HYDRAULIC DESIGN OF A BARRAGE USING C++

By

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CERTIFICATE

This is to certify that the work entitled, "Design of a Barrage using C++" submitted by Bharat Bhagra (031610), Nalin Dinesh (031616), Rashmi (031617), Sukriti Ahluwalia (031604) and Vikram Chauhan (031607) in partial fulfillment for the award of degree of Bachelor of Technology in Civil Engineering of Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

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Certified the above mentioned project work has been carried out by the said group of students.

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ACKNOWLEDGMENT

The Hydraulic Engineering project marks the culmination of all the concepts assimilated while studying the subject. It has presented us with an opportunity to use the technical know-how imparted to us to a real life project.

Learning through the project under the guidance of our esteemed mentors **Prof. (Dr.) R.M.Vasan and Ms. Richa Babbar,** who not only cleared all our ambiguities but also generated a high level of interest and gusto in the subject. We are truly grateful to them.

The prospect of working in a group with a high level of accountability fostered a spirit of teamwork and created a feeling of oneness which thus, expanded our ken, motivated us to perform to the best of our ability and create a report of the highest quality.

To do the best quality work, with utmost sincerity and precision has been our constant endeavor.

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ABSTRACT

Till late forties, the irrigation as well as the power potential of the then nation was very meager and the people were feeling a lot of difficulty in the era of deficient economy. The economic progress of a country and the rise in standard of living of its people entirely depend upon the development and utilization of the available natural resources. The water once going waste and causing havoc is now a boon for agriculture and industrial development. In order to utilize the surplus water in lean period it was envisaged to build multipurpose projects on the various rivers for catering the growing demand of power and irrigation of the corresponding regions. Dams have helped in impounding the water which is further used for power generation and irrigation of the arid areas. The releases through the power houses are tapped by constructing barrages.

Hence, the basic aim of our project is to design a barrage using C++ as the programming language. We have also shown the software development with the help of flowcharts. In our project report we started by describing the hydraulic particulars of some famous Indian barrages, differentiating between a weir and a barrage, design criteria of a barrage and then comparing the software output with manual details of particular solved example. In the present project, a complete hydraulic design based on Khosla theory has been attempted. Given the minimal design requirements, the successful implementation of the program may be a useful tool for a hydraulic designer.

CHAPTER – 1

GENERAL DISCUSSION

1.1 INTRODUCTION

The works which are constructed on the head of a canal in order to (1) divert the river water towards the canal ,and (2) to ensure a regulated continuous supply of silt-free water with a certain minimum head into the canal are known as *diversion head works.*

A typical diversion headwork consists of following components (Figure 1):

1. Weir/Barrage
2. Undersluice portion
3. Divide wall
4. Fish Ladder
5. Canal Head Regulator
6. River Training Works

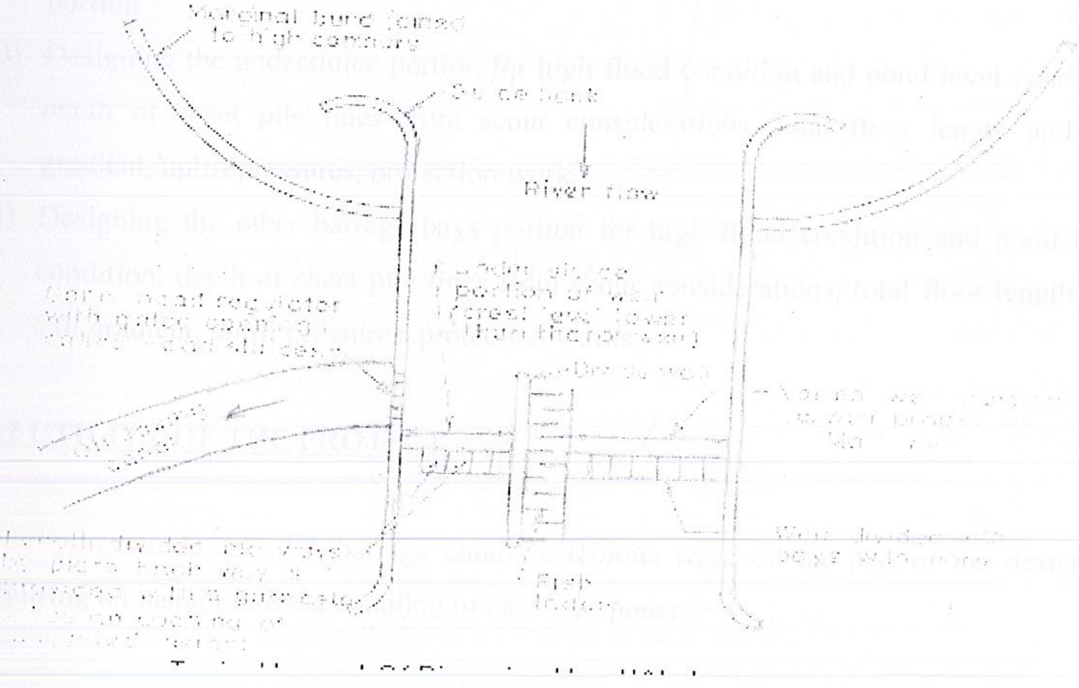


Figure 1: Components of a diversion headwork

A barrage, as a structure across a river to divert flow into a man-made channel, is designed to satisfy surface and subsurface flow considerations. There is, however, no procedure to fix the basic barrage parameters, which are depth of sheet piles/cutoffs and the length and thickness of floor, in a cost-effective manner. A parametric analysis has also been carried out to gain insight into the effects of various parameters on the optimal design barrage using C++ as the programming language.

In the present project, we tend to prepare a complete hydraulic design of the various components of a barrage using Khosla's theory. A safe exit gradient, retrogression and a certain suitable discharge concentration may be assumed where non-uniform flow is likely to occur. Any other data is assumed if not given.

The various designs which shall be performed are:

1) Fixing the crest levels of the undersluice portion and the other barrage bays portion
2) Designing the waterways for the undersluice portion and the other barrage bays portion
3) Designing the undersluice portion for high flood condition and pond level condition, depth of sheet pile lines from scour considerations, total floor length and exit gradient, uplift pressures, protection work
4) Designing the other barrage bays portion for high flood condition and pond level condition, depth of sheet pile lines from scour considerations, total floor length and exit gradient, uplift pressures, protection works.

1.2 UTILITY OF THE PROJECT

The hydraulic design of a barrage entails a tedious work on the part of the designer, requiring an insight into the detailing of each component.

In the present project, a complete hydraulic design based on Khosla theory has been attempted. Given the minimal design requirements, the successful implementation of the program may be a useful tool for a hydraulic designer.

1.3 DESIGN FACTORS

The following data must be collected before the design of a barrage can be designed:

1) High flood levels for the river at the barrage site
2) High flood or maximum flood discharge for the river at the barrage site
3) River cross-section at the barrage site
4) The stage discharge curve for the river at the barrage site

All these information can be obtained from Topographical maps of the area and consulting the Hydrological and Meteorological departments of the area.

Before we start with the actual design of a barrage, let us first review the effects that are produced by the barrage construction, on the regime of the river. The first effect produced by the construction of a barrage across a river, is that: the downstream bed of the river goes on eroding, consequently causing progressive lowering of the downstream levels. This progressive lowering of the downstream levels is known as Retrogression of downstream levels or retrogression.

In outlining the general approach to designing and operating a structured system, we take the very common example of an irrigation project serving many farmers. It has a regulated but not entirely certain source of water, which is frequently inadequate to meet potential demand for the area that can be commanded from the source— that is, land is plentiful compared to water. As noted above, if water is plentiful, then a demand based system may be the best option. If, as is common in monsoon climates, water is plentiful in one season and scarce in another, the system will have to cope with scarcity (often when water is most valuable) and as such a structured system should be considered. As in any well-designed system, the operational plan (or irrigation service) and the physical infrastructure are intrinsically linked, we first describe the operational plan, though with unavoidable reference to aspects of the infrastructure.

1.4 BARRAGE AS A UNIT

A barrage consists of two parts: The main barrage section, called barrage bay section and undersluice section.

The undersluice section is kept at a lower level, so as to provide deeper silent river pocket near the canal head regulator. The undersluice crest is, therefore, kept slightly lower than the barrage bay crest so as to attract a deep current in front of the canal head regulator, so that dry weather flow may remain near the regulator. The undersluice crest is generally kept as near the bed level in the existing deepest channel, as is practically possible.
The complete design of modern glacis-weir or barrage can be divided into two main aspects i.e. (a) Hydraulic Design, (b) Structural Design.

The hydraulic design involves determining the section of the barrage and a detail of its u/s cutoff crest, glacis, floor, d/s cutoff, and protection works u/s and d/s etc.
The structural design consists of designing for uplift pressures as a pure gravity section at each point.

The major benefits of barrage include:

a. The creation of up to 12.5 km of new water space of recreational use.
b. Unsightly mud flats covered by increased retained water level
c. Business attraction
d. Job creation
e. Increased tourism from development
f. The barrage can be a tourism attraction in its own height
g. Enhances flood defense
h. Electricity generation that could provide a source of sustainable power
i. Could incorporate a transport link across river.
j. Reduces salinity across the lower reaches of the river.
k. Stabilize the river level

1.5 BARRAGES IN INDIA

1. FARRAKKA BARRAGE, WEST BENGAL

The 2253 m (7366 ft) long barrage is constructed across river Ganga at Farakka in West Bengal. The total length of 2253 m (7366 ft) between the abutments is divided into a total of 109 bays comprising 84 spill bays plus 24 Undersluice Bays each with a clear width of 18.28 m (60 feet) and one bay for fish lock divided into two units each with clear width of 8.23 m (27 ft). The first 3 bays on the right bank are Silt Excluder Bays.

2. DURGAPUR BARRAGE, WEST BENGAL

It is situated at Durgapur in Burdwan Distt., West Bengal State (on Damodar River). It helps in serving irrigation, industrial water supply, and navigation needs of West Bengal. The work on this barrage was started in the year 1952, and completed in 1955.The design flood discharge for the barrage site is 15,576 cumecs (5.5 lakh cusecs).

3. BHIMGODA BARRAGE, U.P

This is a new barrage, the construction of which has recently been completed, across the holy Ganges at Hardwar in U.P. This barrage is a replacement of the old Bhimgoda Weir. The old weir is presently being dismantled. This headwork serves the irrigation needs of the adjoining areas, and is designed for a flood discharge of 19300 cumecs (6. 8 lakh cusecs).

4. NEW OKHLA BARRAGE, NEW DELHI

This is a new barrage constructed on Yamuna River, at New Delhi, about 3 Km downstream of the existing Old Okhla weir. It aims to serve irrigation and water supply needs through the New Agra Canal. The design flood discharge is 8495 cumecs (3 lakh cusecs).

5. TAJEWALA BARRAGE, HARYANA

It was constructed as long back as the year 1873, across Yamuna River. This barrage is located 37 Km from Jagadhri in Haryana, and the famous Western Yamuna Canal (W.Y.C) and the Eastern Yamuna Canal (E.J.C) takes off from this headworks. The design capacity of this barrage is 10.024 cumecs (3. 5 lakhs cusecs).Other particulars of these head works are given below.

