29 Years

Previous Solved Papers

Civil Services Main Examination

(1995-2023)

Civil Engineering

Paper-II

Topicwise Presentation

Also useful for
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Preface

B. Singh (Ex. IES)

Civil Service is considered as the most prestigious job in India and it has become a preferred destination by all engineers. In order to reach this estimable position every aspirant has to take arduous journey of Civil Services Examination (CSE). Focused approach and strong determination are the pre-requisites for this journey. Besides this, a good book also comes in the list of essential commodity of this odyssey.

I feel extremely glad to launch the revised edition of such a book which will not only make CSE plain sailing, but also with 100% clarity in concepts.

MADE EASY team has prepared this book with utmost care and thorough study of all previous years papers of CSE. The book aims to provide complete solution to all previous years questions with accuracy.

On doing a detailed analysis of previous years CSE question papers, it came to light that a good percentage of questions have been asked in Engineering Services, Indian Forest Service and State Services exams. Hence, this book is a one stop shop for all CSE, ESE, IFS and other competitive exam aspirants.

I would like to acknowledge efforts of entire MADE EASY team who worked day and night to solve previous years papers in a limited time frame and I hope this book will prove to be an essential tool to succeed in competitive exams and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

With Best Wishes

B. Singh (Ex. IES)

CMD, MADE EASY Group

Previous Years Solved Papers of

Civil Services Main Examination

Civil Engineering : Paper-II

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1 Building Materials and Construction Technology

1. Concrete

1.1 (i) Explain how fly-ash can be used in the production of bricks.
(ii) Discuss briefly the applications of fibre reinforced concrete in buildings.

[1996 : 20 Marks]

Solution:

(i) Fly-ash building bricks :

- The chemical composition of clays and fly-ash do not differ very much and the residual carbon content in the fly-ash brings economy in the fuel consumption during firing of bricks.
- The process involves the use of fly-ash, lime, sand and a small quantity of magnesium chloride as chemical accelerator. The fly-ash, sand and lime are mixed approximately in the ratio of 80 : 13 : 7. The hydraulic press is used for making these bricks and ultimately, the semi-dried bricks are cured in a steam chamber at appropriate pressure and temperature.
- The fly-ash buildings are superior to the conventional burnt bricks in shape, technical specifications, compressive strength and impermeability. They are also 20% light in weight and about 10 to 15% cheap as compared to the conventional bricks.

(ii) Applications of fibre reinforced concrete :

- The plain concrete fails suddenly when the deflection corresponding to the ultimate flexural strength is exceeded, on the other hand fibre-reinforced concrete (FRC) continue to sustain considerable loads even at deflections considerably in excess of the fracture deflection of the plain concrete.
- Steel FRC (SFRC) is very ductile and particularly well suited for structures which are required to exhibit:
  (a) high fatigue strength, resistance to impact and shock loads.
  (b) shrinkage control of concrete
  (c) very high flexural strength, tensile strength and shear strength
  (d) Erosion and abrasion resistance to splitting
  (e) High thermal resistance
  (f) Earthquake resistance
- The largest application of SFRC is in floor slab construction.
- Glass FRC(GFRC) is used in facing panels, piping for sanitation network systems, and decorative non-recoverable framework.
- Asbestos fibres have thermal, mechanical and chemical resistance making them suitable for sheet product, piles, tiles and corrugated roofing elements.

1.2 Calculate quantities of various ingredient (by weight) of 1 : 2 : 4 cement concrete required to prepare 4 cylinders of 10 cm diameter and 30 cm height.

[1996 : 15 Marks]

Solution:

$$\text{Volume of concrete required} = 4\times\left(\pi\times\frac{d^2}{4}\times h\right) = 4\times\pi\times\frac{(0.1)^2}{4}\times 0.3$$

$$= 9.4248\times 10^{-3}\ \text{m}^3$$

Assume the following :

Cement : specific gravity 3.15 (G_c)

Sand : Specific gravity 2.65 (G_s)

Coarse aggregate : Specific gravity 2.80 (G_G)

Water-cement ratio = 0.5

$$\text{Volume of concrete} = \text{volume of voids + volume of solids}$$

$$\text{Assume volume of air} = 0$$

$$\Rightarrow \quad \text{volume of voids} = \text{volume of water}$$

$$V_c = V_w + V_c + V_s + V_G$$

or,
$$V_c = \frac{M_w}{\rho_w} + \frac{M_c}{G_c.\rho_w} + \frac{M_s}{G_s.\rho_w} + \frac{M_G}{G_a.\rho_w}$$

or,
$$V_c = \frac{1}{\rho_w}\left[0.5M_c + \frac{M_c}{3.15} + \frac{2.M_c}{2.65} + \frac{4.M_c}{2.8}\right]$$

or,
$$9.4248\times 10^{-3} = \frac{1}{1000}\times[3.007M_c]$$

$$\Rightarrow \quad M_c = 3.1408\ \text{kg}$$

$$\therefore \quad M_w = 1.5704\ \text{kg};$$

$$M_s = 6.2816\ \text{kg};$$

$$M_G = 12.5632\ \text{kg}$$

1.3 Find the quantity of cement, sand and coarse aggregates required for 15 m^3 of 1 : 5 : 10 plain cement concrete and 50 m^2 of 1 : 5 cement plaster 1.25 cm thick

