment

In carrying out the work, the tensioning equipment should be appropriate and operated in accordance with the system manufacture1s instructions.

(3) Force Measuring

The pressure gauge of jacks are required to calibrated by dynamometer in order that the magnitude of the tensioning forces can be adequately controlled. This calibration must be done periodically since they tend to easily become inaccurate.

(4) Safety

Tensioning works can be dangerous. If a tendon breaks or slips there is a sudden and large release of energy which is likely to cause the tendon to be projected from the duct with a considerable force. Precautions must be taken to ensure that stressing is carried out safely.

### 3.1.2 Control of Stressing Operations

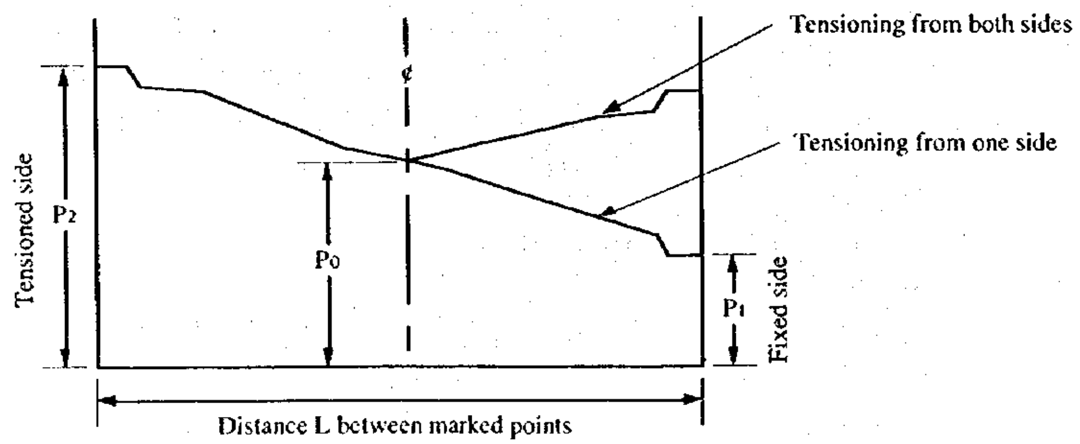
The recorded force and elongation on the site should be compared with the calculated value. If measured and calculated values are in close agreement, the friction losses assumed in the design are confirmed. Where tolerance has not been specified, a realistic value is normally ±6 %.

Valuation of forces and elongation may be arisen from:

- Variation in internal friction in the jack
- Error in measuring elongation
- Variation in cross-sectional area in modules of elasticity of tendon
- Difference between design and actual coefficients of friction
- Variation in friction in the anchorage

Friction Tests

Two jacks are used for measuring actual friction, the force is applied via one end and the other registering the passive force at the other side of the tendon. The distribution of tension along the duct during prestressing and the relation between the forces at the tensioned side and fixed side in the friction measurement are shown below.



## 3.2 Erection of Precast Prestressed Concrete Beams

### 3.2.1 General

The precast prestressed concrete beams are usually erected in position using truck cranes or erection steel girders with gantry crane or bent. The following matters are significant for proper selection of launching method for the precast prestressed concrete beams.

- Geography of the site
- Soil conditions
- Condition of fabrication yard (location, width and length)
- Weight of beam
- Availability of specialized and/or heavy equipment
- Accessibility of the work areas
- Obstacles above and below the beam to be erected
- Safety of handling and erection

### 3.2.2 Erection Method

(1) Erection by Truck Crane

This method is suitable for bridges where the truck crane can either be stationed closely to the bridge abutments or piers, or between the bridge pier. The required capacities of cranes depend on applying of both length and working radius of crane booms.

(a) Single Truck Crane

A truck crane can lift beam and launch them on position and it is suitable for small scale bridge as pre-tensioned concrete beams for weights under 15 tons. In case of truck crane stationed between bridge piers, the lifting capacity of crane required is about 2 to 3 times of the weight of beams (30 to 45 tons truck crane). In the case of the truck crane stationed just behind of bridge abutment, the lifting capacity of crane required is about 6 to 8 times of the weight of the beams (90 to 120 tons truck crane ).

(b) Two Track Crane

In this method, the erection girder is usually placed between the bridge span on which precast bridge beams are carried and placed on abutments or piers by 2 truck cranes. The lifting capacity of crane usually required is about 1.5 to 2.0 times of the weight of beam. Taking availability of heavy truck cranes and safety of erection works into consideration, this method is applicable for weights under 80 tons precast bridge beams. This method is usually applied for weight of 15 to 70 tons precast beams, and is used for over 70 tons as in special case. Applicable truck cranes for erection precast bridge beams are shown in Table 5.1.

Table 5.1 Applicable Truck Crane for Launching Beams

| Length of PC Beam | Weight of PC Beam | Applicable Lifting Capacities of Truck Crane |
|---|---|---|
| 15 - 18m | 15 - 20 tons | (30-40 tons) * 2 cranes |
| 20 - 22m | 25 - 30 tons | (45-60 tons) * 2 cranes |
| 25 - 30m | 50 - 70 tons | (90-130 tons) * 2 cranes |

(2) Erection by Specialized Girder

This method is suitable for erecting post-tensioned beams with lengths of 25m up to 45m (weight of 50 - 135 tons) and for specialized erection girders in succession over several spans. There are two types of specialized girder, single steel girder and two steel girders. Erection is not influenced by the height of the piers or the existence of a waterway, and there is no restriction on the ground condition under the erection girders. Transportation, assembling and disassembling costs for steel girder are necessary, therefore, it is not economical for short span beams or a few spans bridge.

Two types of specialized erection girder are shown in Fig. 5.6.

(3) Erection by Gantry Crane

In this method, a pair of gantry crane straddling projected two piers lifts up and places into position the precast beams which have been delivered by a rail or a trailer truck running alongside of the projected span.

(a) Fixed gantry crane method

In this method, a pair of gantry crane is fixed by its legs to the ground so that it can lift and place concrete beams in position.

(b) Self-traveling gantry crane method

In this method, a pair of gantry crane is positioned on a track laid on the ground along the bridge spans so that it can freely travel over the bridge spans.

Both methods are shown in Fig. 5.7 and Fig. 5.8 respectively.

(4) Erection by Bent

In this method, steel supports are built either partially or entirely between the bridge spans, on which precast beams are carried to be laid them in place.

(a) Bent-type method

In this method, supports which are assembled between the entire bridge spans are utilized, on which the precast concrete beams can be pulled out.

(b) Traveling bent method

In this method, the end of a precast concrete beam is received on the travelling bent running along the ground rail, and erection can be accomplished by pulling out the traveling bent.

Both methods are shown in Fig. 5.9 and Fig. 5.10 respectively.

Characteristics of this method are;

- Sufficient space for the bent to be placed and for it to travel over the span is necessary.
- When the pier height is low and the ground under the bent is firm, heavier beams can be launched.

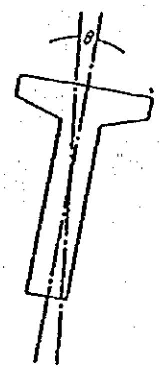
### 3.2.3 Selection of Erection Method

Selection of erection method is shown in Table 5.2 in which the methods are marked ◎, ○ and △ in order of their frequency of employment.

### 3.2.4 Safety Measures

Since, during transportation, the prestressed concrete beams are subjected only to the combined stress corresponding to the prestressing and the bending due to the dead load, the tensile stress at the top fiber of the beam is allowed of 13.4 kg/cm$^2$.

If the beam is inclined left or right, the bending moment acts laterally due to its dead load and the tensile stresses are induced on a side and at the top fiber of the beam.