6. HATHNIKUND BARRAGE, HARYANA

The work includes construction of 363.80 m long barrage with 10 bays of spillway and 3 bays of Left Undersluice and 5 bays of Right Undersluice separated by left and right divide walls. Head regulators are proposed on both sides of barrage with right head regulator of 10 bays and left head regulator of 4 bays

7. PRAKASAM BARRAGE, ANDHRA PRADESH

The famous Prakasm barrage is located at Vijayawada (in Andhra Pradesh State) on Krishna River connecting Guntur and Krishna Districts. It is one of the most famous dams on the river Krishna. It was constructed during the time of British but it is still strong and making considerable amount of Andhra land fertile. The reservoir made by this dam is a good attraction for tourism and it is considered to be official pilgrim lake (called in Telugu as Koneru) of Goddess 'Kanaka Gurga'. The Design flood discharge is as high as 33,984 cumecs (12 lakh cusecs). Its construction started in 1954 and got completed in 1957. Its panoramic lake and the three canals that run through the city give Vijayawada a Venetian appearance.

Some of the salient features of the prominent barrages and already completed barrages are given in Table 1 and Table 2 respectively.

Table 1: Hydraulic Parameters of some of the prominent barrages in India

Name of barrage	Pond Level (m)	Width of River (m)	Length of barrage(m)	Number of undersluice bays	Number of barrage bays
Durgapur Barrage	211.5	2000	692.2	10	24
Bhimgoda Barrage	293.7	675	455	7	15
New Okhla Barrage	201.35	445.73	552	5	22
Grand Anicut	61.567	419	329	5	30
Prakasm Barrage	17.38	-	1138.73	14	70
Shah Nehar Barrage	330.7	609.6	561.87	4	46
Tajewala Head Works	324	-	753	-	-

Table 2: List of completed barrages in India

Wazirabad Barrage across river Yamuna	Delhi
Kowari Barrage	Tripura
Manu Barrage	Tripura
Kosi Barrage & Head regulator	Bihar
Hasdeo Barrage (including Eastern Dam), Korba	M. P.
Ithai Barrage for Loktak Hydel Project	Manipur
Gandak Barrage Head regulator & Pre-stressed Concrete Bridge	Bihar
Log Boom at Aknoor near Jammu	J. & K.
Farraka Barrage Project	W. B.
U/S Navigation Lock & Trach Rack for Bagmari Siphon	
Spillway at Farraka for Farraka Barrage	
Chennai Weir Head Regulator & four Tunnel at Chennai	J. & K.
Weir, Head Regulator & Tunnel for Upper Sindh Hydel Project, Stage-1)	J. & K.
Gumti Hydel Project comprising of Head and Channel etc.	Tripura
Godavari Barrage across river Godavari, Dowlaiwaram	A. P.
Gumti Barrage across river Gumti	Tripura
Bhim Barrage	Bihar