[1999 : 20 Marks]

Solution:

$$\text{Volume of concrete} = 15\ \text{m}^3$$

$$W_c : W_s : W_a = 1 : 5 : 10$$

Let water-cement ratio be 0.50 and percentage air voids be 3%

$$\text{Net volume of concrete} = 15 - \frac{3}{100}\times 15 = 14.55\ \text{m}^3$$

Let specific gravity of cement be 3.15

Let specific gravity of sand be 2.60

Let specific gravity of coarse aggregates be 2.8

$$\Rightarrow \quad 14.55 = \text{volume of water + volume of solids}$$

or,
$$14.55 = \frac{0.5W_c}{1000} + \frac{W_c}{G_c\times 1000} + \frac{W_s}{G_s\times 1000} + \frac{W_a}{G_a\times 1000}$$

or,
$$14.55\times 1000 = 0.5W_c + \frac{W_c}{3.15} + \frac{5.W_c}{2.60} + \frac{10W_c}{2.8}$$

$$\Rightarrow \quad W_c = 2305.14\ \text{kg}$$

$$\therefore \quad W_s = 11525.73\ \text{kg}$$

$$W_a = 23051.4 \text{ kg}$$

$$\text{Volume of plaster} = 50 \times \frac{1.25}{100} = 0.625 \text{ m}^3$$

Considering 25% more due to losses,

$$\therefore \quad \text{Volume of mortar} = 0.625 + 0.25 \times 0.625 = 0.78125 \text{ m}^3$$

[Assuming 1 : 5 as ratio by volume]

$$\text{Quantity of cement required} = \frac{0.78125}{6} = 0.13021 \text{ m}^3$$

$$\text{1 bag of cement} = 0.0347 \text{ m}^3$$

$$\therefore \quad \text{Number of bags} = \frac{0.13021}{0.0347} = 3.75 \simeq 4 \text{ bags}$$

$$\text{and} \quad \text{Quantity of sand} = 0.13021 \times 5 = 0.65105 \text{ m}^3$$

1.4 **Materials required per cu.m. of freshly mixed cement concrete are : 312 kg of dry cement, 855 kg of sand, 1010 kg of gravel and 145 kg of fresh water. Bulking, when mixing in the mixer, is 5%. What would be the density of the freshly mixed and poured cement concrete? What would be the total volume of fresh concrete that can be produced in a nominal 6 cu.m. mixer, in which loading during mixing can be only 65% of nominal capacity, per hour if its working cycle is : charging –35 seconds, mixing 170 seconds, discharging 30 seconds and lost time 18 seconds.**

[2004 : 12 Marks]

Solution:

Let specific gravity of cement be 3.15, of sand be 2.60 and of aggregate be 2.50.

$$\text{Volume of freshly mixed concrete} = \frac{W_w}{1000} + \frac{W_c}{G_c \times 1000} + \frac{W_s}{G_s \times 1000} + \frac{W_a}{G_a \times 1000}$$

$$= \frac{145}{1000} + \frac{312}{3.15 \times 1000} + \frac{855}{2.60 \times 1000} + \frac{1010}{2.5 \times 1000}$$

$$= 0.977 \text{ m}^3$$

$$\text{Density of freshily mixed concrete} = \frac{312 + 855 + 10110 + 145}{0.977} = 2376.66 \text{ kg/m}^3$$

Bulking is 5%,

$$\therefore \quad \text{Volume of poured cement concrete} = 1.05 \times 0.977 = 1.02585 \text{ m}^3$$

$$\text{Density of fresh concrete} = \frac{312 + 855 + 1010 + 145}{1.02585} = 2263.489 .489 \text{ kg/m}^3$$

$$\text{Operating cycle} = 35 + 170 + 30 + 18 = 253 \text{ sec.}$$

$$\text{Number of cycles in 1 hour} = \frac{3600}{253} = 14.229 \simeq 14$$

$$\text{Quantity produced in one cycle} = 0.65 \times 6 = 3.9 \text{ m}^3$$

$$\therefore \quad \text{Quantity produced in one hour} = 3.9 \times 14 = 54.6 \text{ m}^3$$