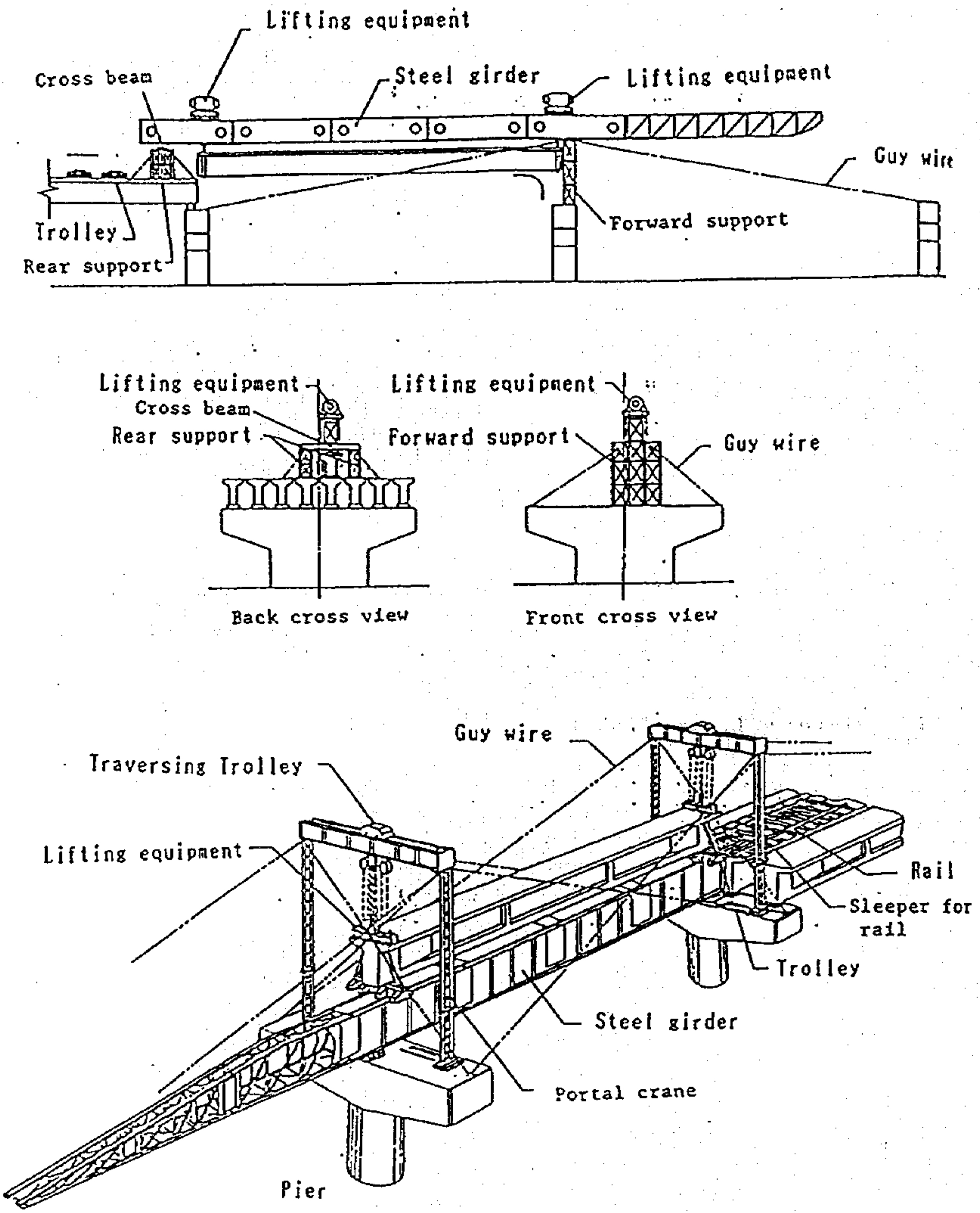



Fig. 5.6 Launching by Single Steel Girder

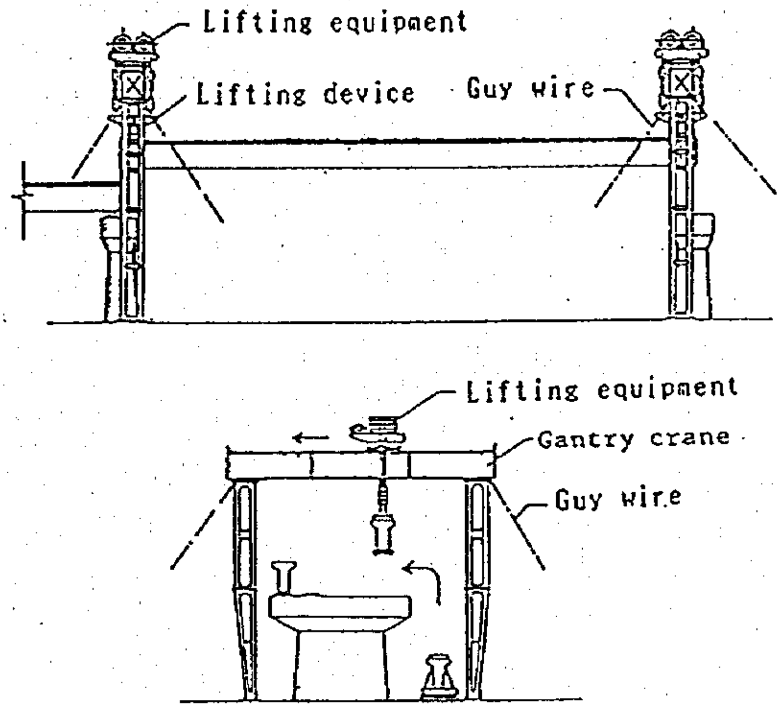



Fig. 5.7 Fixed Gantry Crane Method

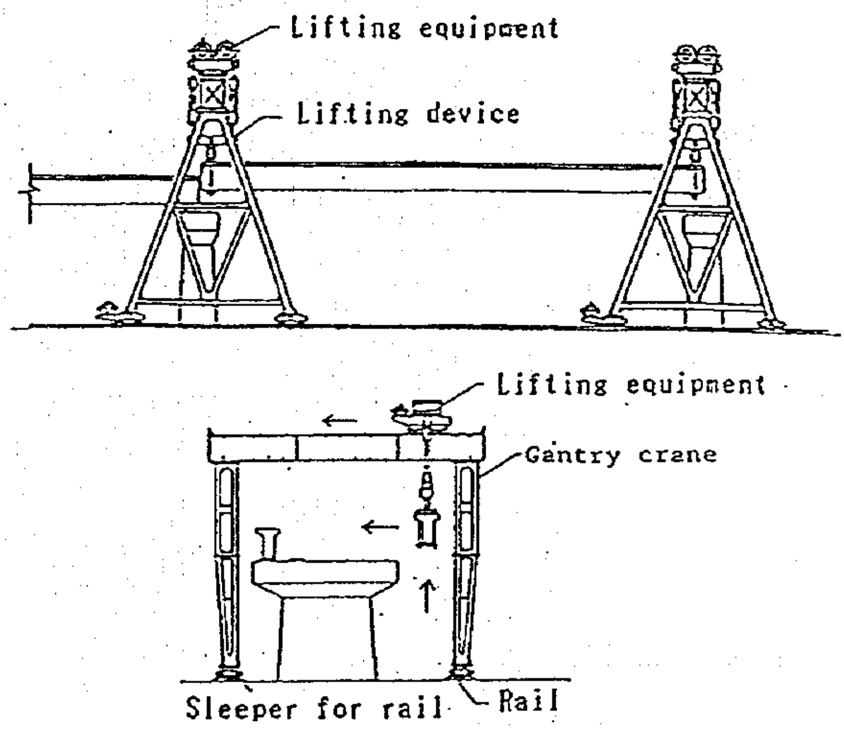
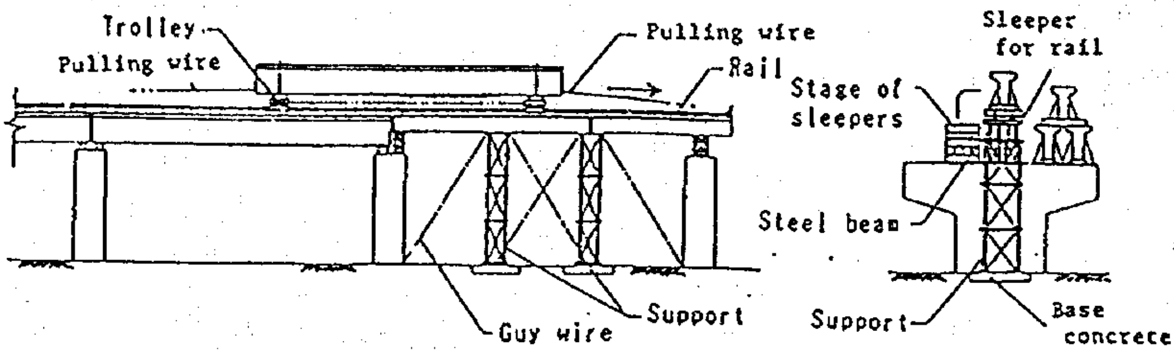



Fig. 5.8 Self Traveling Gantry Crane Method

A Carring and down method




B Carrying and shifting method

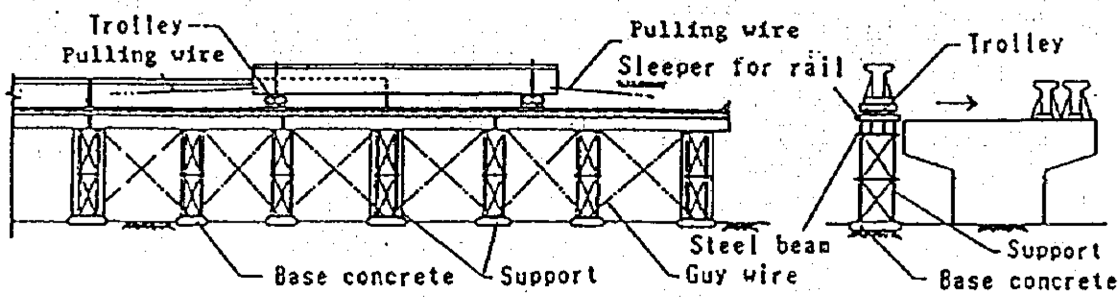



Fig. 5.9 Launching by Bent

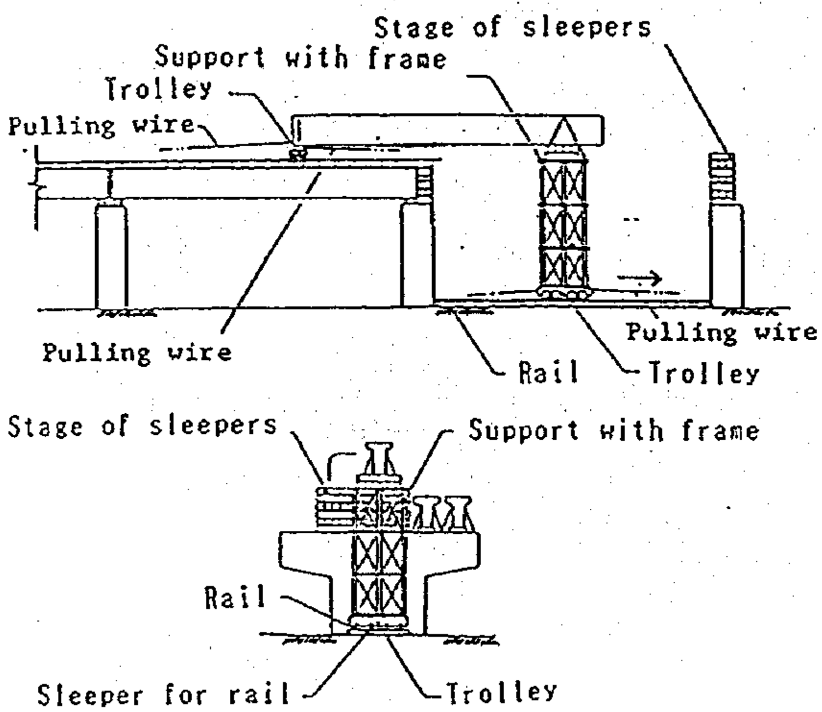



Fig. 5.10 Launching by Traveling Bent

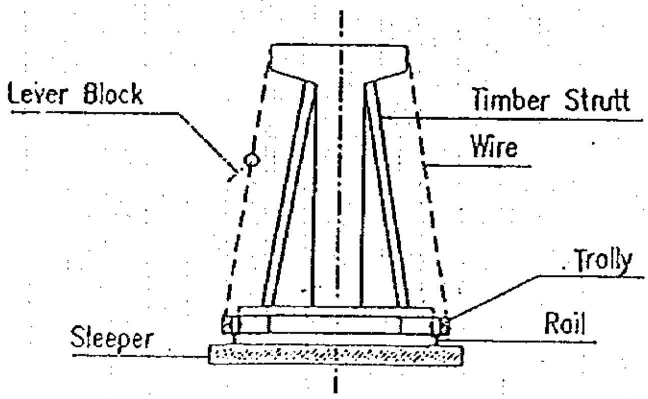
Table 5.2 Adaptability of Erection Method of Precast Concrete Beam

| Condition | Launching Method | Launching steel girder: Two steel girders | Launching steel girder: Hanging from one steel girder | Launching steel girder: One steel girder and two portal cranes | Launching steel girder: Two steel girders and shifting | Launching steel girder: One steel girder and shifting | Launching steel girder: Carrying method | Crane: Single truck crane | Crane: Two truck cranes | Crane: Floating crane | Gantry crane: Fixed gantry crane | Gantry crane: Self-traveling gantry crane | Bent: Bent-type | Bent: Traveling bent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fabrication yard | On approach road or on viaduct | ◎ | ◎ | ◎ | | | ○ | △ | ○ | | | △ | ○ | ○ |
| | Under or near the bridge | | | | ◎ | ◎ | ○ | ◎ | ◎ | | ○ | ◎ | | |
| Space over and/or under the bridge | Obstacle over the bridge | ◎ | ○ | ○ | ◎ | ◎ | ○ | | △ | | △ | △ | ◎ | ◎ |
| | River under the bridge | ◎ | ◎ | ◎ | | | ○ | | | | | | | |
| | Rail way under the bridge | ◎ | ◎ | ○ | | | ○ | | △ | | | | | |
| | Road under the bridge | ◎ | ◎ | ○ | ○ | ○ | ○ | ○ | ○ | | △ | | | |
| Weight of PC beam | Light (under 10t) | ○ | ○ | ○ | ○ | ○ | ○ | ◎ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Heavy | ◎ | ◎ | ◎ | ◎ | ◎ | ◎ | △ | ◎ | ○ | ○ | ○ | ○ | ○ |
| | Very heavy (over 100t) | ◎ | ○ | ○ | ◎ | ○ | △ | | ○ | ○ | ◎ | ○ | | ◎ |
| Schedule | Necessary to be in stock | ◎ | ○ | ○ | ◎ | ◎ | ◎ | ◎ | ◎ | ◎ | ○ | ◎ | △ | △ |
| | Launching without stock | ○ | ○ | ○ | ○ | ○ | ○ | | | | ○ | ○ | ○ | ○ |
| | Immediately launching after casting the bridge slab | △ | △ | △ | ◎ | ◎ | ◎ | ◎ | ◎ | ◎ | ◎ | ◎ | △ | △ |
| Size and figure of pier | No space for support (transverse) | ○ | ○ | ○ | ○ | ○ | ○ | ◎ | ◎ | ○ | ◎ | ◎ | | |
| | No space for support (longitudinal) | ◎ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ◎ | ◎ | | |
| Curvature and slope | Curvature | ◎ | ○ | ○ | ◎ | ○ | ○ | ◎ | ◎ | ◎ | ◎ | ◎ | ○ | ○ |
| | Large slope | ○ | △ | ○ | ○ | ○ | | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Others | Large skew | ◎ | △ | ○ | ◎ | △ | ◎ | ◎ | ◎ | ◎ | ◎ | ◎ | ○ | △ |
| | Over river or sea | ○ | | | ◎ | ◎ | ○ | | | ◎ | | | | |