1.5.1 PICTURE PROFILE

1) FARRAKKA BARRAGE, WEST BENGAL

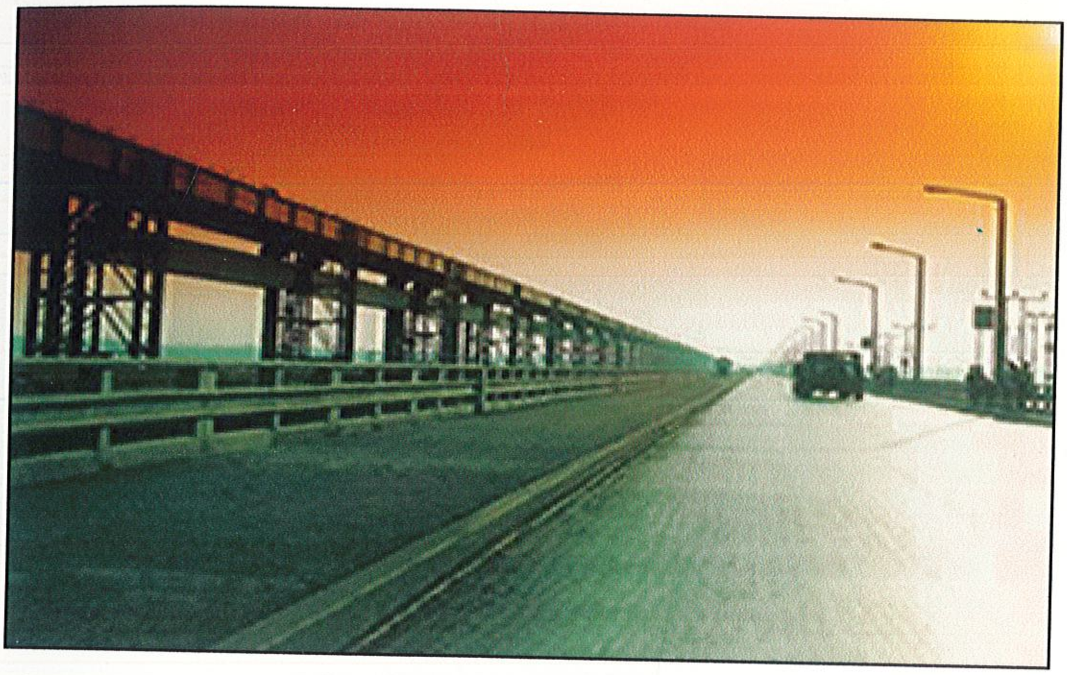


FIGURE – 2: Farrakka Barrage

2) DURGAPUR BARRAGE, WEST BENGAL

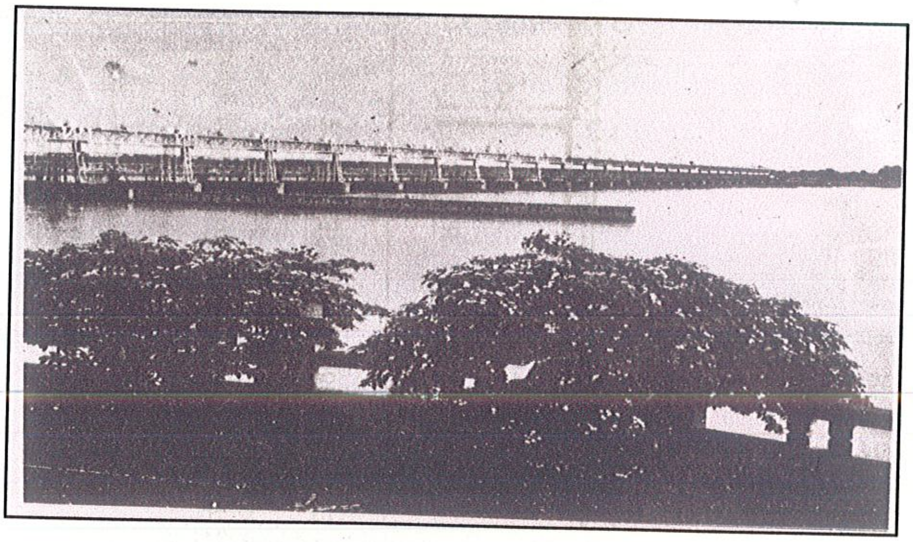


FIGURE-3: Durgapur Barrage

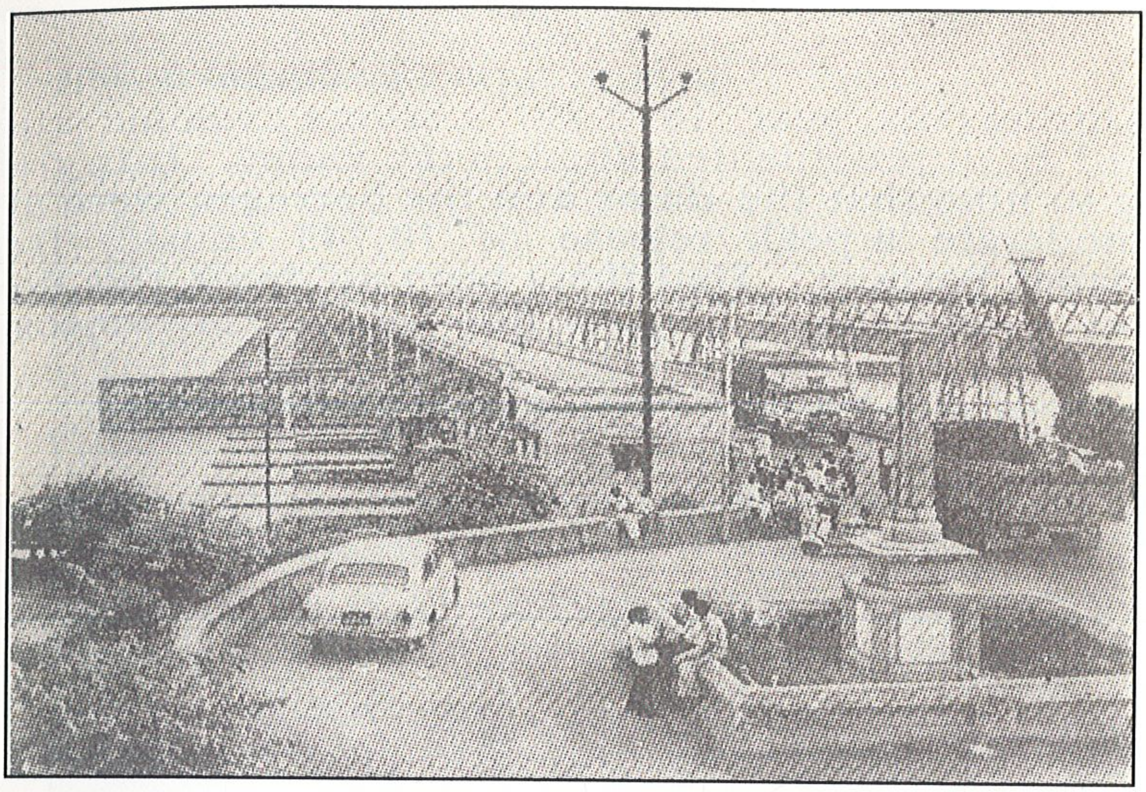


FIGURE – 4: Top – view of the barrage

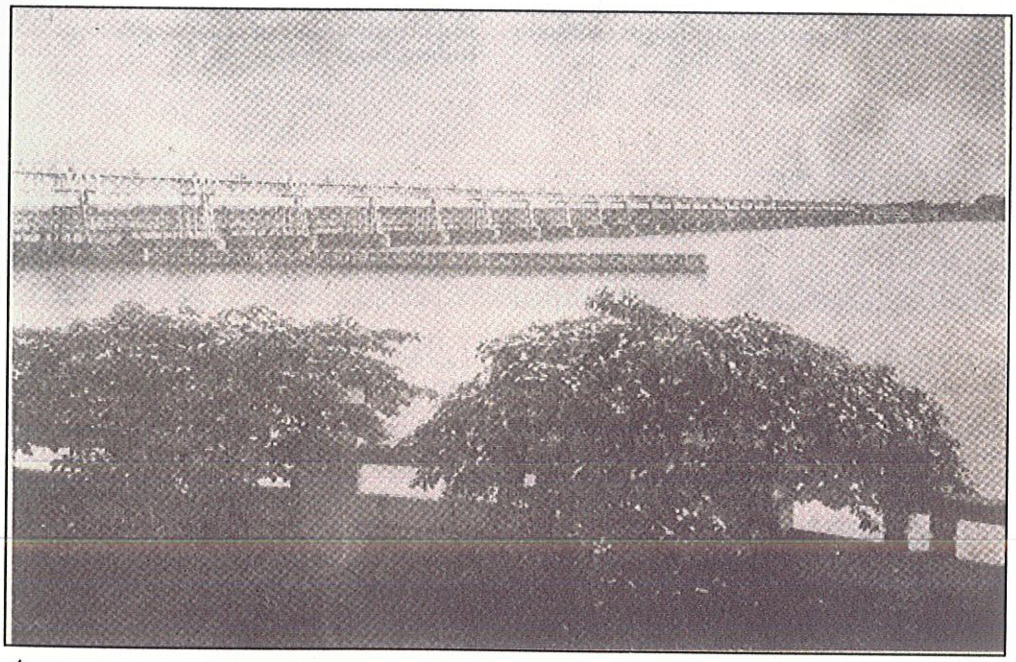


FIGURE – 5: Upstream – view of the barrage

3) BHIMGODA BARRAGE, UTTAR PRADESH

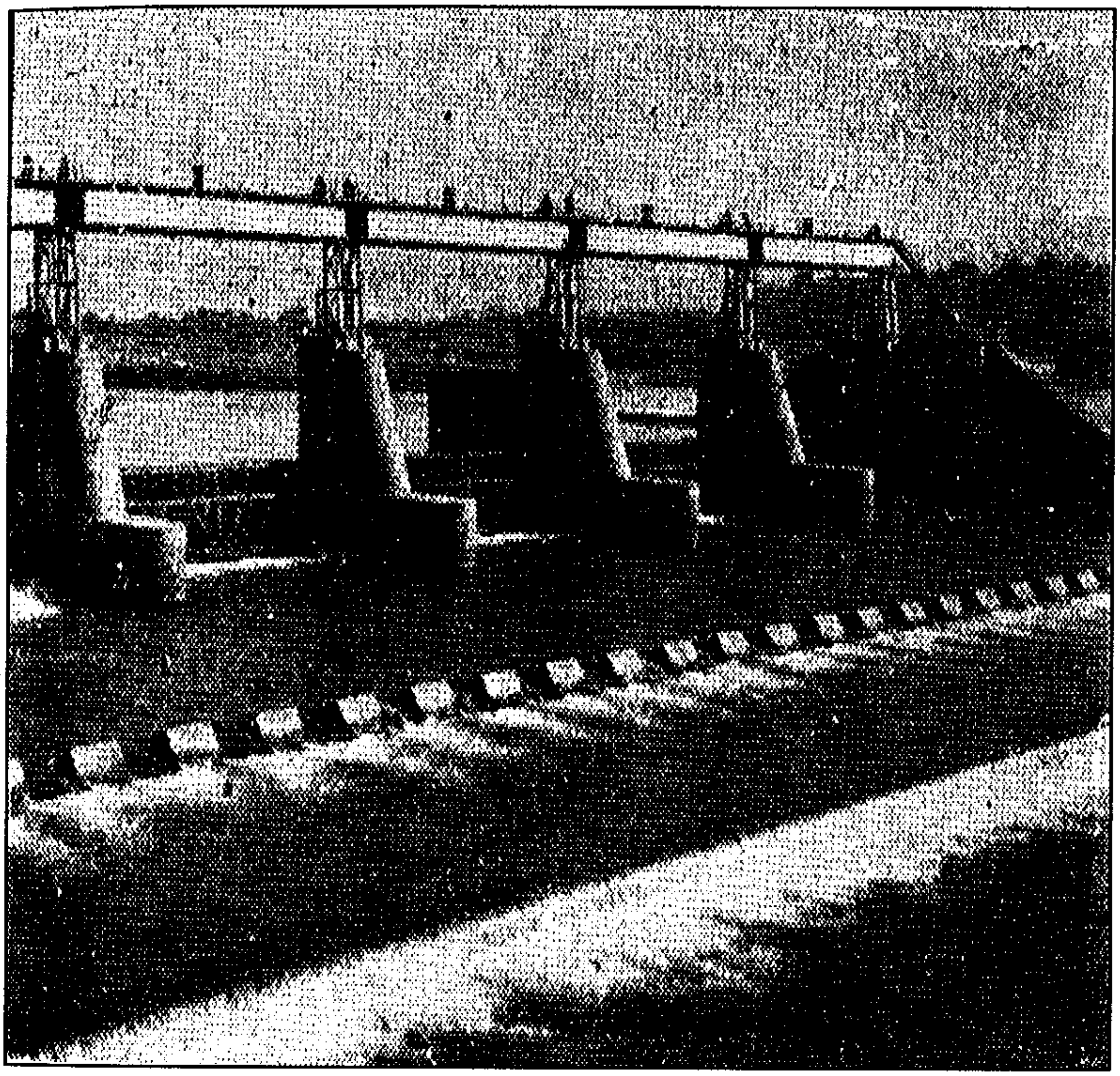


FIGURE – 6: Photo – view of Bhimgoda Barrage

4) NEW OKHALA BARRAGE, NEW DELHI

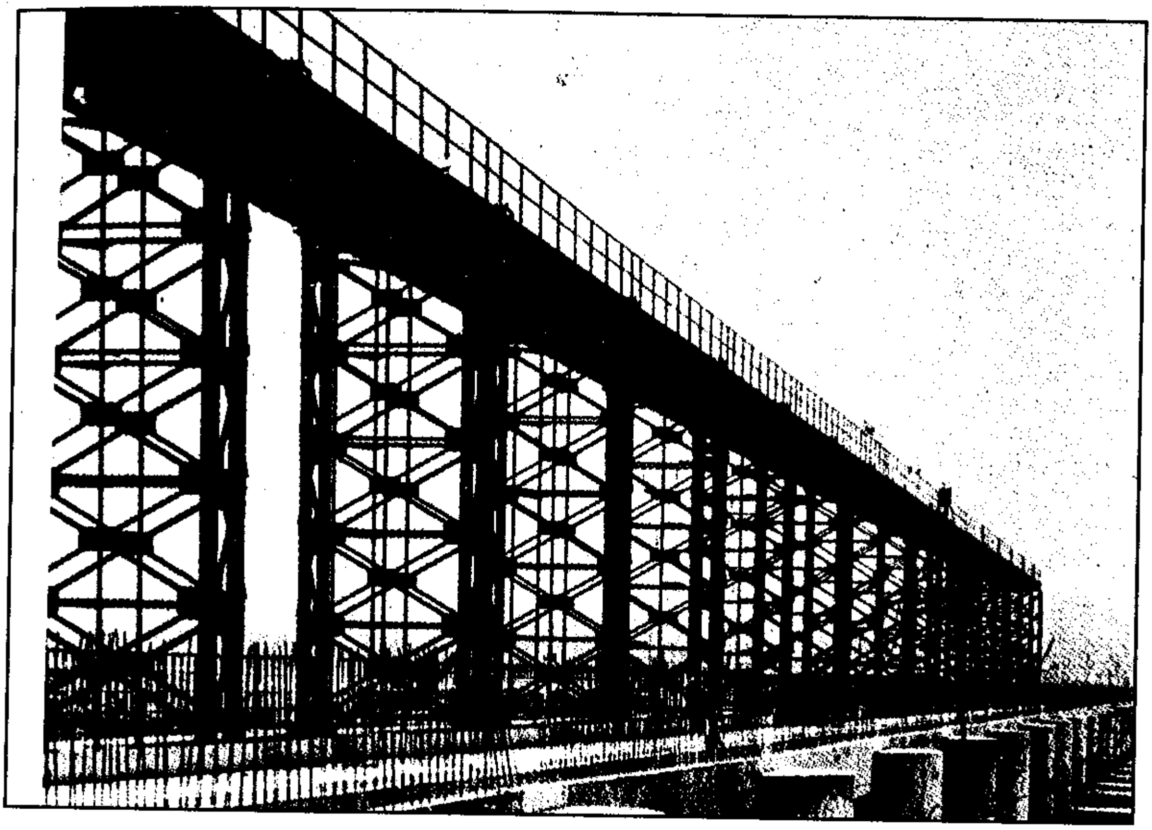


FIGURE – 7: Photo – view of New Okhla Barrage

5) TAJEWALA BARRAGE, HARYANA

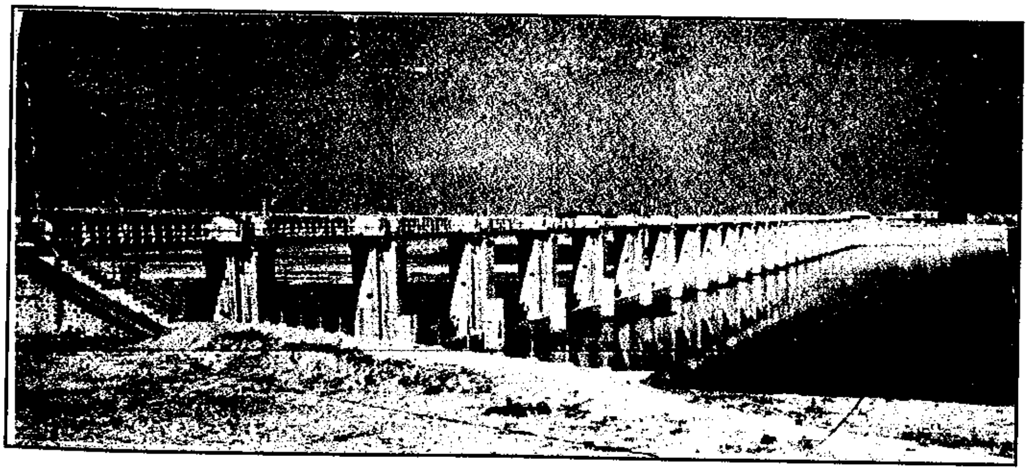


FIGURE – 8: Close – view of Tajewala barrage bay

6) HATHNIKUND BARRAGE, HARYANA

FIGURE – 9: Photo – view of Hathnikund Barrage

8)PRAKASAM BARRAGE, ANDHRA PRADESH

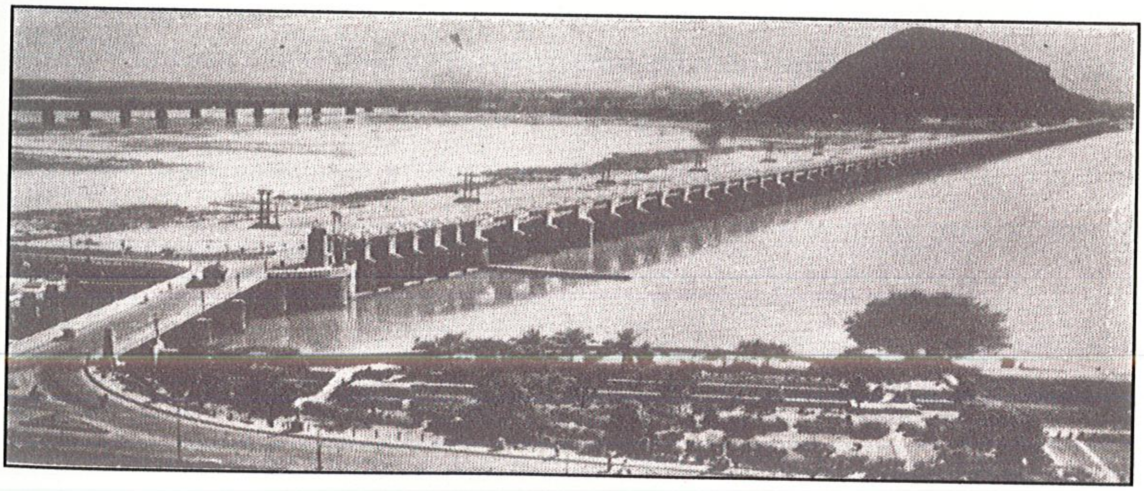


FIGURE -10: Photo – view of Prakasm Barrage (1)

1.6 WEIR AND BARRAGE

Weir and barrages are both constructed across the river so as to raise the water level on the upstream side of obstruction and thus to feed the main canal taking off from its upstream side at one or both of its flanks.