1.5 **What is slump? How is it measured? What are the generally recommended maximum and minimum magnitudes of slump for (i) RCC foundation for walls and footings, (ii) Plain footings, (iii) RCC beams and reinforced walls, and (iv) columns in buildings?**

[2005 : 12 Marks]

4. **Rising damp**: Moisture can rise from the ground through capillary action in porous building materials like bricks and mortar, causing dampness in walls, especially in basements or ground floors.
5. **Poor ventilation**: Inadequate airflow within a building can trap moisture, increasing humidity levels and promoting damp conditions.
6. **Lack of insulation**: Insufficient insulation can also lead to temperature difference between indoor and outdoor surfaces, promoting condensation and dampness.
7. **High ground water levels**: Buildings constructed in areas with a high water table may experience dampness due to proximity of ground water.

To make a building damp proof and address dampness issues, remedies and preventive measures can be suggested, depending upon underlaying causes. Below are some of them.

1. **Identify and fix the source:** Firstly identify the source of dampness, wheather it's a leaking roof, damaged plumbing or other issue. Fixing the source of leakage is essential.
2. **Improve the drainage**: Ensure proper drainage systems are in place to divert rainwater away from the building's foundation.
3. **Seal cracks and gaps**: Seal any gaps or cracks in the building's exterior to prevent rainwater penetration.
4. **Roof maintenance**: Regularly inspect and maintain the roof to prevent the leaks. Replace the damaged roofing materials if needed.
5. **Plumbing repairs**: Fix any plumbing leaks prompty and ensure the pipes and fixtures are in good conditions.
6. **Ventilation**: Improve ventilation within the building to reduce the humidity levels and prevent condensation.
7. **Damp-proof course (DPC)**: Install or repair damp-proof courses, which are barriers in walls that prevent rising dampness from the ground.
8. **Water proofing**: Apply water proof coatings or membranes to vulnerable areas like basements foundations and external walls.

■■■■

2 Construction Planning and Management

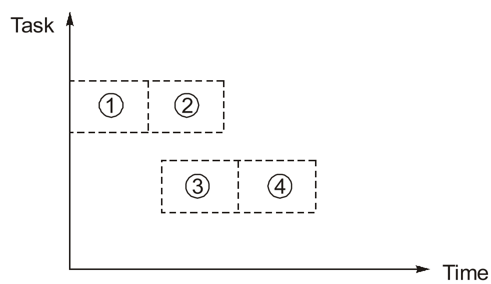
1. Project Management and Fundamentals of Network

1.1 What is a milestone chart? How does it differ from a bar chart? Define 'Earliest expected time', 'Latest allowable time' and 'slack' for a PERT network.

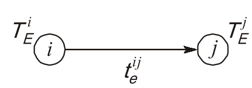
[1999 : 20 Marks]

Solution:

- Milestone chart is the modification over the original Gantt chart. Milestones are key events of a main activity represented by a bar: these are specific points in time which mark the completion of certain portions of the main activity. These points are those which can be easily identified over the main bar.
- When a particular activity represented by a bar on bar-chart is very long, the details lack. If, however the activity is broken into a number of sub-activities each one of which can be easily recognised during the progress of the project, controlling can be easily done and inter-relationships between other similar activities can be easily established.

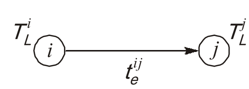


Earliest Expected time: It is the minimum time in which an event may occur. An event will occur when all the preceding activities are completed.



$$T_E^j = \left(T_E^i + t_e^{ij}\right)_{max}$$

Latest Allowable time: It is the maximum time of an event by which it may be allowed to occur without affecting the completion time of the project.



$$T_L^i = \left(T_L^j - t_e^{ij}\right)_{min}$$

Slack: It is defined as the difference between the latest allowable time and earliest expected time of the event. It is the excess time available by which occurrence of an event can be delayed without affecting the project completion time.

$$S = T_L - T_E$$

1.2 What are the methods of management of a large construction project in Civil Engineering? How do we have control over various activities from daily and monthly point of view? How is the schedule updated?

[2001 : 12 Marks]

Solution:

Methods of management:

1. Bar charts or Gantt charts
2. Milestone charts
3. Network analysis $\rightarrow$ CPM is used for construction project
4. Work breakdown structure.