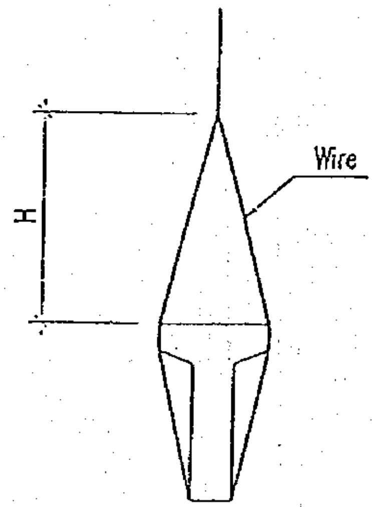
Therefore, appropriate handling and erection study shall be undertaken specially for long and slender girders, to ensure against lateral buckling or cracking during various stages of handling and erection.

- Position of temporary support
  Prestressed beams are only allowed to be suspended or supported firmly at their bearing points

- Erection of beams
  Long and slender beams shall be safeguarded against tilting by means of auxiliary supports and temporary strutting or bracing.




Transpontatin of Beam




Launching by Truck Crane

$H \geq 1.5m$ for Pre-tensioned Beam

$H \geq 2.0m$ Post-tensioned Beam

Allowable Inclination of Beam

The following equation to be satisfied

$$\delta ct' \times \eta + \delta do' \times \{1-(Zc')/(Zh) \times \sin \theta\} \geqq \delta cat''$$

therefore, $\theta = \sin^{-1}\{(\delta cat'' - \delta ct' \times \eta - \delta do') / \delta do' \times (Zh/Zc')\}$

where; $\theta$ : Allowable inclindation angle (°)

$\delta cat''$ : Allowable tensile stress due to temporary load during handling and erection = $-25 kg/cm^2$

$\delta ct'$ : Tensile stress at top fibre due to prestressing ($kg/cm^2$)

$\delta do'$ : Compressive stress at top fibre due to girder weight ($kg/cm^2$)

Zc' : Section modulus of X-Xaxis at top fibre ($cm^3$)

Zh : Section modulus of Y-Y axis at flange end fibre ($cm^3$)

$\eta$ : Effective coefficient of prestressing due to loss = 0.95

### 3.3 Erection of Steel Girders

#### 3.3.1 General

Erection of steel superstructure means to assemble steel elements fabricated at a plant over the substructures at a construction site. In order to economically and efficiently achieve required quality within a limited construction period, construction procedure has to be taken into consideration from the every beginning of the bridge project.

#### 3.3.2 Preliminary Investigation

Described below are items which have to be investigated for making implementation plan of the erection of steel girders.

(1) Transportation Route

The route for transporting construction materials and machinery has to be investigated practically from the stockyard to the exact point at the site beforehand in order to know if there's no problem, and to work out a countermeasure if any problems arise.

(2) Situation at the Site

The investigation items are roughly classified into an investigation of structure and a geological one. Both affect deeply the preparation for the transportation.

(a) Investigation of structures

- Measurement of Substructure
  Substructures have to be measured in terms of not only the principle dimensions but the exact location of bearings and voids for the anchor bolts.

- Existing Structures
  Investigation must be made in terms of existence, location and dimension of structures such as aerial lines, underground burial cables, approach road and so on.

(b) Geographical and Geological Investigation

- Geography
  Yards for preparation and stockpile, and access roads must be geographically studied

and then secured.

- Bearing Ground
  Soils, bearing force of the ground and existence of ground water seriously affect selection of structure of temporary foundations or location of outriggers of automotive crane.

- Riverbed
  Geology, depth and width have to be investigated before the erection plan is made, and the result may be used for determining the location of crane and making plan on various kind of protection against water flow.

(3) Natural Conditions

Principally items below must be studied and the results must be reflected into the erection plan.

(a) Weather: number of days of rainfall, temperature, direction of wind and fog
(b) Hydrology: Precipitation, snowfall, water level, velocity of flow and discharge

(4) Environmental Conditions

Those investigation items as listed below must be carried out for drawing up environmental countermeasures at the site.

(a) Natural environment: Forest, lakes and landscape
(b) Historical environment: Historical remains
(c) Environment in everyday life: Living environment, settlement of the ground, noise, vibration, sunlight etc.

### 3.3.3 Implementation Plan

(1) General

The contractor must make a detail construction plan based on the result obtained from the preliminary investigation, and the plan needs to include considerations on those items shown below.

(a) Organization chart of the contractor
(b) List of principle materials and construction machines employed at the site
(c) Working procedure (including erection drawings)
(d) Verification of the erection stresses
(e) Quality and safety control measures

(2) Erection Drawings

The contractor must submit drawings illustrating fully their proposed method of erection. The drawings must show details of all falsework bents, bracing, guys, dead-men, lifting devices, and attachments to the bridge members: sequence of erection, location of cranes and barges, crane capacities, location of lifting points on the bridge members, and weights of the members. The plan and drawings shall be complete in detail for all anticipated phases and conditions during erection. Calculations may be required to demonstrate that allowable stresses are not exceeded and that member capacities and final geometry will be correct.

(3) Verification of Erection Stresses

Any erection stresses that are induced in the structure as a result of a method of a erection or equipment which differs from that shown on the plans or specified, and which will remain in the finished structure as locked-in stresses shall be accounted for.

(4) Quality and Safety Control Measures

(a) Quality Control

Quality must be controlled to assure the quality of a structure.
To achieve the purpose, it is necessary to confirm that the strength and dimension of the structure correspond with the specifications and the drawings at each construction step and completion.
Photo is often used for recording. In case that some parts of a structure is to be hidden after the completion, then the quality of the part must be recorded by photos and they must saved.
The principle items, which are to be controlled, are:

- Torque introduced into high strength bolts at site
- Elevation of top surface of a bridge(including camber control) and the final geometry
- Dry film thickness of finished paint coatings

(b) Safety Control

Safety measures must be taken as carefully as possible against loss and damage of life, and these measures must be shown in the erection plan.

### 3.3.4 Erection Procedure

(1) Classification of Erection Procedure

Erection procedure of steel bridges is classified by two viewpoints.
They are:

- Classification by a principle erecting machine employed, and
- Classification by a method of supporting bridge elements .

Usually an erection method is expressed by both the principle machine and the supporting method such as " the erection method over temporary supports by crawler crane".

(2) Selection of Erection Procedure

In selecting the best suitable erection procedure, several feasible alternatives must be studied and compared from viewpoints of economy, safety, and construction period. Commonly the simplest plan is the most economical. Practicable methods of erecting steel bridge can be selected based on geographical features around the bridge using the flow chart shown in Fig. 5.11 and Table 5.3.

(3) Types of Erection Procedure

### 3.3.5 Detail Work of Erection

(1) Conformance to Drawings

The erection procedure must conform to the erection drawings submitted. Any modifications to or deviations from this erection procedure will require verification of stresses and geometry.

(2) Maintaining Alignment and Camber

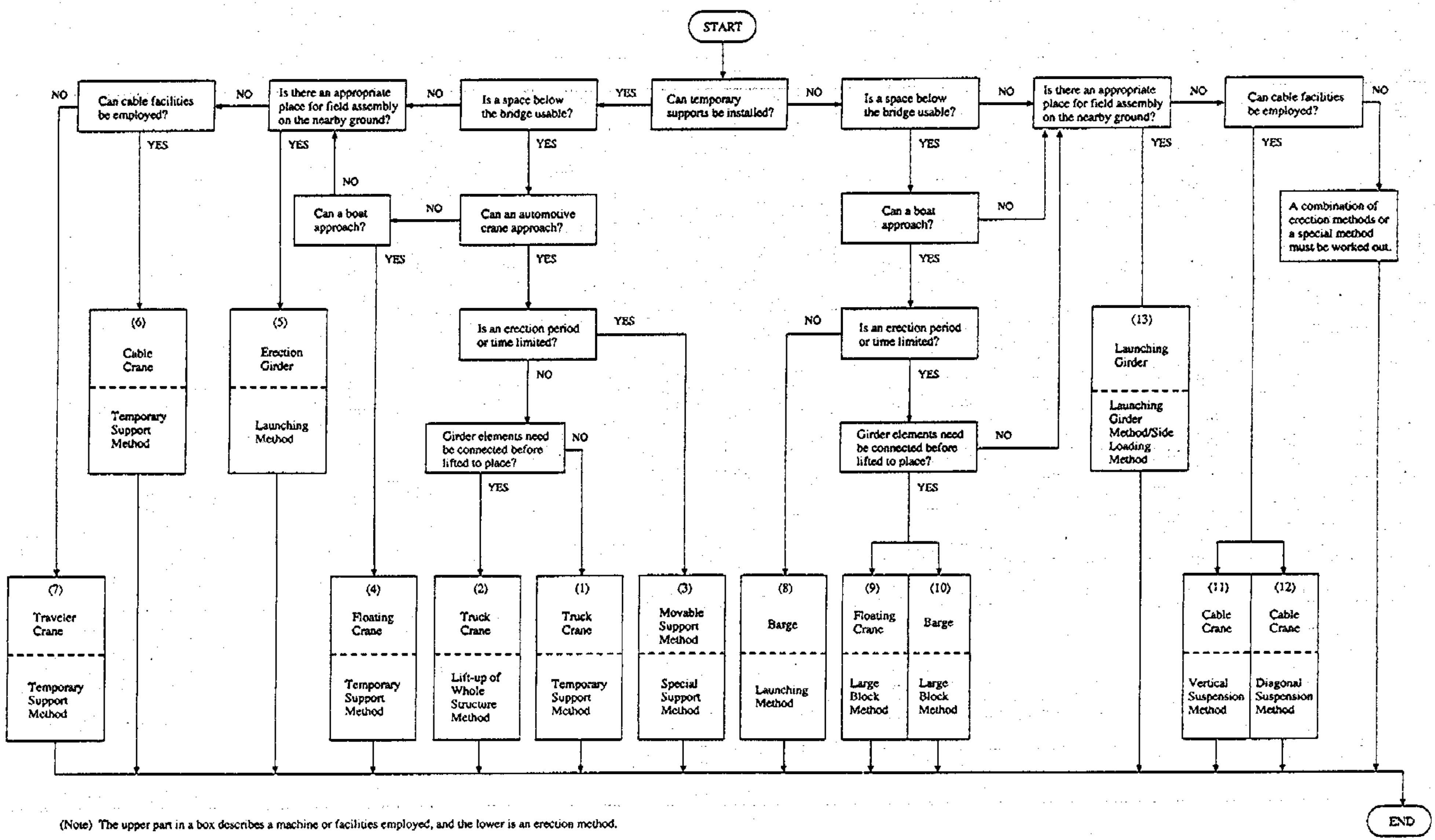
During erection the contractor will be responsible for supporting segments of the structure in a manner that will produce the proper alignment and camber in the completed structure. Cross frames and diagonal bracing shall be installed as necessary during the erection process to provide stability and assure correct geometry.