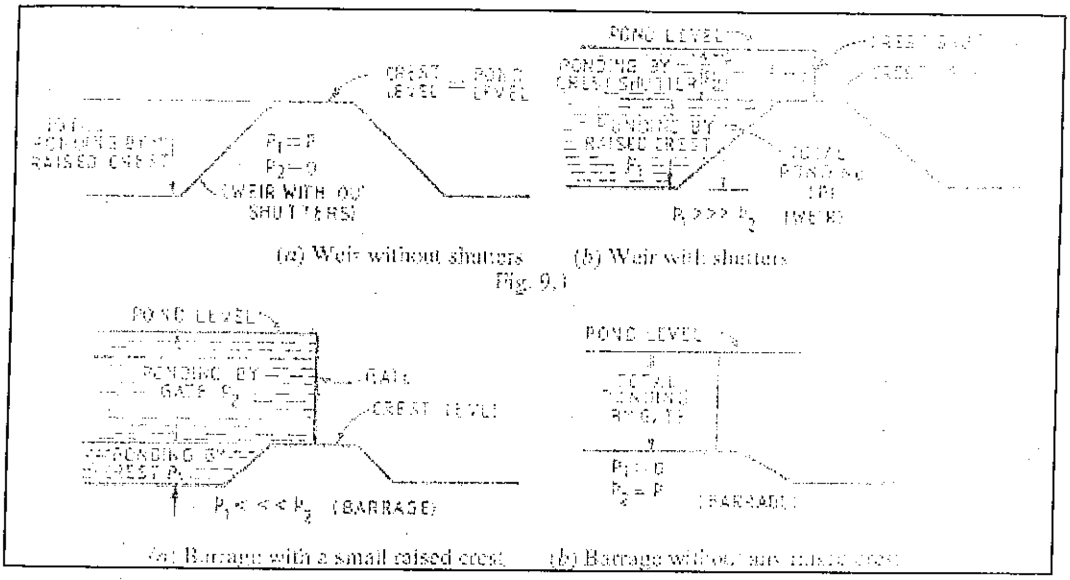


FIGURE –11: Difference between a Weir and a Barrage

If the major part or the entire pounding of water is achieved by the shutters, then this barrier is known as weir whereas if the most of the pounding is done by gates and a smaller or nil part of it is done by the raised crust, then the barrier is known as Barrage or a River Regulator. If the most of the pounding or he entire pounding is done by a permanent raised crest, as in a weir, then afflux caused during high floods is quite high. On the other hand, if most of the pounding is done by gates, as in the barrage, then the gates can be opened during high floods and afflux(i.e. rise in HFL near the site) will be nil or minimum.Hence the barrages gives less afflux and a better control upon the river flow, because the inflow and outflow can be controlled to a much greater extent by suitable manipulations of its gate.

CHAPTER – 2

DESIGN OF BARRAGE

2.1 DESIGN REQUIREMENTS OF A BARRAGE

Certain factors which have to be decided while designing a barrage are:

1. Retrogression of the downstream levels
2. Crest levels
3. Afflux
4. Waterway and the discharge per meter
5. Pond level

They are described below:

1. Retrogression of the Downstream Levels:

Before we start with the actual design of a barrage, let us first review the effects that are produced by the barrage construction, on the regime of the river. The first effect produced by the barrage construction of a barrage across a river is: the downstream bed of the river goes on eroding, consequently causing progressive lowering of the downstream levels. This progressive lowering of the downstream levels is known as Retrogression of downstream levels or retrogression.

The basic cause of retrogression is the variation in the silt carrying capacity of the channel. As soon as a barrage is constructed, the water starts pounding on its upstream side, causing the water surface slope to flatten for some distance behind the barrage. This reduces the silt carrying capacity of the river in its reach, and consequently the silt deposition starts, i.e. the river starts dropping sediment, and this leads to the formation of shoals and islands on the upstream side. The clearer water passes over the barrage and picks up sediment from its downstream bed, so as to fulfill the increased demand of the silt carrying capacity of the channel in the downstream, i.e. the sediment deficit caused on the upstream is made up by eroding extra sediment from the downstream. This causes the progressive lowering of the downstream bed levels. The process continues for a number of years till the river start to regain its original slope in the upstream portion by extending the afflux more and more upstream. The sage is gradually reached, when the upstream pond absorbs no more silt. As the off-taking water takes comparatively silt free water, the sediment will go downstream, while the discharge going down will be below normal, and hence, the sediment taken shall be more than the 'carrying capacity of the river'; consequently resulting in sediment deposition on the downstream river bed and long range recovery of downstream bed levels.

A provision must, therefore, be made for retrogression of the downstream bed, while designing a barrage, as it shall lower the downstream TEL and increase H_L. Hence, if retrogression is not taken into account, it may lead to undermining of floor. Observations on various barrages in Punjab have shown a retrogression of 1.2 to 2.2 meters. The retrogression of such a high magnitude has been observed at low water levels, the maximum retrogression is between 0.3 to 0.5 meters.

Hence, a retrogression of 0.5m at high flood stage, and a higher retrogression varying linearly up to 2.0m at lower discharges, is generally considered in the design of barrages.

The recovery of downstream bed levels sometimes continues even beyond the original bed levels. This may lead to reduced control on silt regulation. Hence, sufficient margin must be provided between the canal full supply level and the pond level, so as to allow raising of the crest of the canal Head Regulator, if found necessary, in future.

Since the afflux extends on the upstream of the barrage with the passage of time, it increases the high flood levels on the upstream even beyond the original backwater curves. Hence, the marginal bunds will have to be extended upstream as soon as the above effects come into picture. Sine it happens after many years, it is economical to construct marginal afflux bunds only for the backwater length in the beginning, and to extend them upstream afterwards

2. Crest Levels:

A barrage consists of two parts:

a. The main barrage section, called *Barrage Bay Section*
b. Undersluice section

The undersluice section is kept at a lower level, so as to provide deeper silent river pocket near the canal head regulator. The undersluice crest is, therefore, kept slightly lower than the barrage bay crest so as to attract a deep current in front of the canal head regulator, so that dry weather flow may remain near the regulator. The undersluice crest is generally kept as near the bed level in the existing deepest channel, as is practically possible.

The crest level of other barrage bays is generally kept 1.0 to 1.5m higher than the crest level of the undersluices. It is also guided by the general bed level of the river in the barrage bay portion.

It can be easily seen that the afflux and the discharge per meter are dependent upon the crest levels. If crest level is low, afflux shall be less, and since the depth of water over the crest will be more, it will lead to higher discharge per meter. A low set barrage, with increased depth of water over the crest may, therefore, result in the increase of height of gates, thickness of floor, and cost of superstructure above the floor.

3. Afflux:

The rise in the maximum flood level of the river upstream of the barrage after the construction is known as afflux. The afflux is confined only to short reach (equal to length of the backwater curve), in the beginning, but extends very far up, as explained earlier.

The amount of afflux will determine the top levels of the guide banks and marginal bunds. The lengths and sections of marginal bunds are also dependent upon it. It will govern the dynamic action downstream of the work as well as the depth and location of the hydraulic jump. *By providing a higher afflux, the waterway and, therefore, the length of the barrage can be reduced, but it will increase the cost of training works and the risk of failure by outflanking.* At the same time the discharge intensity and the consequent scour shall go up, and hence, *the sections of loose protections upstream and downstream as well as depth of pile lines at either ends will have to be increased*, thereby making it costly. It is therefore always desirable to limit the afflux to a safe value of 1.0 to 1.2m, more commonly 1.0m. However, in step reaches with rocky bed, a higher value of afflux may be permitted.

4. Waterway and discharge per meter:

The waterway and afflux are inversely correlated. Hence, a limit placed on maximum afflux shall limit the maximum waterway. It shall be seen that the cost of work as a whole is minimum for a certain afflux and waterway. Attempts should, therefore, be made to attain the most economical combination of these two factors. This can be made by trial and error, generally limiting the maximum value of afflux.

A likely figure for the waterway is obtained by **Lacey's wetted perimeter formula**, given by:

$$P = 4.75 \sqrt{Q} \qquad \textbf{2.1}$$

A waterway equal to **1.2 to 1.4 *P*** is assumed in rivers in plains. Some engineers preferred to keep a shorter waterway inspite of costlier woks, as it was thought that a shorter waterway reduces shoaling, but as a matter of fact it is not so.

5. Pond Levels:

The pond level is the minimum water level that is required in the undersluice pocket upstream of the canal head regulator, so as to feed the canal with its full supply. The pond level is generally obtained by adding 1.0 to 1.2 meters to the canal FSL.

Water in the undersluice pocket has to be maintained at Pond Level, even during dry weather flow. This can be accomplished either by a raised crest or by shutters or by a combination of both. A permanently raised crest will lead to higher afflux during floods and is likely to result in loss of control over the river.

In modern design of a barrage, the entire pounding is done by gates which are opened during floods and the crest level of the undersluices is generally taken as the available river bed in the deepest channel. No raise crest is generally provided for the undersluices. A raised crest is provided where possible, as it improves the coefficient of discharge.

6. Discharge estimation

a. For a broad crested barrage:

$$Q = 1.7\,(L - K\,n\,H)\,H^{3/2} \qquad 2.2$$

Where Q = discharge in cumecs

H = total head in meters including velocity head

n = no. of end contractions (twice the number of gated bays)

L = clear waterway length in meters

K = coefficient of end contractions varying from 0.1 for thick blunt pier noses to 0.04 for thin pointed noses: generally taken as 0.1 in ordinary calculations

b. For a sharp crested barrage:

$$Q = 1.84.\,(L - K\,n\,H)H^{3/2} \qquad 2.3$$

Where Q, L, n, K and H have the same meaning as given above. If the head over the barrage crest is more than 1.5 times the width of the barrage, the barrage behaves as a sharp crested barrage.