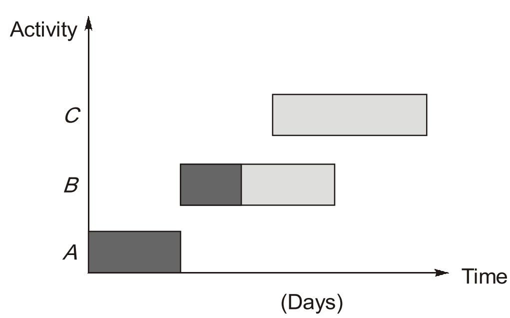
- Control of large projects involves close monitoring of resources, costs, quality and budgets.
- Feedback loop is used to revise the project plan.
- Resources are shifted where they are needed most to meet time, cost and quality demands.
- Updating is the process of rescheduling the activities on the basis of actual prevailing conditions at the given point to time.
- During updation neither new activities are added nor existing are removed.
- Since activity duration may be changed during the updation critical path and project completion time also may be changed.

1.3 What is a bar chart? Explain how it can be used to monitor progress of a project. What are the limitations of a bar chart?

[2002 : 12 Marks]

Solution:

- Bar chart is the graphical representation of the activities on the time scale.
- It consists of two coordinates: $x \rightarrow$ time and $y \rightarrow$ activity
- Activity is referred with the help of a bar.
- The starting and end point of the bar represents the starting and finish time of the activity.
- Length of the bar represents duration of the activity.



Monitoring program of a project:

- Firstly, activities are identified alongwith its duration.
- Activities are sequenced and mapped on the Activity–Time scale known as Gantt chart.
- Bars are shaded as and when activities are completed to monitor the progress of project.
- In the diagram, activity A is completed while activity B is partially complete and activity C has not yet started.

Limitations:

- It can be used for simpler and smaller projects.
- Lack of degree of details.
- No interdependency between the activities is shown by the bar chart.
- Lack of project progress display.

- It cannot differentiate between critical and non-critical activities.
- Uncertainties are not taken into account in case of bar chart.

1.4 What is revised estimate and what is a supplementary estimate? In what contexts are they respectively prepared? What are the main differences between them?

[2005 : 20 Marks]

Solution:

Revised Estimate: Due to change in the rate of material or change in specification of materials, an estimate is often required to be modified. Thus, we prepare revised estimate against the original estimate. In the preparation of revised estimate original estimate is also provided such that comparison can be made. There is no change in structural drawing and additional items are not added in the revised estimate.

Revised estimate is a detailed estimate. It is also accompanied by the original estimate for comparative purpose. While submitting revised estimate, the reason for revision should be stated.

Supplementary Estimate: During the execution of project, structural modification are required or addition work is added for construction. The estimate for additional work is called supplementary estimate. Supplementary estimate is also required to be prepared when some of the items are overlooked. In preparing the supplementary estimate reason for preparing the estimate would be clearly stated.

E.g.: Additional partition can be planned in the building. The estimate is prepared for partitioning as supplementary estimate. Structural/architectural changes are prerequisite for supplementary estimate.

1.5 What is one significant addition in recent NBC other than changes in individual clauses?

[2007 : 6 Marks]

Solution:

Significant addition: A new part *O* 'Integrated Approach - Prerequisite for applying the provisions of the code' emphasizing on multi-disciplinary team approach for successfully accomplishing building/development project, has been incorporated.

Other addition are:

- New chapters on significant areas like structural design using bamboo, mixed/composite construction and landscaping.
- The latest revised earthquake code, **IS 1893 (Part I): 2002.**

1.6 (i) Briefly discuss the Fulkerson rule of numbering events in a network.

(ii) What is the difference between CPM and PERT in network analysis?

[2009 : 6 + 6 Marks]

Solution:

(i) **Rule 1:** Number the initial event as (1).

Rule 2: Remove all the activities emerging from the initial node.

Rule 3: Number the new initial events sequentially.

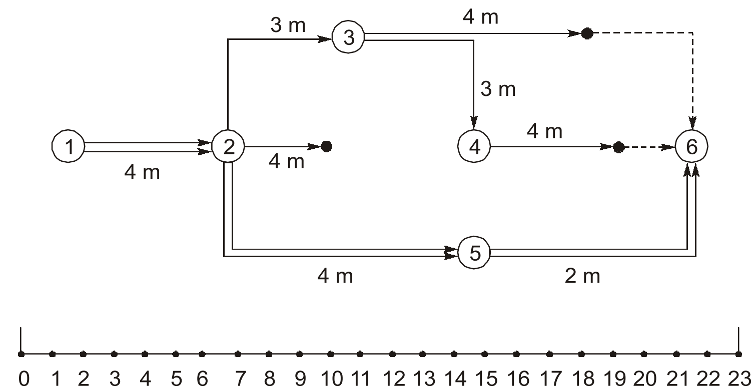
Rule 4: Repeat rule (2) until all the events of network are numbered.

(ii) PERT:

(a) It is event oriented network.
(b) It is based on probabilistic approach.
(c) It is generally preferred for research project.
(d) 3 time estimates are done for each activity.
(e) Each activity is assumed to follow 'β-distribution'
(g) Cost is directly proportional to time.