(3) Field Assembly

The parts must be accurately assembled as shown on the plans or erection drawings, and any match-marks shall be followed. The material shall be carefully handled so that no parts will be bent, broken, or otherwise damaged. Hammering which will injure or distort the members must not be done. Bearing surfaces and surfaces to be in permanent contact shall be cleaned before the members are assembled. Splices and field connections shall have one-half of holes filled with bolts and cylindrical erection pins (half bolts and half pins) before installing and tightening the balance of high-strength bolts. Splices and connections carrying traffic during erection shall have three-fourths of the holes so filled.

(4) Misfits

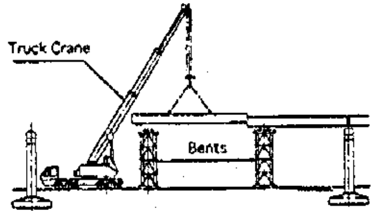
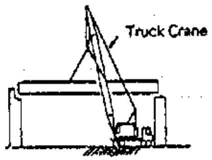
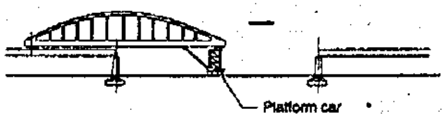
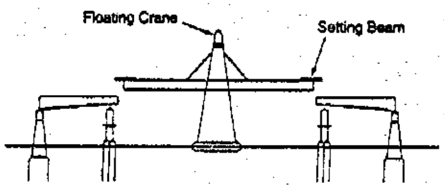
The correction of minor misfits involving minor amounts of reaming, cutting, and chipping will be considered a legitimate part of the erection. However, any error in the shop fabrication or deformation resulting from handling and transporting have to be avoided as much as possible.



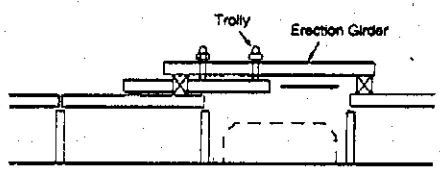
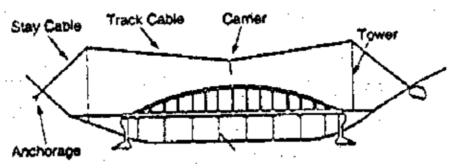
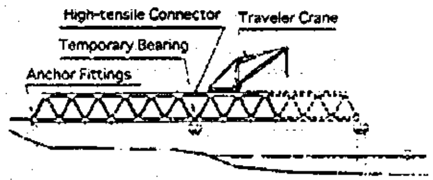
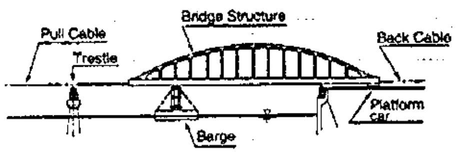

(Note) The upper part in a box describes a machine or facilities employed, and the lower is an erection method.

Fig. 5.11 Flow Chart

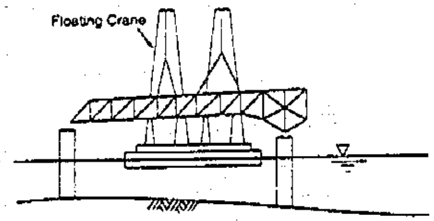
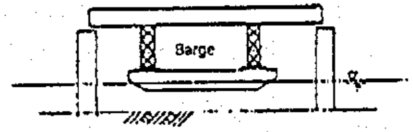
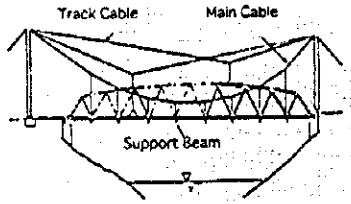
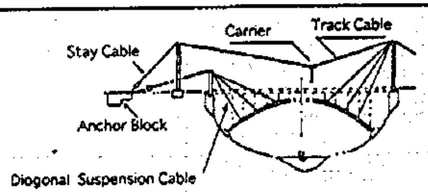
Table 5.3 ERECTION PROCEDURE (1)

| No. | Procedure | Figure | Conditions | Description | Chatacteristics |
|---|---|---|---|---|---|
| 1 | Truck Crane & Temporary Support |   | (1) A truck crane can approach the site.<br>(2) Falsework bents can be installed below the bridge.<br>(3) The ground is strong enough against reaction forces of outriggers of the crane. | (1) Temporary supports are installed at points near field joints of the main girders on the ground.<br>(2) Bridge members are lifted up and placed on these supports by a truck crane.<br>(3) The bridge is assembled by connecting with high-strength bolts. | (1) A truck crane has enough mobility.<br>(2) Less temporary facilities are needed than other methods.<br>(3) Erection period is minimum among others.<br>(4) Adjustment of geometry is easy. |
| 2 | Truck Crane & Lift-up of Whole Structure |   | (1) A heavy truck crane can approach the site.<br>(2) The ground is strong enough for the heavy crane.<br>(3) There' no aerial cables or they can be removed temporarily, if any. | (1) Girders are assembled into a whole span length on the nearby ground.<br>(2) It is lifted up and installed by a heavy crane in the right position at a time. | (1) Because the crane has mobility, temporary facilities can be minimized.<br>(2) In case that the ground is not strong enough, it must be reinforced.<br>(3) A heavy crane is required and it is difficult to procure and expensive. |
| 3 | Movable Support & Girder Sliding |   | (1) A spacious yard for the field assembly of the whole bridge is required next to the bridge position.<br>(2) The soil at the assembly yard and below the bridging point must be strong enough against the reaction force of the dead load of the dead load of the whole bridge. | (1) The bridge is assembled on the ground.<br>(2) One end is supported by a movable bent sliding on rails laid under the bridge, and the other end is also by a platform car.<br>(3) The bridge structure is pulled out longitudinally along the rail by a winch or automotive platform car.<br>(4) After the bridge arrives at the other abutment, it is jacked down. | (1) Various facilities for moving and lowering the bridge are necessary.<br>(2) Occupation period of the ground under the bridge can be minimized. |
| 4 | Floating Crane & Temporary Support |   | (1) A river or sea under the bridge is deep enough, but the flow is not too fast for the work of a floating crane.<br>(2) A floating crane can approach the bridging point or a collapsible crane can be procured. Temporary supports can be installed under the bridge. | (1) Bridge segments are assembled into a large bridge block at a nearby yard.<br>(2) The block is transported to the bridging point directly by a floating crane, or by one placed on a barge and transported to the site.<br>(3) The block is lifted up and placed to the right position by the floating crane.<br>(4) The block is connected with neighboring blocks by high-strength bolts. | (1) An erection period is short and manual work at high elevation is little.<br>(2) The structural system during transportation and erection is different from that of completed structure, therefore deflection and erection stresses must be checked, and members must be reinforced as necessary.<br>(3) Block length and weight must fit to a capacity of the floating crane. |

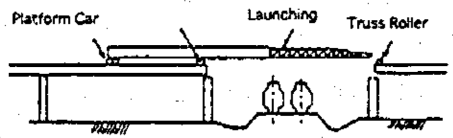
## ERECTION PROCEDURE (2)

| No. | Procedure | Figure | Conditions | Description | Chatacteristics |
|---|---|---|---|---|---|
| 5 | Erection Girder<br>&<br>Launching |  | (1) Use of the space under the bridge is limited by traffic or some other reasons.<br>(2) A special erection girder capable of supporting a main girder is needed.<br>(3) This erection metod is good for a bridge of which spans are short and multiple. | (1) The erection girder is assembled and a launching girder is attached thereto at a nearby assembly yard.<br>(2) The erection girder is pulled out and fixed to the right position.<br>(3) Main girder of the bridge is assembled at the neighboring yard, and is pulled out longitudinally being suspended by the erection girder.<br>(4) The main girder is lowered and then shifted laterally to the right. | (1) There's no need to make use of the space below the bridge.<br>(2) Adoption of the erection method depends on the capacity on the erection girder.<br>(3) The metod is not suitable for a bridge with long span.<br>(4) Erection facilities must be installed on a large scale. |
| 6 | Cable Crane<br>&<br>Temporary<br>Support |  | (1) It must be possible to install steel towers and anchorage for a cable crane and temporary supports.<br>(2) The girder is not curved.<br>(3) There has to be an access road on one of the bank, through which bridge elements are transported.<br>(4) In case there are aerial cables above or near the bridge, it is possibly moved or removed. | (1) Cable crane facilities are installed, which enables to carry bridge elements to any points included in the work place.<br>(2) The crane carries materials to build the bents on the ground temporarily supporting the bridge elements.<br>(3) The crane lights up and places steel elements on the bents one by one. | (1) It takes many days to install anchorage and assemble and assemble temporary facilities such as cable crane.<br>(2) Length and weight of the elements are limited by the capacity of the cable crane.<br>(3) The camber can be easily adjusted.<br>(4) Possibility of whether this method is adopted depends on geographical conditions. |
| 7 | Traveller Crane<br>&<br>Temporary<br>Support |  | (1) Bents can be installed under the bridge.<br>(2) A traveller crane fitting to the bridge must be procured. | (1) Temporary bents are installed on the ground.<br>(2) Side span is erected by such means as a truck crane on the bents.<br>(3) A traveller crane is assembled on the side span.<br>(4) A bridge element is lifted and is connected to the completed part.<br>(5) This step continues until the whole bridge is completed. | (1) The erection work dose not depend on the conditions of the space below the bridge.<br>(2) Deflection and erection stress must be checked and bridge elements must be reinforced as necessary.<br>(3) After the bridge reaching the other end, temporary bearings and connecting elements must be removed.<br>(4) Bolt holes must be be accurately drilled. |
| 8 | Barge<br>&<br>Launching |  | (1) There's a suitable yard for fielf assembly just next to the bridge.<br>(2) The water below the bridge is deep enough and the flow is not too fast<br>(3) There's enough space for mooring the barge to keep the right position sreadily.<br>(4) The water level must be constant. | (1) A superstructure is assembled on the access road.<br>(2) One end is supported on the barge, and the other is on the access road.<br>(3) The barge and the superstructure are pulled with a rope until one end reach the other abutment. | (1) When the water level is very low, the barge needs high platform and becomes unstable.<br>In case that a sliding eleveation on which<br>(2) the structure is pulled out is too high compared with the bridge seat, then a large-scale facilities of jacking down is required. |