2.1.1 Design Steps

1. Fixing the crest levels
2. Determining the length of waterway
3. Determining the length and thickness of impervious floor
4. Fixing dimensions for the protection works

2.2 KHOSLA'S THEORY AND CONCEPT OF FLOW NETS

1. The seeping water does not creep along the bottom contour of pucca floor as stated by Bligh, but on the other hand, this water moves along a set of stream lines. This steady seepage in a vertical plane for a homogenous soil can be expressed by Laplacian equation:

$$\frac{d^2\phi}{dx^2} + \frac{d^2\phi}{dz^2} = 0 \qquad 2.4$$

Where, Φ = flow potential= Kh where K is the coefficient of permeability of soil and h is the residual head at any point within the soil.

The above equation two sets of curves intersecting each other orthogonally. One set of lines is called *streamlines,* and the other set is called *equipotential* lines. The resultant flow diagram showing both the set of curves is called a *Flow Net.*

2. The seepage water exerts a force at each point in the direction of flow and tangential to the streamlines. This force has an upward component from the point where the streamline turns upward. For soil grains to remain stable, the upward component of this force should be counter balanced by the submerged weight of the soil grain. This

force has the maximum disturbing tendency at the exit end, because the direction of this force at the exit end is vertically upward, and hence full force acts at its upward component. For the soil grain to remain stable, the submerged weight of the soil should be more than the upward disturbing force. The disturbing force at any point is proportional to the gradient of pressure at that point. The gradient of pressure of water at the exit end is called the **exit gradient**. In order that the soil particles at the exit remain stable, the upward pressure at the exit should be safe.

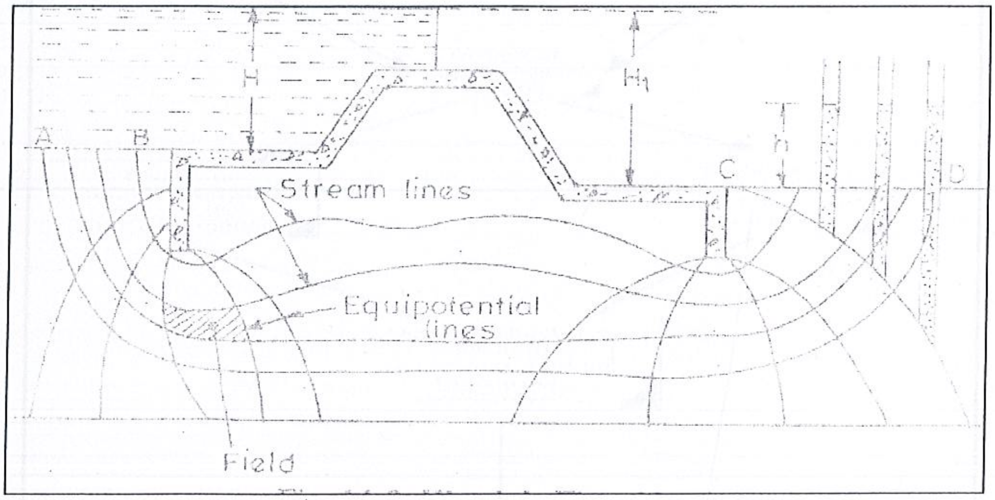
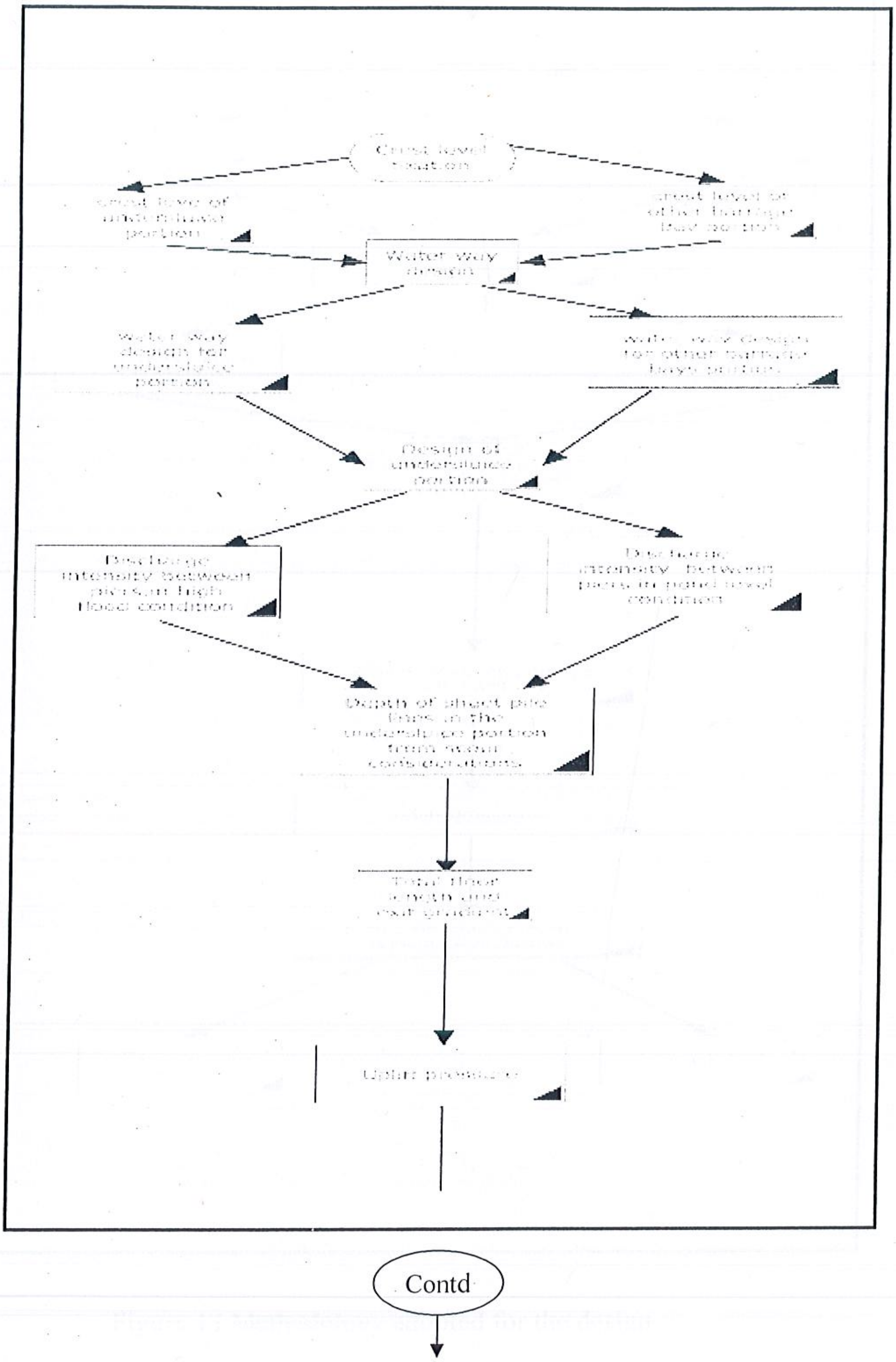


FIGURE –12: Concept of Flow Net

3. A barrage may fail not only due to seepage as stated by Bligh, but may also fail due to the surface flow. The surface flow may cause scour, dynamic action; and in addition, will cause uplift pressures in the jump through. The maximum uplift due to this dynamic action should then be compared with the maximum uplift under steady seepage and the two chosen for designing the aprons and the floor of the barrage.

2.3 METHODOLOGY

The methodology adopted for the hydraulic design keeping in view the various design components mentioned above have been provided in the form of a flow chart shown in Figure 14.


Water way design
Design of
Discharge intensity between
Depth of sheet pile lines in the
Total floor length and exit gradient
Contd

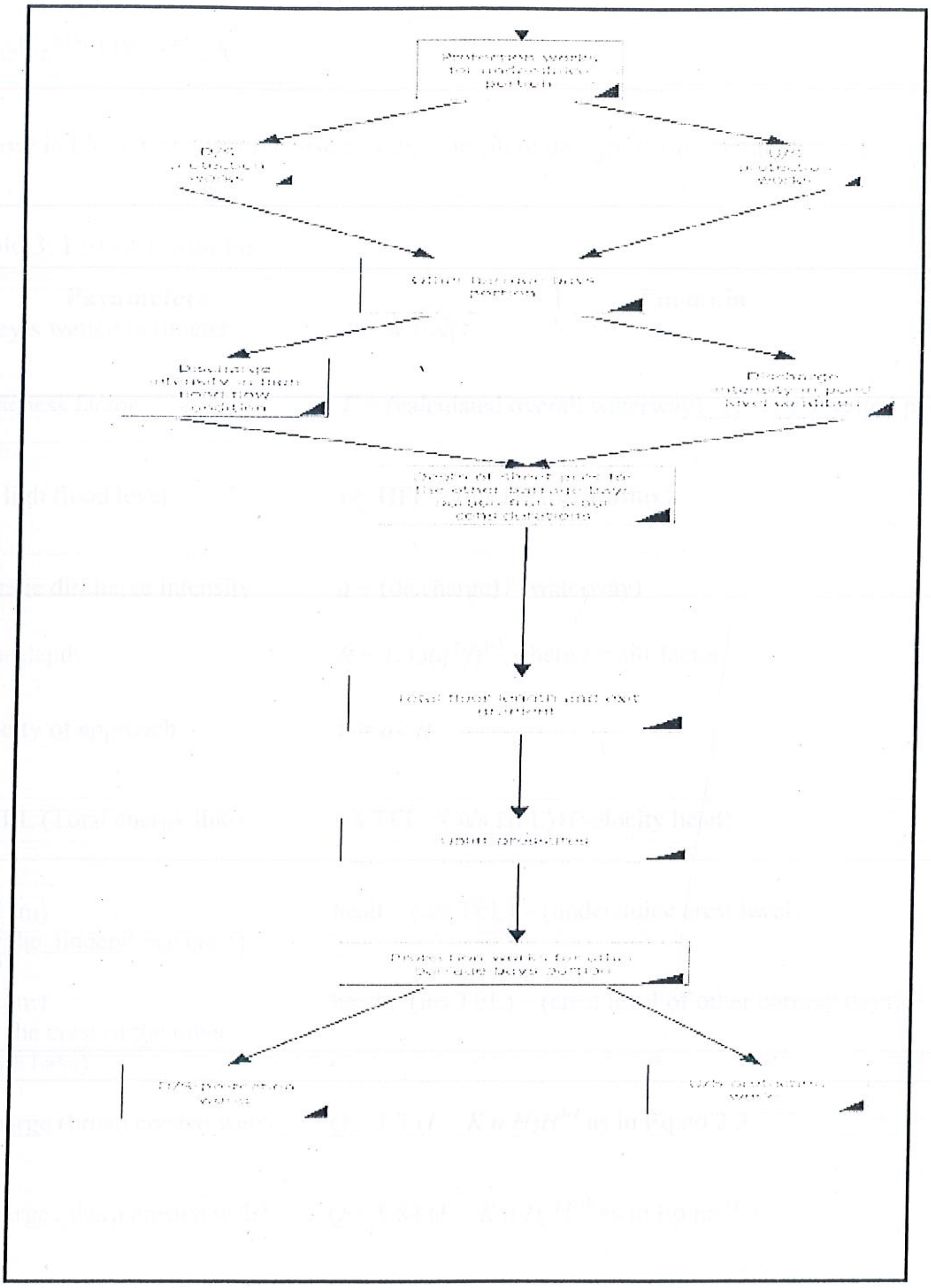


Figure 13 Methodology adopted for the design

2.4 DESIGN FORMULA

Below is the list of formulas used in the complete design of the barrage:

Table 3: List of Formulas

Parameters	Formula
Lacey's wetted perimeter	$P = 4.75\sqrt{Q}$
Looseness factor	F = (calculated overall waterway) / (Lacey's wetted perimeter)
u/s High flood level	u/s HFL = (d/s HFL) + (afflux)
Average discharge intensity	q = (discharge) / (waterway)
Scour depth	$R = 1.35(q^2/f)^{1/3}$, where f = silt factor
Velocity of approach	$V = q / R$
u/s TEL (Total energy line)	u/s TEL =(u/s HFL)+(velocity head)
Head (m) (over the undersluice crest)	head = (u/s TEL) – (undersluice crest level)
Head (m) (over the crest of the other barrage bays)	head = (u/s TEL) – (crest level of other barrage bays)
Discharge (broad crested weir)	$Q = 1.7\ (L - K\ n\ H)H^{3/2}$ as in Eq.no 2.2
Discharge (sharp crested weir)	$Q = 1.84\ (L - K\ n\ H)H^{3/2}$ as in Eq.no 2.3
Exit gradient	$G_e = (H/d) \times 1/(\pi\ \sqrt{\lambda})$

CHAPTER – 3

SOFTWARE DEVLOPMENT USING C++

3.1 C++ OVER C

C++ is a versatile language for handling very large problems. It is capable of performing tasks like development of editors, compilers, etc.

Procedure-Oriented Programming(C programming):

1. Focus is on Functions
2. Exists global data (share) and local data
3. Emphasis is on Algorithms
4. Top-down approach

Object Oriented Programming(C ++ programming):

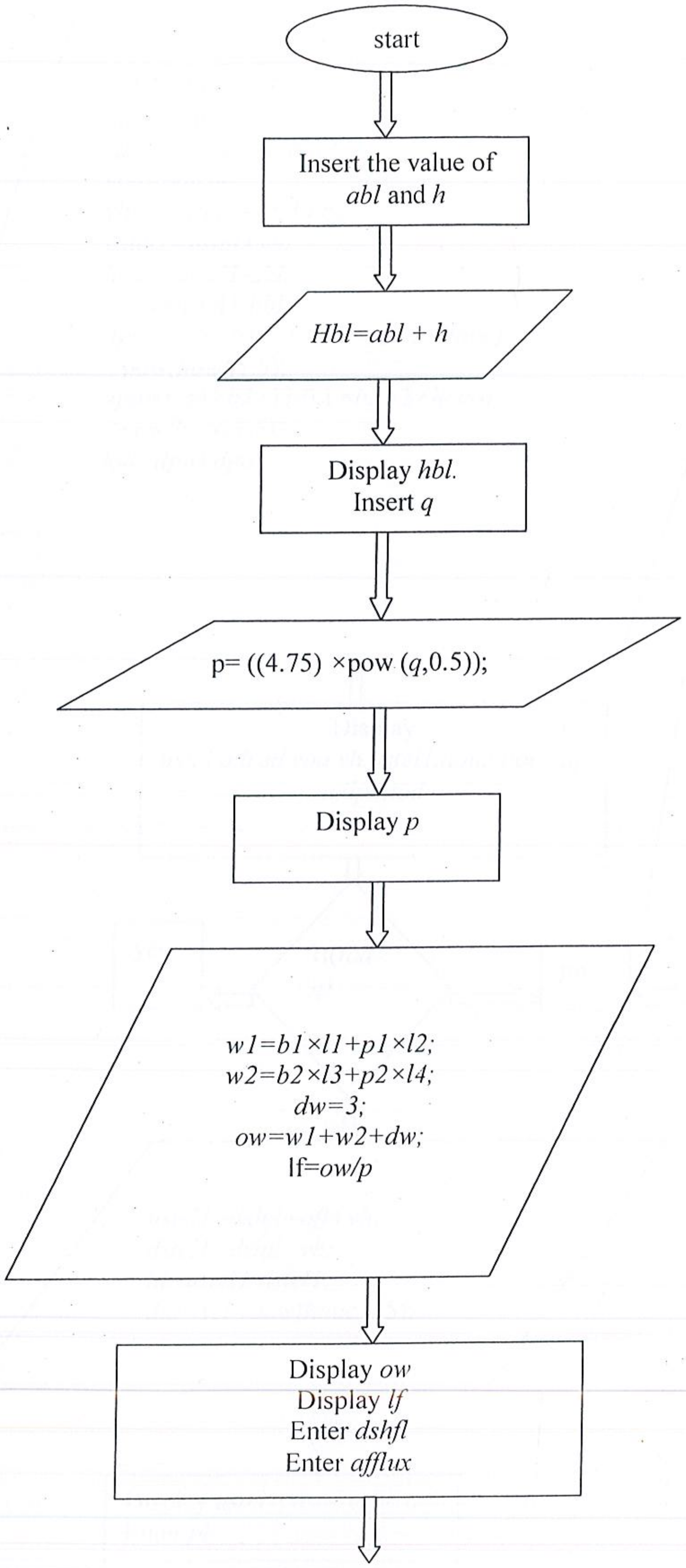
1. Emphasis on data rather than functions
2. Programs are devised in to objects that can communicate
3. Change is easy and data is secured
4. Additions are easy
5. Bottom-up approach

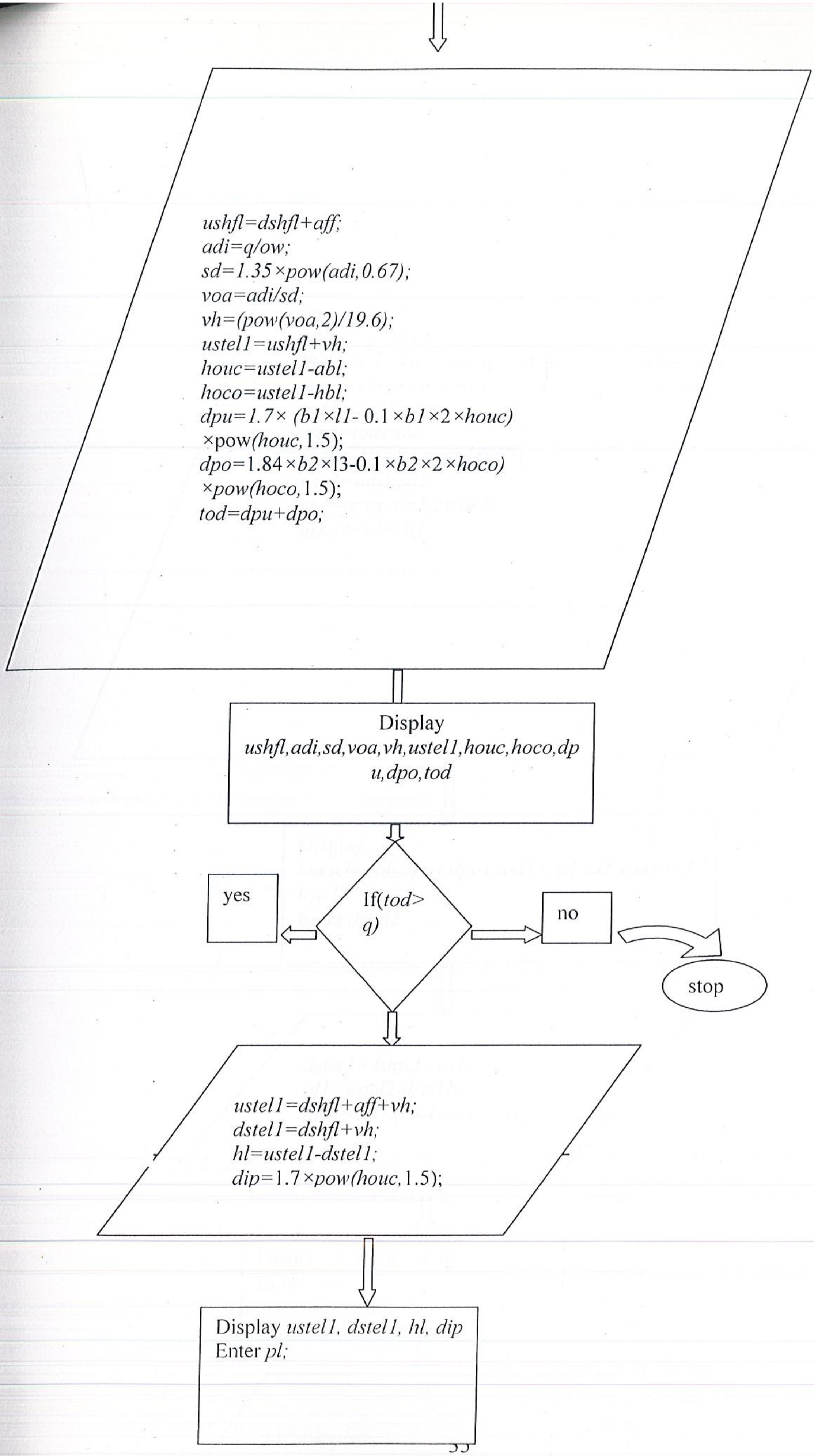
Procedural vs. Object-Oriented Programming:

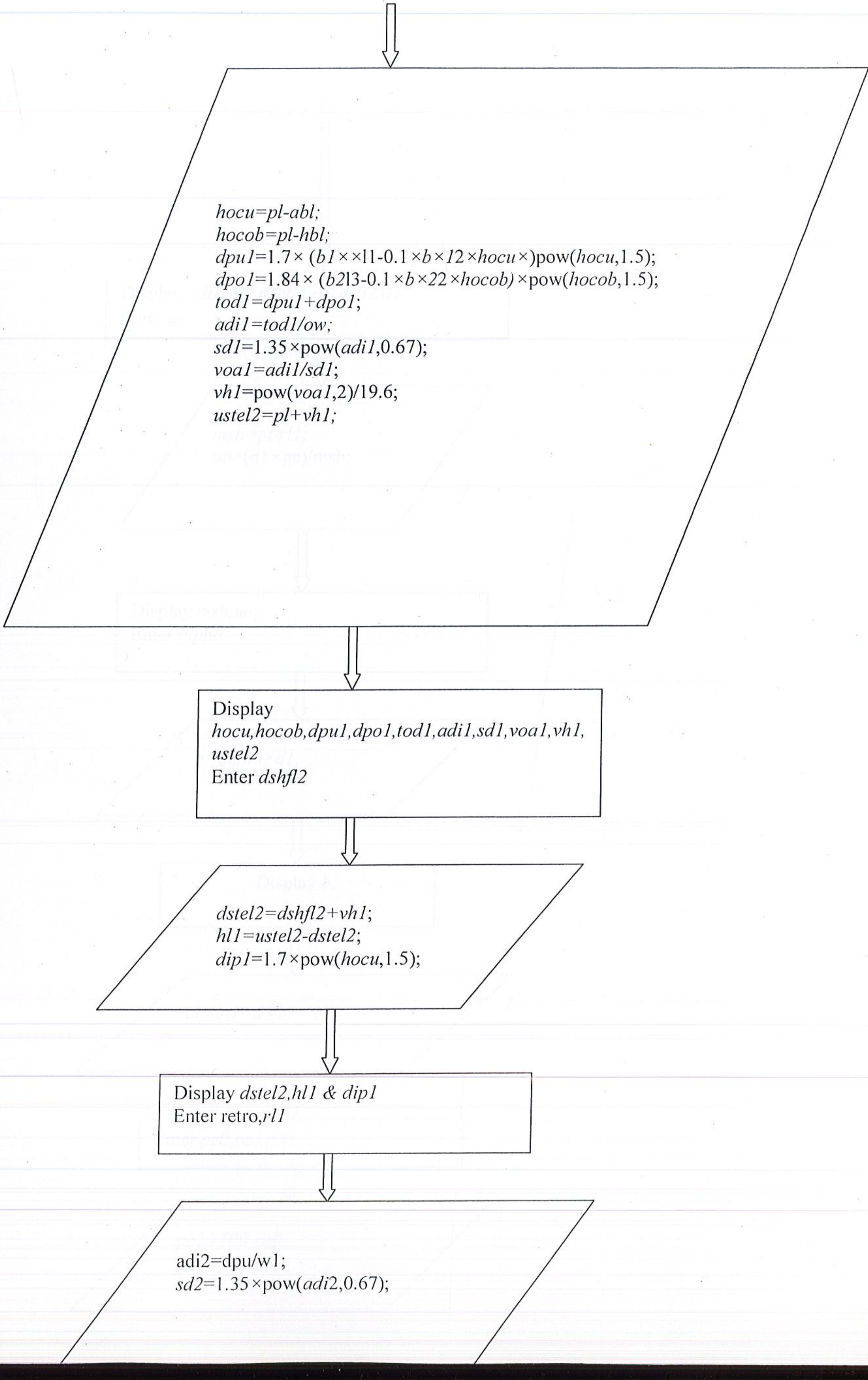
2. The unit in procedural programming is *function,* and unit in object-oriented programming is *class*
3. Procedural programming concentrates on creating functions while object-oriented programming starts from isolating the classes, and then looks for the methods inside them.
4. Procedural programming separates the data of the program from the operations that manipulate the data, while object-oriented programming focuses on both of them.

3.2 TOOL USED

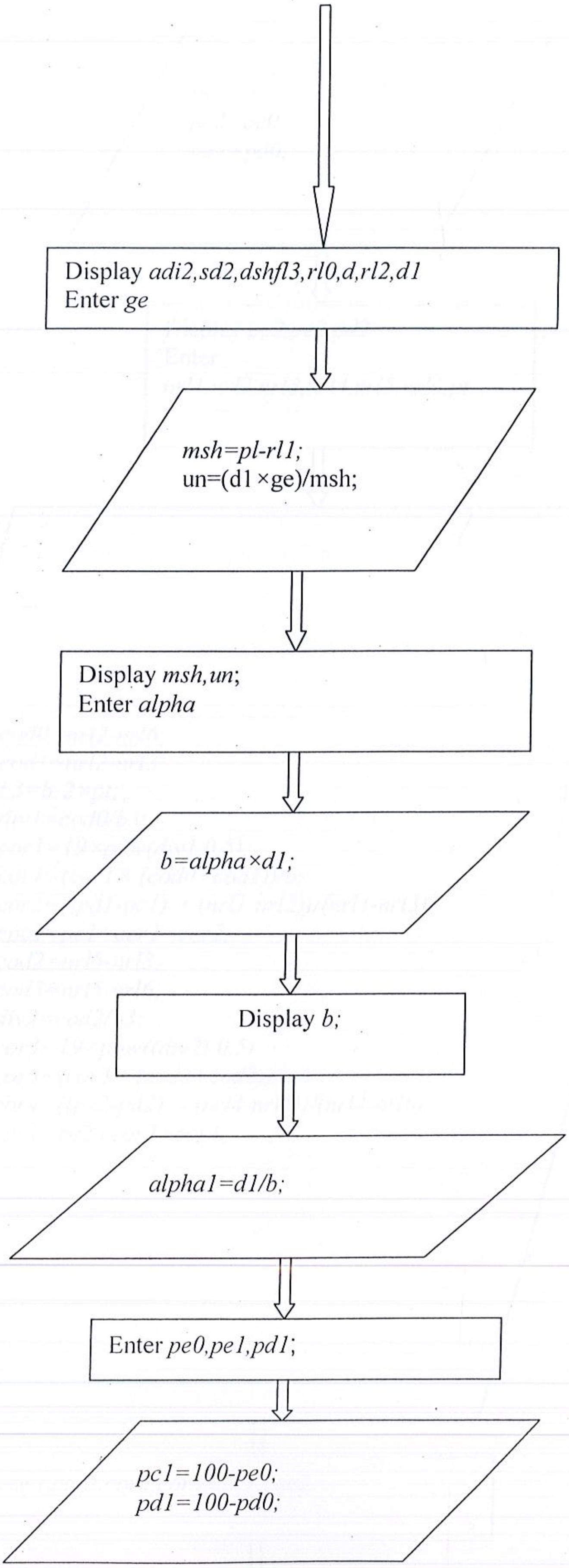
C++ as programming language has been used to develop the above methodology. The basic aim of our project is to design a barrage faster and effectively using C++ as a programming language and therefore avoid all the tedious work that goes in doing manual designing


start
Insert the value of abl and h
Hbl=abl + h
Display hbl. Insert q
p= ((4.75) ×pow (q,0.5));
Display p
w1=b1×l1+p1×l2;
w2=b2×l3+p2×l4;
dw=3;
ow=w1+w2+dw;
lf=ow/p
Display ow
Display lf
Enter dshfl
Enter afflux


ushfl=dshfl+aff;
adi=q/ow;
sd=1.35×pow(adi,0.67);
voa=adi/sd;
vh=(pow(voa,2)/19.6);
ustel1=ushfl+vh;
houc=ustel1-abl;
hoco=ustel1-hbl;
dpu=1.7× (b1×l1- 0.1×b1×2×houc)
×pow(houc,1.5);
dpo=1.84×b2×l3-0.1×b2×2×hoco)
×pow(hoco,1.5);
tod=dpu+dpo;
Display
ushfl,adi,sd,voa,vh,ustel1,houc,hoco,dp
u,dpo,tod
yes
If(tod>
q)
no
stop
ustel1=dshfl+aff+vh;
dstel1=dshfl+vh;
hl=ustel1-dstel1;
dip=1.7×pow(houc,1.5);
Display ustel1, dstel1, hl, dip
Enter pl;



hocu=pl-abl;
hocob=pl-hbl;
dpu1=1.7× (b1××l1-0.1×b×12×hocu×)pow(hocu,1.5);
dpo1=1.84× (b2l3-0.1×b×22×hocob)×pow(hocob,1.5);
tod1=dpu1+dpo1;
adi1=tod1/ow;
sd1=1.35×pow(adi1,0.67);
voa1=adi1/sd1;
vh1=pow(voa1,2)/19.6;
ustel2=pl+vh1;
Display
hocu,hocob,dpu1,dpo1,tod1,adi1,sd1,voa1,vh1,
ustel2
Enter dshfl2
dstel2=dshfl2+vh1;
hl1=ustel2-dstel2;
dip1=1.7×pow(hocu,1.5);
Display dstel2,hl1 & dip1
Enter retro,rl1
adi2=dpu/w1;
sd2=1.35×pow(adi2,0.67);


Display adi2,sd2,dshfl3,rl0,d,rl2,d1
Enter ge
msh=pl-rl1;
un=(d1 ×ge)/msh;
Display msh,un;
Enter alpha
b=alpha×d1;
Display b;
alpha1=d1/b;
Enter pe0,pe1,pd1;
pc1=100-pe0;
pd1=100-pd0;

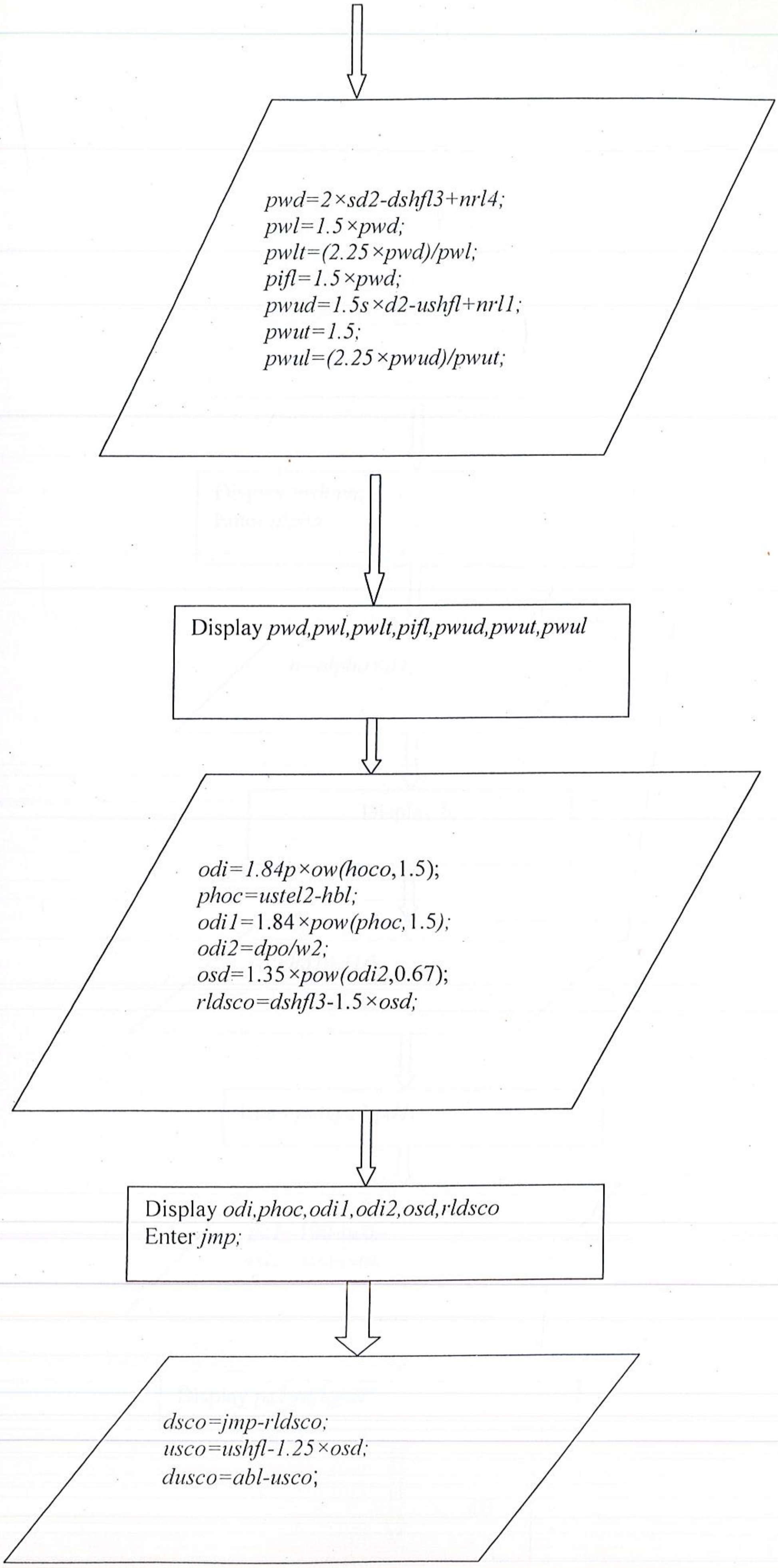
Display *pe1,pc1,pd1*;