∴Critical path is 1-2-5-6 and project duration is 23 days.

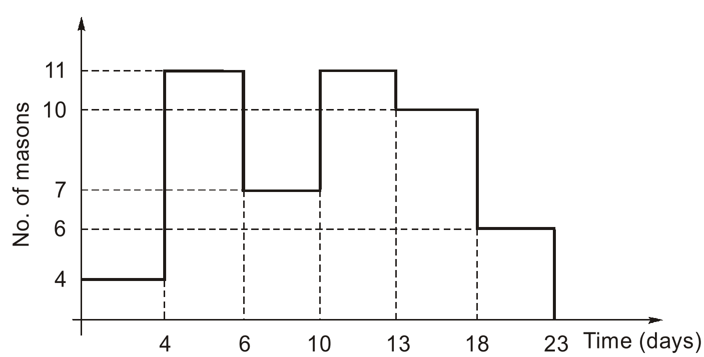
Let us analyse the project from resource requirement point of view.



M	4	4	4	4	11	11	7	7	7	7	11	11	11	10	10	10	10	10	6	6	6	6	6

Critical path is marked by double arrow. The dotted lines show the total float of each activity. The requirement of masons for each activity is marked under the activity arrow.

Variations of requirements of masons with time as shown in the diagram which is called resource uses profile or resource histogram.



From the resource histogram, it is clear that requirement of masons is not uniform along the project duration. The demand of masons is very high as 11 on 5th, 6th, 11th, 12th, 13th day where as it is very low as 4 on the beginning of 4 days of project. This shows two great variation in the resources requirements. Therefore planning should be done in such a manner that resources are utilized in more or less uniform manner.

This can be achieved by two approaches:

(i) Resource smoothening

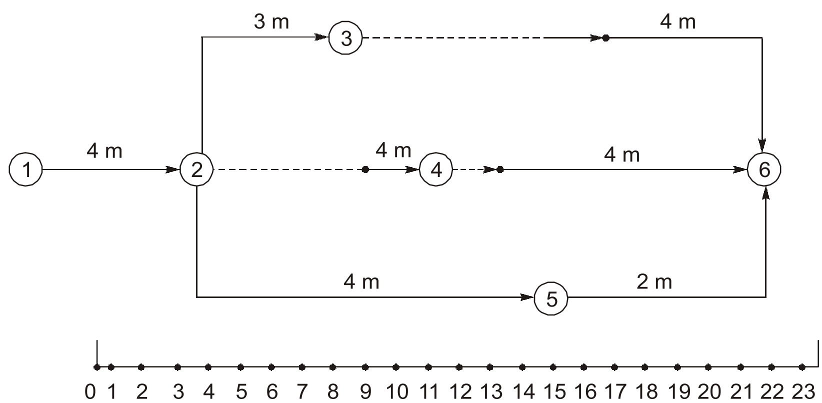
(ii) Resource levelling

Resource smoothening: In the process of resource allocation, the total project duration is not changed but some of the activity start time shifted by their available total float so that uniform demand of resources is achieved. However resources are considered to be unlimited.

Now resource allocation with unlimited number of resources. Peak requirement of masons on 5th, 6th day, 11th day, 12th day and 13th day.

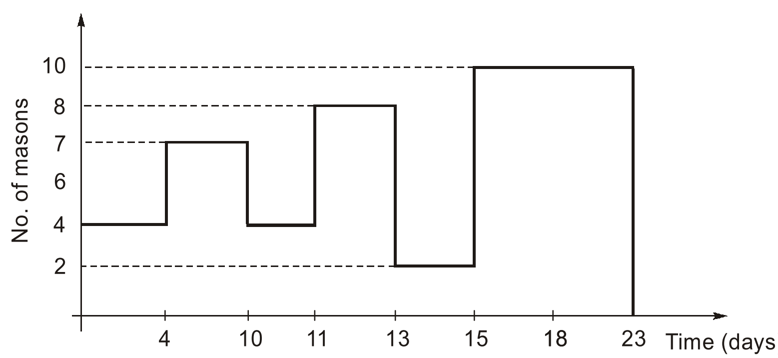
By inspection, we find total float for activity (2)-(4) is 7th day and total float for activity (3)-(6) is 5th days.

Hence start time of activity (2)-(4) is shifted by 7th days. Start time of activity (3)-(6) is shifted by 5th days. Also activity (4)-(6) start time is shifted by 2 days.