ERECTION PROCEDURE (3)

| No. | Procedure | Figure | Conditions | Description | Chatacteristics |
|---|---|---|---|---|---|
| 9 | Floating Crane & Large Block |   | (1) The water is deep enough to enable the floating crane to approach the bridging point.<br>(2) The structure can be assembled at a nearby yard, or assembled at a plant and then transported on a barge.<br>(3) There's no cable obstructing in the air nor water.<br>(4) Stresses during the transportation and erection must be checked, and reinforced if necessary. | (1) The elements are assembled into a large block at a wharf or a yard near to the site.<br>(2) The block is carried on a barge or suspended by a floating crane to the bridging point directly.<br>(3) The block is placed by the floating crane to the position. | (1) Construction period is very short.<br>(2) There's no manual work at a high elevation, and thus it is safe.<br>(3) Much cost must be spent for reinforcing the structure and the barge, and for the temporary support which connects the block with the barge.<br>(4) The floating crane incurs a high cost return trip from and to the mother port.<br>(5) The method of erection depends much on the weather, therefore it had better avoid seasons when wind is strong. |
| 10 | Barge & Large Block |   | (1) The water is deep enough to enable the barge to approach the right point.<br>(2) The large block is such that it is of a shape which is stable while transported on a barge.<br>(3) Stability and local stresses of the structure together with the barge must be checked and reinfoced if | (1) The large block is assembled at a yard and transported on the barge to the bridging point.<br>(2) The barge is anchored, and the block is lowered onto the pier by jacking down, pouring seawater into the barge or wait for a low tide. | (1) Construction period is very short.<br>(2) There's few manual work at a high elevation, and thus it is safe.<br>(3) When the bridge is to be located very high above the water, then the method is almost impossible due to the unstability.<br>(4) The barge must be equipped heavily. |
| 11 | Cable Crane & Vertical Suspension |   | (1) A tower and anchorage for a cable crane and cable suspension can be installed on both banks.<br>(2) There has to be a strong ground on which the tower can be erected.<br>(3) It is very difficult to place bents due to the topographical features. | (1) Towers are erected, and equipped with cable cranes and other supporting cable facilities.<br>(2) Each bridge element is lifted up and carried to the right position.<br>(3) The element is temporarily supported on a beam huging from the supporting cable.<br>(4) The elements are connected each other by high-strength bolts, and then assembled into a whole bridge. | (1) Implementation of the procedure can be independent from conditions below the bridge.<br>(2) Safety against wind must be verified, and the bridge must be designed as occasion needs.<br>(3) Many kinds of machines are needed.<br>(4) A camber control is complicated. |
| 12 | Cable Crane & Diagonal Suspension |   | (1) A tower and anchorage for a cable crane and cable suspension can be installed on both banks.<br>(2) There has to be a strong ground on which the tower can be erected.<br>(3) It is very difficult to place bents due to the topographical features. | (1) Towers are erected, and equipped with cable cranes.<br>(2) Each arch segment is lifted up, carried to the right position by the cable crane and then supported by cables extended from the tower.<br>(3) The segments are connected each other by high-strength bolts. | (1) Implementation of the procedure can be independent from conditions below the bridge.<br>(2) Safety against wind must be verified, and the bridge must be reinforced as occasion needs.<br>(3) This erection procedure is advantageous for arch bridge of deck type. |

ERECTION PROCEDURE (4)

| No. | Procedure | Figure | Conditions | Description | Chatacteristics |
|---|---|---|---|---|---|
| 13 | Luanching Girder<br>&<br>Launching and<br>Side Loading | <br> | (1) The space below the bridge cannot be utilized for such reasons that there runs a road, railway or water.<br>(2) Bridge girder and launching girder can be assembled on the next span or access road.<br>(3) After the launching girder arriving ate the other side, the disassembly is possible.<br>(4) Bridge girdres are designed as to bearranged parallel.<br>(5) The girdres are straight. | (1) Bridge girders are assembled on the deck of the next span which was previously finished.<br>(2) Launching girder is assembled and attached to the front end of the bridge girder.<br>(3) The structure is moved forward by winches, hydraulic jacks and so on.<br>(4) The front end reaches the other side and the launching girder is disassemble.<br>(5) The whole girder is lowered onto the bridge seat.<br>(6) If it is a multi-girder bridge, then the girder is slided transveresly. | (1) Implementation of the work is independent from the conditions below the bridge.<br>(2) During luanching , intensive erection stresses work locally in the girder and it is vulnerable to a lateral buckling. These stresses and deformation must be verfied before deciding to adopt the erection and reinforce web plates, flange plates or welds between them. |
| | | | | | |
| | | | | | |
| | | | | | |

## 3.4 Structure Excavation and Temporary Works

### 3.4.1 General

Foundation of substructures are constructed in open excavation if ground-water level is low and depth of excavation is less 5 m, and if necessary, steel sheet pile retaining wall or a cofferdam will be constructed to exclude earth and water from an area in order that work may be performed there under reasonable dry condition. Temporary water control consists of dikes, by-pass channels and flumes are also carried out specially in dry season.

### 3.4.2 Open Excavation

The following critical slope grade of excavated surface and depth may be maintained during excavation works, without any cofferdam and falseworks, if the ground-water level is low.

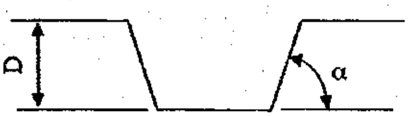
Critical Slope Grade and Depth During Excavation

| Type of Ground | Depth of Excavation (D) | Slope Grade ($\alpha$) |
|---|---|---|
| Rock or Hard Clay | $D < 5m$<br>$D \geqq 5m$ | $\alpha < 90^\circ$<br>$\alpha < 75^\circ$ |
| Other Soil | $D < 2m$<br>$2m \leqq D < 5m$<br>$D \geqq 5m$ | $\alpha < 90^\circ$<br>$\alpha < 75^\circ$<br>$\alpha < 60^\circ$ |
| Sandy Soil | $D < 5m$ | $\alpha < 35^\circ$ |

Generally, the depth of open excavation is taken from the following equation if ground-water level is low:

$$D = 2c/\gamma \cdot \tan(45^\circ + \phi/2)$$

where;
- $D$ : Depth of open excavation
- $C$ : Cohesion of soil (t/m2)
- $\gamma$ : Unit weight of soil (t/m3)
- $\phi$ : Coefficient of internal friction (°)



### 3.4.3 Retaining Wall Methods

Retaining Wall Methods are classified as support type and wall kind, as shown in Fig. 5.12 and Fig. 5.13, respectively.

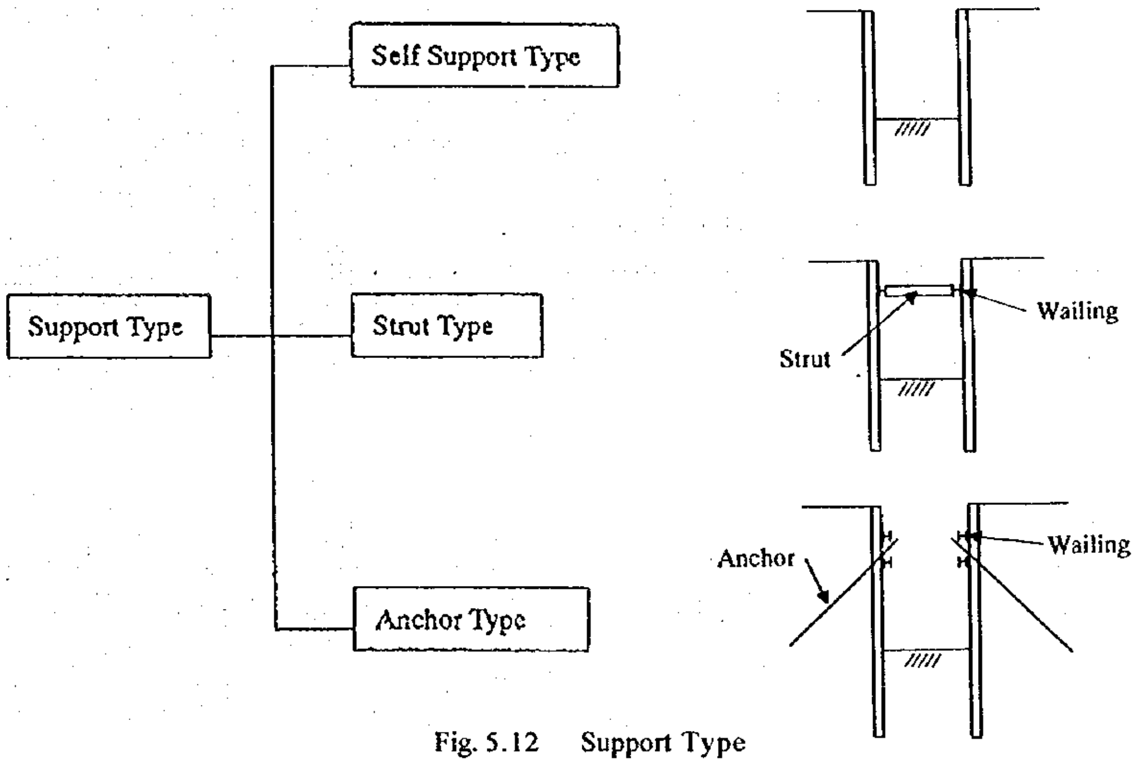



Fig. 5.12 Support Type

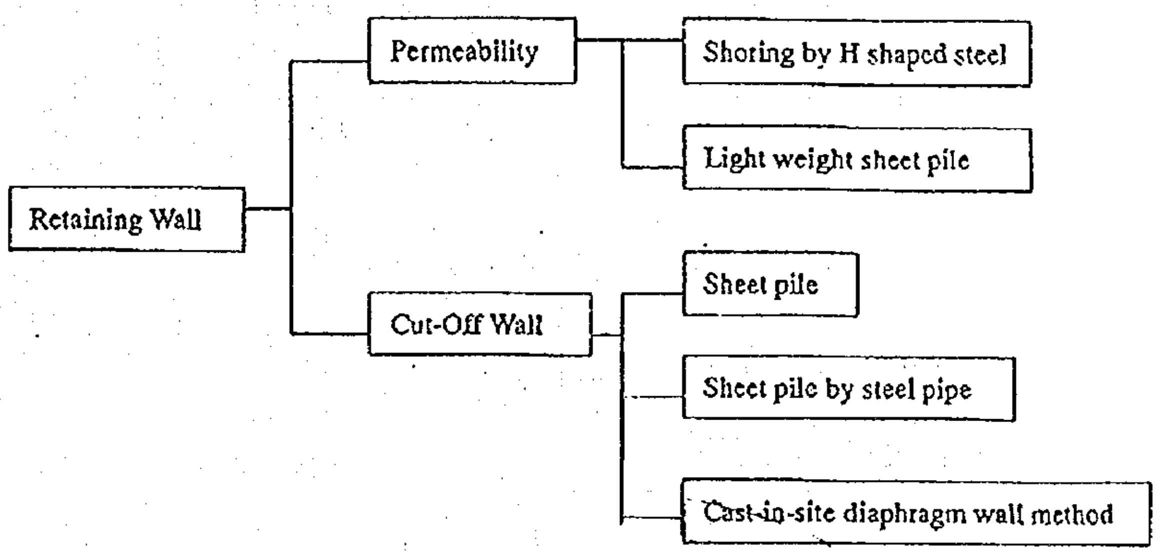



Fig. 5.13 Retaining Wall Type

(1) Self Support Type

This type should be adopted when the depth of excavation is shallow, and earth and water pressure are low.

(2) Strut Type

In generally, this type would be adopted the to support the retaining wall receiving earth and water pressure.

- Mostly using the shaped steel H, more than 300.
- Vertical intervals of walling around 3 m in principle, the first walling should be set 1 m from the top.
- Horizontal intervals of the strut should be set less than 5 m, vertical intervals around 3 m.
- Connection for walling mostly over 6 m.

(3) Anchor Type

This method should be adopted in case Self-Support Type or Strut Type are not applicable. Verification of bearing ground and condition of the site (underground utilities, adjacent structure foundation, etc.) in design is necessary.

(4) Shoring by H shaped steel

Used chiefly to prevent ground failure. During construction water should be pumped.

- In most case, H shaped steel 300 should be used for shoring.
- Embedding depth should be more than 1.5 m, even in cases where earth pressure against retaining wall is negligible.
- The stability of excavation surface should be studied regarding boiling (sand) and heaving (clay).

(5) Sheet Pile Method

This method is for cutting-of water flow and preventing ground failure. It can also serve as a cofferdam.

- This method is sued for a median scale of excavation (3 m to 10 m).
- Depth of embedment is determined according to the results of study of either boiling or heaving. Minimum length should be 3 m.

### 3.4.4 Cofferdam Method

The types of cofferdam are shown in Fig. 5.14.

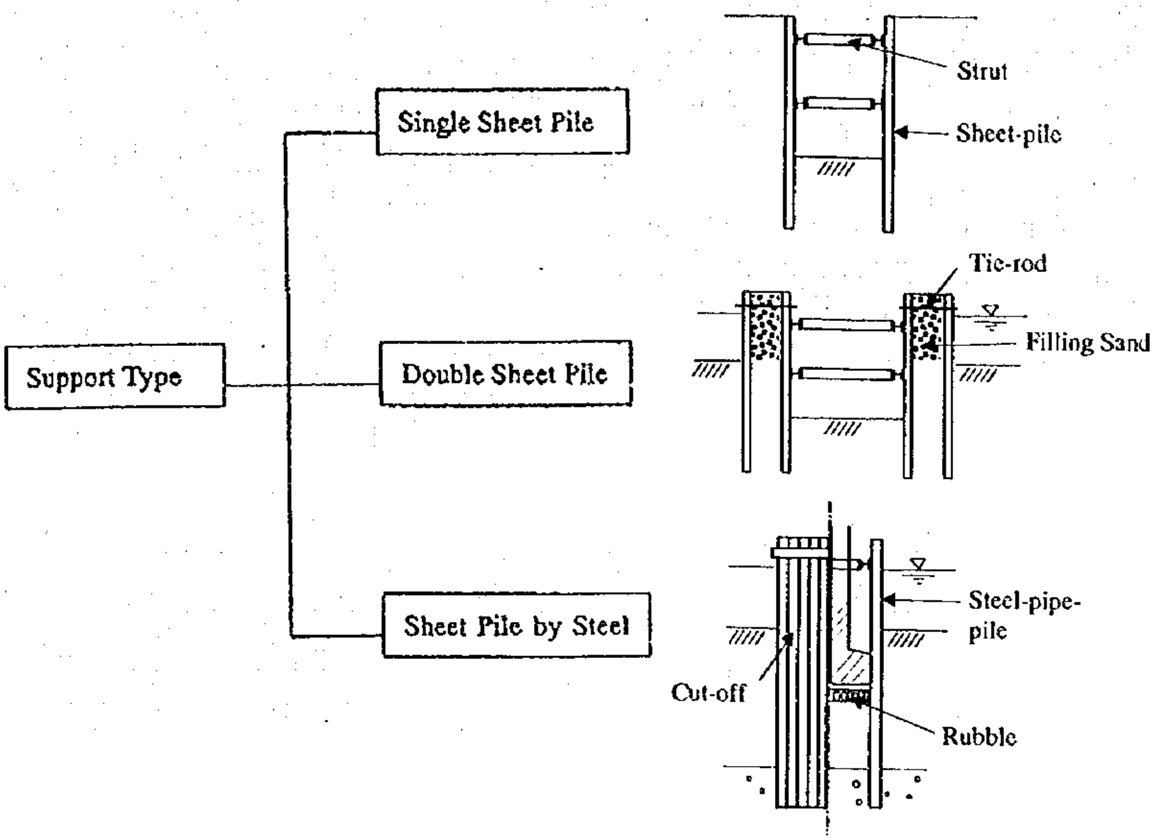



Fig. 5.14 Type of Cofferdam

(1) Single Sheet Pile

Method generally applied.

(2) Double Sheet Pile and Sheet Pile by Steel

Areas heavily influenced by tides and flow, such as sea coast, river mouths, etc., should apply a sufficiently rigid cofferdam in order to resist repeated loads.
Steel pipe should be sued itself as a foundation in some circumstances. In such a case, the combined stresses of foundation with residual stress such as common in cofferdams, should be checked.

### 3.4.5 Temporary Bridges

Temporary bridges or causeways are often needed for diversions of traffic or transport of material/equipments during the reconstruction of an existing permanent bridge. When a temporary causeway is needed on a diversion road, a causeway may be formed either by constructing a pipe culvert or by using timber stringers and planking over cribs used as piers. The following temporary bridges are generally used.

- Timber bridge
- H-shaped or I-shaped steel beam bridge
- Military bridge (Bailey bridge)
- Floating or Pontoon bridge

# DIVISION VI

# BRIDGE CONSTRUCTION COST ESTIMATE

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# DIVISION VI BRIDGE CONSTRUCTION COST ESTIMATE

## CHAPTER 1. GENERAL

This manual is prepared to assist engineers in understanding the estimating procedure of standard bridge construction project.

The construction plan presents mainly current practices and problems on construction method and work approach of bridge construction, and it will relate to the cost estimate. However, materials and workmanship stipulated in the specifications are not described in this manual. Also, the following kinds of manual and guideline will be referred for site management and quality control.

- Standard Contract Form for Construction
- General Specification
- Inspection and Testing of Bridge Works

Bridge construction costs, even though the same in size, are varied depending on site condition, environment, construction method and location of the site. The accuracy of any cost estimate will depend on the amount of information known about the project. This cost estimate presents fundamental method and procedure which are universally applicable.

# CHAPTER 2. COST ESTIMATE

## 2.1 Objective of Cost Estimate

The purpose of cost estimate is to determine the forecast cost required to complete a project in accordance with the Specifications and preliminary construction plan. There are so many variations and factors that can influence the cost of construction, such as geology, topography, site environment, workmanship and construction difficulties. The construction cost should be estimated according to site condition, construction plan and construction time which were clarified in plan and design stage.

The estimated cost shall be reasonably enough to allow the contractor to complete the project with a reasonable profit, yet low enough to be within the Government budget.

Because construction estimates are prepared before a project is constructed, an estimate is to be close approximation of the actual cost. The true construction cost will not be known until the project has been completed and all costs have been recorded.

## 2.2 Type of Cost Estimate

Cost estimates may be divided into at least two different types, depending on the purpose as approximate estimates (preliminary estimate) and detailed estimates.

Early in a project, prior to the design, the Government may wish to know the approximate cost of a project. At the detailed design stage, the Consultants will estimate the cost in detail in order to finalize the design to satisfy the Government's budget. The Contractor must know the costs required to perform the works in accordance with the final contract documents.

### 2.2.1 Approximate Cost Estimate

Approximate cost may be estimated according with the statistical contract rate of the similar projects. It may be estimated to multiply the number of square meter of bridge surface area for superstructure, and the concrete volume for substructure excluding pile.

The unit cost to be obtained from a weighting of the data that emphasizes the average value yet it account for the maximum and minimum values as shown by the equation below.

$$UC = (A+4B+C)/6$$

where; UC: Proposed unit cost per m2
A : Minimum unit cost of previous bridge
B : Average unit cost of previous bridge
C : Maximum unit cost of previous bridge

It is necessary to adjust the cost information from previous completed bridge, such as year built, location and bridge size.

The adjustment should be present the relative inflation or deflation of costs with respect to year built, and relative costs of materials, equipment, and labor with respect to the geographic location of bridge under construction. Although the total construction cost of bridge will increase with size of bridge, however, the unit cost per square meter of bridge surface area may decrease.

Proposed cost = Previous cost x fy x fl x fs x fc

where; fy : Adjusting factor of year built
fl : Adjusting factor of location
fs : Adjusting factor of bridge size, such as span length and number of span
fc : Adjusting factor of construction difficulty

### 2.2.2 Detailed Cost Estimate

A detailed estimate is prepared by determining the cost of the materials, labor, equipment, subcontract work, overhead, profit, and some contingencies. The process of estimate begins with a thorough review of the contract document - contract requirements, drawings and technical specifications. It is necessary to visit the project site to clarify factors that can influence the cost of construction, such as site conditions, control of traffic, security, and existing underground utilities.

There are two distinct tasks in estimation; to determine the probable real cost and to determine the probable real time to construct the project. It is required to provide production rates, crew size, equipment and the estimated time to perform various individual work items for planning and scheduling of the project. This information concerning costs can cover an integration of the estimating and scheduling function of construction project management.

Flow chart of cost estimate and work schedule are shown in Fig. 6.1 and Fig. 6.2 respectively.

### 2.3 Structure of Total Project Cost

Total project cost consists of construction cost and project cost, such as administration cost, engineering cost, land acquisition and compensation cost, and contingencies.