M	4	4	4	4	7	7	7	7	7	7	4	8	8	2	2	10	10	10	10	10	10	10	10

Variation of resources with time is as shown below:



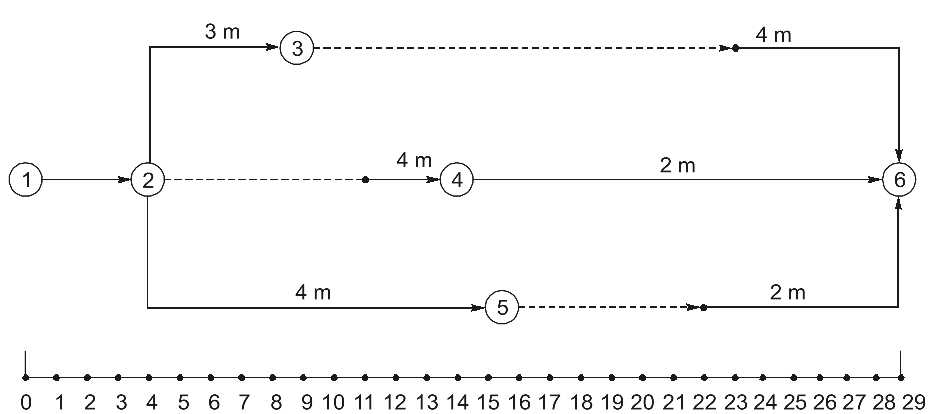
Resource allocation with limited number of resource.

In this process of resource allocation, activities are rescheduled that maximum requirement does not cross the limit of available resources.

Let us consider, limit of available resources is 8 masons.

In rescheduling, the available floats are used first. If by doing so, the resources demand is more than the available resources, the duration of some of the activities is increased so that resource requirement for some activities is decreased.

Let us increase the duration of activity (9)-(6) by 6 days. Hence activity duration of (4)-(6) will be 16 days because we use 2 days of total float.



$$= \text{Rs. 4 lakhs}$$

$$\text{Retained amount} = 0.05 \times 4 = \text{Rs. } 20000$$

$$\therefore \quad \text{Amount payable to contractor} = \text{Rs. } (400000 - 20000)$$

$$= \text{Rs. } 380000$$

At the end of 4th month

$$\text{Bill raised} = \text{Bill of activities B, C, D + Half of monthly bill of activity E}$$

$$= (4 + 12 + 15) + 0.5\,(4) \text{ lakhs}$$

$$= \text{Rs. 33 lakhs}$$

$$\text{Retained amount} = 0.05 \times 33 = \text{Rs. } 165000$$

$$\therefore \quad \text{Amount payable} = 3300000 - 165000$$

$$= \text{Rs. } 3135000$$

At the end of 5th month

$$\text{Bill raised} = \text{Bill of activity E + Half of monthly bill of activity C}$$

$$= 4 + 0.5\,(12) \text{ lakhs} = \text{Rs. 10 lakhs}$$

$$\text{Amount retained} = 0.05 \times 10 = \text{Rs. } 50000$$

$$\therefore \quad \text{Amount payable} = \text{Rs. } 950000$$

At the end of 6th month

$$\text{Bill raised} = \text{Bill of activity F} = \text{Rs. 20 lakhs}$$

$$\text{Amount retained} = 0.05 \times 20 = \text{Rs. } 100000$$

$$\therefore \quad \text{Amount payable} = \text{Rs. } 1900000$$

$\therefore$ Total retained amount to be released after 6 months

$$= \text{Rs. } 22500 + 42500 + 20000 + 165000 + 50000 + 100000$$

$$= \text{Rs. } 400000$$

$$\text{Total quoted cost of contractor} = \text{Rs. } 4.5 + 8.5 + 4 + 33 + 10 + 20 \text{ (lakhs)} = \text{Rs. 80 lakhs}$$

After 10% profit on quoted cost,

$$\text{Amount quoted} = \text{Rs. } 1.1 \times 80 = \text{Rs. 88 lakhs}$$

At 15% annual rate of interest on locked up capital, interest gained on retained amount

$$= 22500\left(\frac{0.15}{12}\right)\times 5 + 42500\left(\frac{0.15}{12}\right)\times 4 + 20000\left(\frac{0.15}{12}\right)\times 3$$

$$+165000\left(\frac{0.15}{12}\right)\times 2 + 50000\left(\frac{0.15}{12}\right)\times 1 + 100000\left(\frac{0.15}{12}\right)\times 0$$

$$= 1406.25 + 2125 + 750 + 4125 + 625 + 0$$

$$= \text{Rs. } 9031.25$$

$\therefore$ Total amount payable to contractor after 6 months

$$= \text{Rs. 80 lakhs + 10\% profit on 80 lakhs + Interest on retained capital}$$

$$= 8000000 + 800000 + 9031.25$$

$$= \text{Rs. } 88{,}09{,}0.31.25$$

$$\therefore \quad \text{Total profit of contractor} = \text{Rs. } 8809031.25 - 8000000$$

$$= \text{Rs. } 809031.25$$

■■■■

3 Surveying

1. Fundamental Concepts of Surveying and Linear Measurement

1.1 **What are the fundamental principles of land surveying? How are the controls inland surveying achieved?**

[2002 : 12 Marks]

Solution:

Fundamental principles of land surveying:

1. Measurement of location of a point form atleast two reference points.
2. Working from whole to part: In this, firstly, major control points with greater accuracy is determined and then minor details can be measured with less accuracy. By doing this, error involved in minor measurements won't get reflected in major measurements.