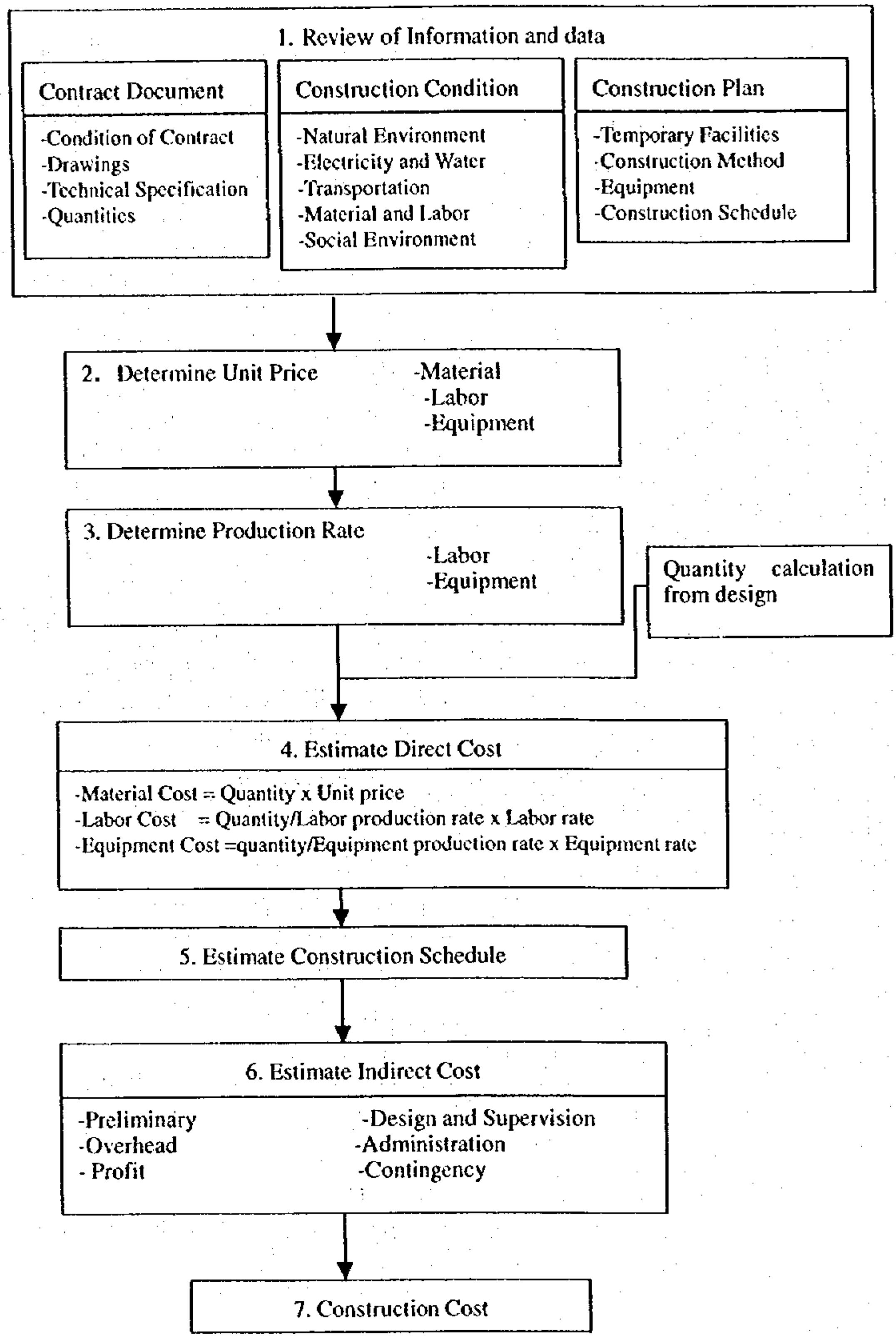


Fig. 6.1 Flow Chart of Cost Estimate

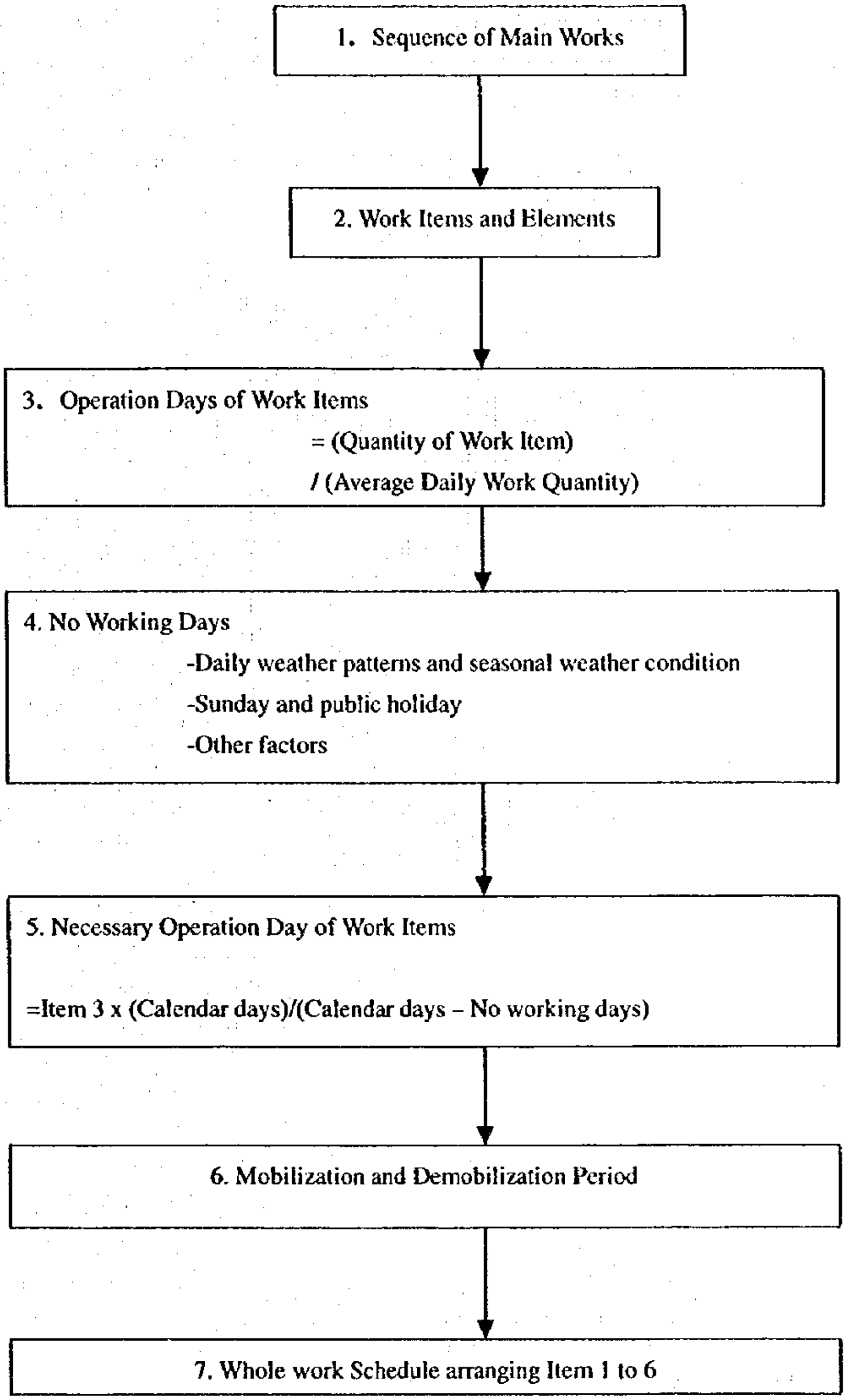


Fig. 6.2 Flow Chart of Work Schedule

Construction cost is subdivided into direct cost and indirect cost. Direct cost consists of labor cost, material cost and equipment cost. Indirect cost comprises of general cost, preliminary cost and, contractor's overhead and profit.

Structure of total project cost is charted in Fig. 6.3.

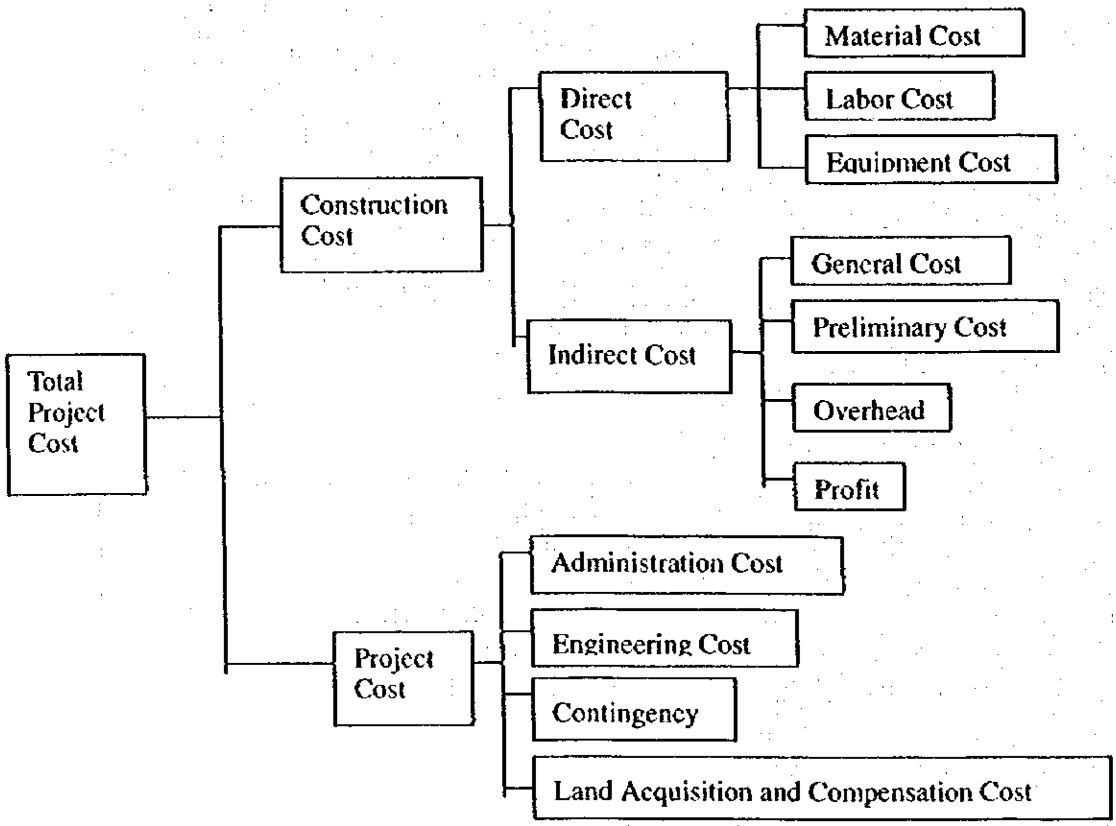


Fig. 6.3 Structure of Total Project Cost

### 2.3.1 Direct Cost

(1) Labor Cost

Labor Cost is calculated as follows:

Labor Cost = Number of Labor x Labor Rate
= Quantity of work item x Production rate x Labor rate

Labor rate includes wages, income tax, insurance and all fringe benefits, such as vacation, sick leave, medicare and workmen's compensation. The labor rate is estimated on the basis of data researched from the market investigation.

Production rate is the number of unit of work produced by a person in a specified time, usually an hour or a day. Production rate may also specify the time in labor-hours or labor-days required to produce some unit of works.

Such data may be obtained by keeping accurate records of the production of labor on projects during the progress of construction.

(2) Material Cost

Material cost is calculated as follows:

Material Cost = Quantity x Unit price
= Designed quantity x (1 + Rate of loss)
x (Material unit price + Transportation cost)

The quantity of material can be taken from the drawings, however, loss of material due to storage and construction should be considered.

Construction materials are delivered by the supplier or producer directly to the project site in trucks, however, some materials may be obtained by the Contractor at the storage yard of the supplier.

(3) Equipment Cost

There are two types of equipment costs: ownership costs and operating costs. Ownership costs refer to the costs incurred even if the machine is not working. They include depreciation, interest, taxes, insurance, and maintenance and repair. Operation costs are the costs incurred in operating the machine. They include costs for repair, fuel, lubricants, tires, consumable parts and operator's wages. Composition of equipment cost is shown in Fig. 6.4.