The various examples of land surveying includes:

1. Topographical survey
2. Cadastral survey
3. City survey.

Horizontal and Vertical controls in land surveying:

Horizontal and vertical controls are developed to create a framework around which other survey can be adjusted. These control surveys are used for accurate mapping projects in land surveying and many other high precision projects.

1. **Horizontal control:** Horizontal control coordinate horizontal positional data. These positions can be referenced by parallels or plane coordinate axes. Because they are used as framework for other surveys, this must be precise and accurate. Most horizontals should be connected to control network.
2. **Vertical Control:** A vertical control determines the elevation w.r.t. sea level. These are used as bench marks upon which land surveys are based and high degree of accuracy is required.

   In vertical control system atleast two permanent benchmark should be used but more may be required depending upon the needs and complexity of the object. These controls are needed for the construction of water supply and sewer systems, highway, bridges etc. These surveys can be done alone but are often done with horizontal control survey.

1.2 **The distance between two stations was measured with 20 m chain and found to be 2500 m. The same was measured with 30 m chain and found to be 2460 m. If 20 m chain was 5 cm too short, what was error in the 30 m chain?**

[2003 : 12 Marks]

Solution:

Let l be true distance/chain length and l' be faulty length of chain. Then,

Case I: 20 m chain,

$$\text{True distance} = \left(\frac{l'}{l}\right) \times \text{Measured distance}$$

$$\Rightarrow \qquad \text{True distance} = \frac{19.95}{20} \times 2500 = 2493.75 \text{ m} \qquad ...(i)$$

Case II: 30 m chain,

$$\text{True distance} = \frac{\text{Faulty length of 30 m chain}}{\text{True length of 30 m chain}} \times \text{Measured distance}$$

$$\Rightarrow \qquad 2493.75 = \frac{l'}{30} \times 2460$$

$$\Rightarrow \qquad l' = 30.416 \text{ m}$$

$$\therefore \qquad \text{Error in 30 m chain length} = 30.4116 - 30$$

$$= +0.4116 \text{ m}$$

It means 30 m chain was 41.16 cm too long at time of the measurement.

1.3 **Describe the common mistakes in linear measurements using chains and the measures to be adopted to eliminate these mistakes.**

[2004 : 12 Marks]

Solution:

Errors in chaining (Linear Measurements) : Errors in chaining are classified as: (i) Compensating Error (ii) Cumulative Errors.

(i) Compensating Error: These are the errors which are liable to occur in both directions and tend to compensate. Compensating errors are proportional to the square root of the length of line.

The compensating error are caused by the **following**:

(a) Incorrect holding and marking of arrows.

(b) Fractional parts of the chain may not be correct i.e. the chain may not be calibrated uniformly.

(c) Plumbing may be incorrect while chaining by stepping on slopes.

(d) In setting chain angles with a chain.

(ii) Cumulative Error: The cumulative **errors** are proportional to the length of the line and may be positive or negative.

Positive Cumulative Errors: These errors may be caused due to the **following reasons**:

1. The length of chain is shorter than the standard length.
2. Not applying sag correction.
3. Not applying slope correction.
4. Bad ranging, bad straightening and wrong alignment.
5. Bending of links, knots in links, clogging of rings with muds etc.
6. Not applying temperature corrections, when field temperature is less than standard temperature.

Negative Cumulative Errors: These **error** may be caused due to **following reasons**:

1. Length of chain more than its standard lengths.
2. Not applying temperature correction when temperature during the measurement is more than standard temperature.

1.4 Differentiate between systematic errors and accidental errors in survey work.

[2016 : 5 Marks]

Solution:

Systematic errors versus accidental errors:

Systematic errors	Accidental errors
These errors are called as systematic because they always follow a definite pattern or a mathematical/physical law. These are also called as *cumulative errors.* This type of error makes the result either too large or too small.	This type of error occurs due to human limitation in reading an observation. These are also called as *random errors* or *compensating errors.* When a large number of observations are made, then they use to cancel out because there is equal probability of the error to be positive or negative.

1.5 What is normal tension? Determine the normal tension for a steel tape supported between two supports 10 m apart if the standard tension is 65 N and the weight of the tape per metre is 0.62 N. Take E = 200 GPa and the area of cross-section as 8 mm².