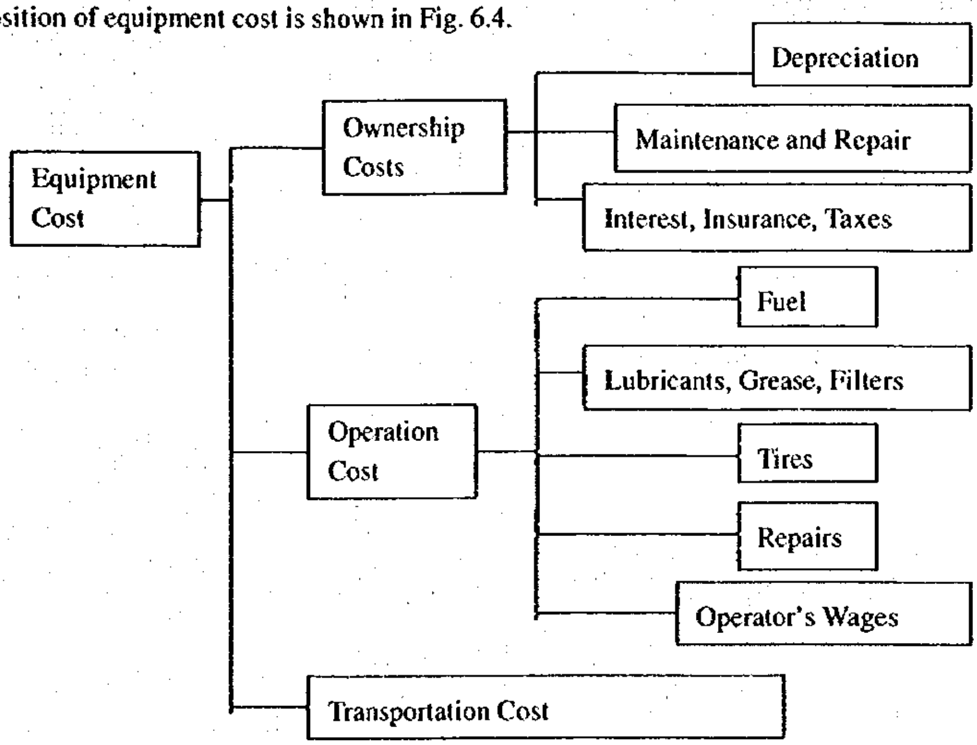


Fig. 6.4 Composition of Equipment Cost

The equipment cost is calculated in unit of hourly cost ($/hour) which is suitable for use on any project.

(a) Depreciation

In general, depreciation is a tax term referring to the legally permitted decline in value from the original purchase price of equipment for the depreciation periods from the view point of economical life of equipment.

Depreciation = (Net depreciation value)
/ (Depreciation period in hours)
= (Purchase price - Salvage value)
/ (Depreciation period in hours)

(b) Interest, Insurance and Taxes

Whether or not purchased equipment is actually in operation, its owner must pay interest, insurance and taxes. Interest refers to the interest on the investment, when the investment is covered by the owner's own fund or to the interest on the debt, when the investment is covered by a debt. In either case, the interest will be an equal amount.

Calculation is made of the average value of the residual value at the beginning of each year within the depreciation period, and interest, insurance and taxes are imposed on this value. By dividing this value by the number of hours and expects to operate the machine in one year, the hourly value can be calculated.

This can be calculated by using the following formula.

Interest, insurance, tax = (Factor x Delivered price x Annual rates)
/ (Annual use in hours)

The factor can be calculated by the following formula.

Factor= 1 - {(n-1)(1-r)} / 2n

where; n : Depreciation period in year
r : Salvage value rate
= (Machine worth at trade-in or resale time)
/ (Delivered price)

(c) Revision of Equipment Cost

The hourly cost of ownership and operating construction equipment will vary with the condition where the equipment is operated. If bulldozers are operated on soft rocks surface, equipment cost will be higher than when the same bulldozers are operated on common soil surface. Therefore, the equipment costs will be adjusted according to the site condition where the equipment is to be operated.

### 2.3.2 Indirect Cost

(1) General Cost

General cost includes the following items, which depend on site condition and construction requirement:

- Construction of temporary bridge and road for public
- Demolition of existing bridge
- Relocation of existing public utilities
- Temporary diversion of river/waterway

(2) Preliminary Cost

Preliminary cost includes the following items and it is assumed to be 10 to 15% of the direct cost depending on period of the project and amount of the contract.

- Site office and laboratory
- Waterhouse
- Survey
- Laboratory equipment
- Facilities for electricity and water supply
- Safety measures
- Transportation
- Engineering

Preliminary costs of PC bridge are;

| | | |
|---|---|---|
| Pre-tensioned bridge | : | (Direct cost- Manufacturing cost)x(10 to 15%) |
| Post-tensioned bridge | : | Direct cost x (10 to 15%) |

(3) Overhead and Profit

The overhead cost is divided into two categories: job overhead and general overhead.

The job overhead can be specifically charged to a project and general overhead can be charged to the general office of the company.

| Job Overhead | General Overhead |
|---|---|
| - Salaries of project staff | - Salaries |
| - Site office supplies | - Office supplies |
| - Communication | - Office rent |
| - Rent | - Welfare |
| - Travel expenses and allowance | - Travel expenses and allowance |
| - Insurance and tax | - Insurance and tax |

The amount of profit is depending on the risk involved, desire of the Contractor to get the job and other factors.

The actual amount of overhead and profit may be ranged between 20 to 30% of the direct cost depending on the risk involved, desire of the contractor to get the work and others.

### 2.3.3 Project Cost

(1) Administration Cost

Administration cost is an expense of the Government arising from implementation of the project cost and is assumed to be 3 % of construction cost.

(2) Engineering Cost

Engineering cost consists of detailed design (Geological and topographical survey, and detailed design) and construction supervision and it is assumed to be 5 to 10% (for example 2% for the detailed design and 6% for supervision) of the construction cost.

(3) Contingency

Contingency is divided into physical contingency and price contingency as described below:

- Physical contingency is mainly to cover unforeseeable or unavoidable matters during construction, such as temporary land acquisition and some variations. The contingency is usually considered 5 to 10% of the construction cost.

- Price contingency allows for future price escalation and fluctuation of exchange rates.

(4) Land Acquisition and Compensation Cost

A considerable amount of land acquisition and compensation costs are required for new bridge construction.

## 2.4 Major Work Classification

### 2.4.1 Clearing and Grabbling

Prior to staring structure excavation operations, all surface objects and all trees, stumps, roots and other obstructions shall be cleared and/or grubbed. This work will be operated by bulldozers. Measurement will be by area basis (hectares) or lump-sum basis or individual removal of trees (each).

### 2.4.2 Structure Excavation and Backfill

This work consist of the necessary excavation for foundations of substructures and placing backfill with free draining granular material in excavated area around structures.
This work may include necessary diverting of water streams, bailing, pumping, draining, and the necessary construction of cofferdams or grubs, with all sheeting and bracing involved.

All rock or other hard foundation material should be cleaned of all loose material and cut to a firm surface, either level or stepped. Blinding stone, such as cobble stone or crushed rock for use as a foundation to be provided.

(1) Operation of Excavation and Backfill

The operations of this work are as follows:

| Operation | Equipment |
|---|---|
| Excavation | Power shovel (0.35 to 0.6m3)<br>Bulldozer (15 tons) |
| Backfill | Power shovel (0.35 to 0.6m3) |
| Compaction | Bulldozer (15 tons)<br>Vibration roller (0.8 to 1.1 tons)<br>Compactor (60 to 100kg) |
| Transportation | Dump truck (11 tons) |

(2) Temporary Works

| | Operation | Material | Equipment |
|---|---|---|---|
| Cofferdam | Driving<br>Removing<br>Draining | Wood plate sheet-pile or Steel Sheet-pile or H-shaped pile | Diesel hammer<br>Truck crane<br>(20 to 22 tons)<br>Vibro-hammer<br>(30 to 40 kW)<br>Pump |
| Diversion of Water Stream | Construction of Dikes or By-pass channels | | Bulldozer<br>Power shovel |

### 2.4.3 Concrete

This work consist of the construction of portion of structures of Portland cement concerted which is a mixture of cement, water, admixture, and coarse and fine aggregates, and may include temporary works.

(1) Use of Concrete

The uses of concrete are as follows:

- Post-tensioned concrete girders
- Cross beam
- RC slab
- Abutments and piers
- Curb and parapet
- Approach slabs
- Leveling concrete

(2) Operation of Concrete Work

| Operation | Equipment |
|---|---|
| - Trial mix | Mixing plant |
| - Mixing concrete | |
| - Transport | Truck |
| - Handling | Cart |
| - Placing | Truck crane (15 to 20 tons)<br>Concrete pump<br>Hopper and chute |
| - Compacting | Vibrator |
| - Finishing | |
| - Curing | |

(3) Temporary Works

This work include falsework, formwork and base for manufacturing post-tensioned beam.

| Work Item | Use of Concrete | Operation | Material | Equipment |
|---|---|---|---|---|
| Falsework | Abutment<br>Pier<br>RC slab bridges | Piling or compaction<br>Erection<br>Fixing<br>Removing | Foundation<br>Pile or concrete<br>or timber<br>Scaffoldings<br>Timber or<br>Steel frame or<br>Steel pipe | Truck crane<br>(15 t 16 tons) |
| Formwork | Abutment<br>Pier<br>RC slab bridges | Fabrication<br>Erection<br>Fixing<br>Removing | Plywood or steel<br>or aluminum form<br>Form tie<br>Form oil | Truck crane<br>(15 to 16 tons) |
| Base for<br>Manufacturing<br>Beam | Post-tensioned<br>beam | Compaction | Concrete or<br>timber<br>Blinding stone | |

### 2.4.4 Reinforcing Steel

This work consist of furnishing, fabricating (cutting bending), splicing, and placing (erecting, fastening) reinforcing steel bars of the type and size conformed with Drawings. Tie wires and separators and other materials used in fastening the reinforcing steel bars are included in this work.

### 2.4.5 Furnishing Pre-tensioned Beam and Spun Concrete Pile

Pre-tensioned beams and spun concrete piles are manufactured and supplied by manufacturer. The cost will depend upon the type, length and number of purchase, and the distance from the manufacture yard of the supplier to the job site. The cost estimate and other information will be obtained from the manufacture suppliers.

### 2.4.6 Pile Driving

The work may consist of spun concrete pile driving, cut and spliced, and loading test. Operation of the work is as follows:

| Work Item | Operation | Equipment |
|---|---|---|
| Pile Driving | Handling<br>Driving Method<br>- Percussion<br>- Vibration<br>- Excavation<br>Splicing<br>Cut off | Crawler driving machine<br>Truck crane<br>Vibro hammer<br>Earth auger machine |
| Loading Test | Maintained load (ML) test or Constant-rate of penetration (CRP) test | Hydraulic jack<br>Steel I-beam<br>Timber crib<br>Kentledge block |

### 2.4.7 Prestressing

This work may consist of furnishing, placing and tensioning of prestressing steel, and grouting for post-tensioned concrete beams.

Operating of prestressing and grouting are as follows:

| Work Item | Operation | Material | Equipment |
|---|---|---|---|
| Prestressing | Placing ducts<br>Placing strand wire<br>Prestressing | Duct<br>Strand wire<br>Anchorage<br>Supporter of duct<br>Grid | Cutter for strand wire<br>Tensioning jack<br>Tensioning pump |
| Grouting | Mixing grout<br>Injecting grout | Cement<br>Admixture | Grouting mixer<br>Grouting pump |

### 2.4.8 Handling and Launching

This work includes lifting, handling, transporting, launching and placing in position of pre-tensioned or post-tensioned beams.

Operation of the work are as follows:

| Work Item | Operation | Equipment |
|---|---|---|
| Handling | Lifting<br>Transportation | Truck crane<br>Gantry crane<br>Jack<br>Rail<br>Trolley<br>Winch |
| Launching | Launching<br>Shifting<br>Placing | Track crane<br>Launching steel girder<br>Gantry crane<br>Bent and rail |

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