[2020 : 10 Marks]

Solution:

Normal tension: The pull or tension which when applied to a tape supported in air over two ends, equalizes the correction due to pull and the correction due to sag is known as normal tension. As the pull increases the length of a tape and the sag decreases its length, the normal tension neutralizes both the corrections and hence no corrections is necessary.

The correction for pull, $$C_p = \frac{(P-P_0)L}{AE}(+\text{ve}) \quad \text{...(i)}$$

The correction for sag, $$C_s = \frac{W^2L}{24P^2}(-\text{ve}) \quad \text{...(ii)}$$

Equating numerically the eq. (i) and (ii), we get

$$\frac{(P-P_0)L}{AE} = \frac{W^2L}{24P^2}$$

or, $$P = \frac{0.204W\sqrt{AE}}{\sqrt{P-P_0}} \quad \text{...(iii)}$$

Where, W = Weight of the tape supported

P = Applied normal tension

P_0 = Tension at which tape was standarised.

The value of normal tension P, is determined by trial and error with the help of equation (iii)

Given, L = 10 m

Standard tension, P_0 = 65 N

Weight of tape per meter = 0.62 N

E = 200 GPa = 200×10^3 N/mm²

Area of cross-section = 8 mm²

∴ Total weight of tape, W = $0.62 \times 10 = 6.2$ N

Now, $$P = \frac{0.204W\sqrt{AE}}{\sqrt{P-P_0}} = \frac{0.204 \times 6.2\sqrt{8 \times 200 \times 10^3}}{\sqrt{P-65}} = \frac{1599.86}{\sqrt{P-65}}$$

$\therefore$ $$P \times \sqrt{P-65} = 1599.86$$

By trial and error, $P = 162.24$ N

2. Compass Surveying, Theodolites and Traverse Surveying

2.1 **In a prismatic compass measurement the field observations are usually corrected for (a) local attraction and (b) declination. Briefly discuss why?**

[2000 : 12 Marks]

Solution:

Need of correction for local attraction:

The compass in a prismatic compass contains magnetic needle which aligns along the magnetic lines of force due to the Earth's magnetism and points N-S direction. However, the magnetic needle will not point to the magnetic north, when it is under the influence of external attractive forces. In presence of the magnetic materials, such as iron pipes, steel structures, iron lamps, posts, rails, cables, chains, arrows, mineral deposits in the ground wrist watch etc. the needle is deflected from its normal position. Hence, local attraction by the magnetic materials is the disturbing influence on the magnetic needle of the compass. The amount of deviation of magnetic needle is the measure of local attraction.

Need of correction for declination:

The earth's magnetic poles are continually changing their positions relative to the geographical poles due to which the magnetic meridian of the earth also changes and thus the magnetic bearings. Therefore, the magnetic bearing are not very reliable measurements over a period of time. If over a period the surveyor would want to retrace the survey lines plotted by magnetic bearings, it would not be able to do so.

True bearing = Magnetic bearing ± magnetic declination (East/west). The angle of declination is said to be positive if magnetic meridian is on the eastern side of the true meridian and vice-versa.

2.2 **In a closed traverse, how omitted measurement if any are estimated? What are the possible combinations of elements of traverse that can be estimated?**

[2002 : 20 Marks]

Solution:

Omitted measurements: Often it becomes impossible to measure all the lengths and bearings of a closed traverse. The values of the missing quantities can be determined, provided they do not exceed two in number. Since the observed and omitted measurements are part of a closed traverse, the algebraic sum of all latitudes and that of all the departures are each zero. i.e., $\Sigma L = 0$, $\Sigma D = 0$. Thus.

$$\Sigma L = l_1 \cos\theta_1 + l_2 \cos\theta_2 + l_3 \cos\theta_3 + \ldots. = 0$$

$$\Sigma D = l_1 \sin\theta_1 + l_2 \sin\theta_2 + l_3 \sin\theta_3 + \ldots. = 0$$

Where l_1, l_2, l_3 and θ_1, θ_2, θ_3 are respectively the lengths and bearings of the lines.

Combination/cases of omitted elements of traverse:

1. **Bearing and length of one side omitted:** Let it be required to calculate bearing and length of the line *EA*. Calculate $\Sigma L'$ and $\Sigma D'$ of the four known sides *AB*, *BC*, *CD* and *DE*. Then,

$$\Sigma L = \text{Latitude of } EA + \Sigma L' = 0$$

or, $$\text{Latitude of } EA = -\Sigma L'$$

Similarly, $$\text{Departure of } EA = -\Sigma D'$$

knowing latitude and departure of *EA*, its length and bearing can be calculated by proper trigonometrical relations.