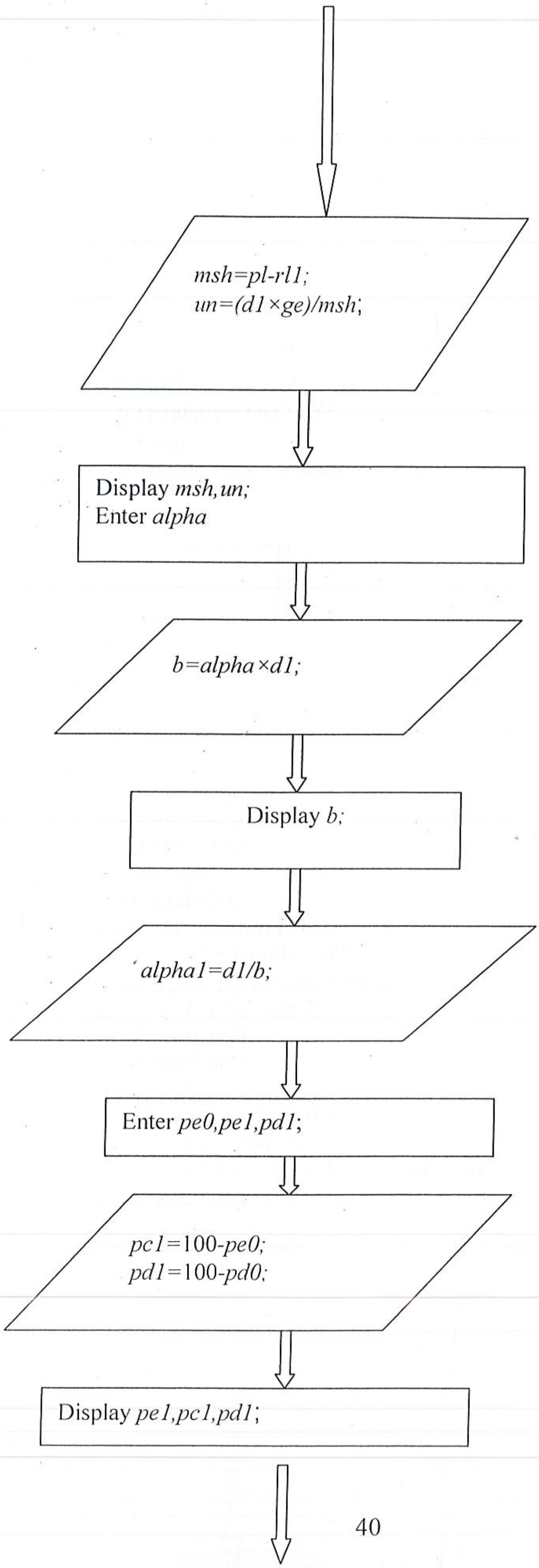
pc2=0;
pe2=pe0;
pd2=pd0;

Display *pc2,pe2,pd2*
Enter
nrl1,nrl2,nrl3,nrl4,nrl5,nrl6,pt

```
cod0=nrl2-nrl6;
cod1=nrl2-nrl3;
b3=b-2×pt;
div1=cod0/b3;
cor1=19×pow(div1,0.5);
cor1=(cor1× (cod0+cod1))/b;
cor2=((pd1-pc1) × (nrl1-nrl2))/(nrl1-nrl3);
cpc1=pc1+cor1+cor2;
cod2=nrl5-nrl3;
cod3=nrl5-nrl6;
div2=cod2/b3;
cor3=19×pow((div2),0.5);
cor3=(cor3× (cod2+cod3))/b;
cor4=((pe2-pd2) × (nrl4-nrl5))/(nrl4-nrl6);
cpe2=pe2+cor3+cor4;
```

Display *cor1,cor2,cor3,cor4,cpc1,cpe2*


pwd=2×sd2-dshfl3+nrl4;
pwl=1.5×pwd;
pwlt=(2.25×pwd)/pwl;
pifl=1.5×pwd;
pwud=1.5s×d2-ushfl+nrl1;
pwut=1.5;
pwul=(2.25×pwud)/pwut;
Display pwd,pwl,pwlt,pifl,pwud,pwut,pwul
odi=1.84p×ow(hoco,1.5);
phoc=ustel2-hbl;
odi1=1.84×pow(phoc,1.5);
odi2=dpo/w2;
osd=1.35×pow(odi2,0.67);
rldsco=dshfl3-1.5×osd;
Display odi,phoc,odi1,odi2,osd,rldsco
Enter jmp;
dsco=jmp-rldsco;
usco=ushfl-1.25×osd;
dusco=abl-usco;

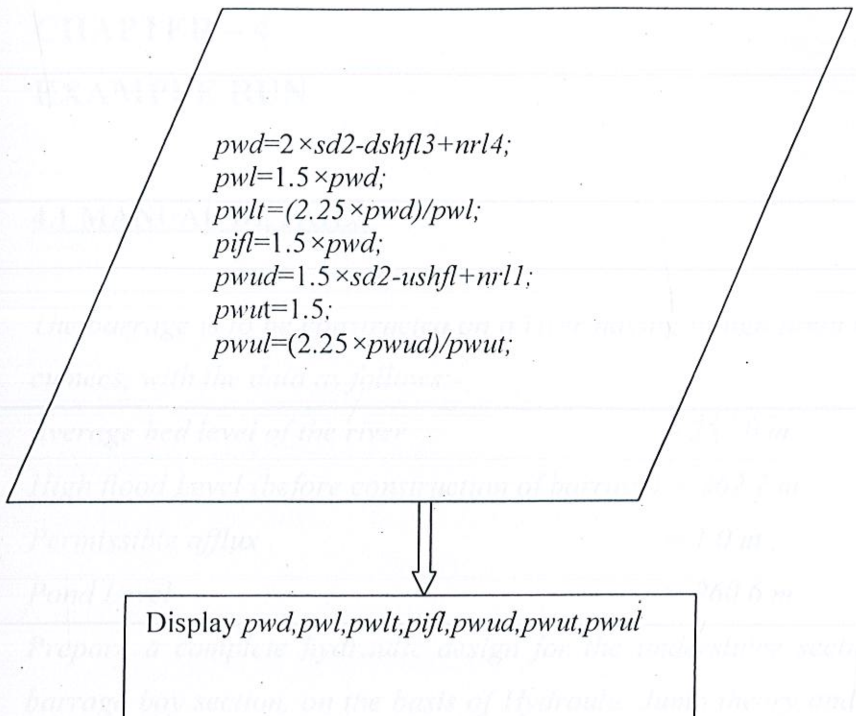

msh=pl-rl1;
un=(d1×ge)/msh;
Display msh,un;
Enter alpha
b=alpha×d1;
Display b;
alpha1=d1/b;
Enter pe0,pe1,pd1;
pc1=100-pe0;
pd1=100-pd0;
Display pe1,pc1,pd1;

Display dsco,usco,dusco
Enter ge;

pc2=0;
pe2=pe0;
pd2=pd0;

Display pc2,pe2,pd2
Enter
nrl1,nrl2,nrl3,nrl4,nrl5,nrl6,pt

cod0=nrl2-nrl6;
cod1=nrl2-nrl3;
b3=b-2×pt;
div1=cod0/b3;
cor1=19×pow(div1,0.5);
cor1=(cor1× (cod0+cod1))/b;
cor2=((pd1-pc1) × (nrl1-nrl2))/(nrl1-nrl3);
cpc1=pc1+cor1+cor2;
cod2=nrl5-nrl3;
cod3=nrl5-nrl6;
div2=cod2/b3;
cor3=19×pow((div2),0.5);
cor3=(cor3× (cod2+cod3))/b;
cor4=((pe2-pd2) × (nrl4-nrl5))/(nrl4-nrl6);
cpe2=pe2+cor3+cor4;


pwd=2×sd2-dshfl3+nrl4;
pwl=1.5×pwd;
pwlt=(2.25×pwd)/pwl;
pifl=1.5×pwd;
pwud=1.5×sd2-ushfl+nrl1;
pwut=1.5;
pwul=(2.25×pwud)/pwut;
Display pwd,pwl,pwlt,pifl,pwud,pwut,pwul

FLOWCHART

CHAPTER – 4

EXAMPLE RUN

4.1 MANUAL DETAILS

The barrage is to be constructed on a river having a high flood discharge of about 8,100 cumecs, with the data as follows:-

Average bed level of the river = *257.0 m*

High flood Level (before construction of barrage) = *262.2 m*

Permissible afflux = *1.0 m*

Pond Level = *260.6 m*

Prepare a complete hydraulic design for the undersluice section as well as for other barrage bay section, on the basis of Hydraulic Jump theory and Khosla's theory. A safe exit gradient of 1/6 may be assumed. 0.5 metres retrogression may be assumed where non-uniform flow is likely to occur. Assume any other data if not given.

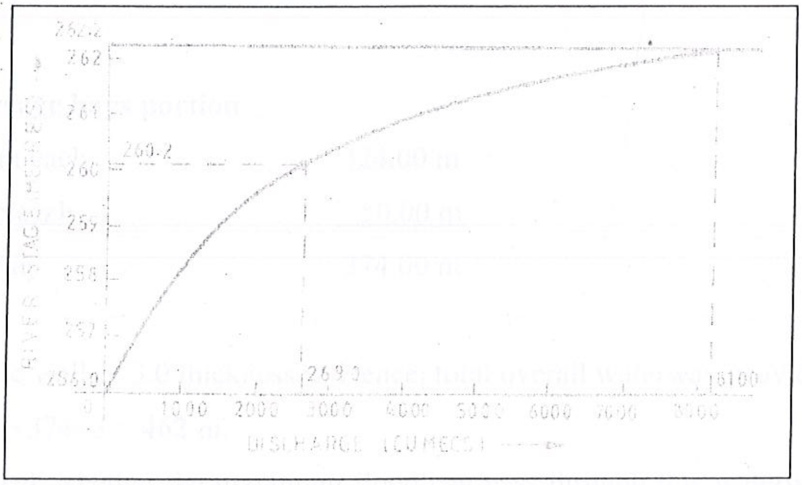


FIGURE – 15 Stage – Discharge Curve

Solution:

1.Fixing the Crest Level and Waterway

Crest Levels. The average bed level of the river is given to be 257.0 m, which may be taken as the crest level of the undersluices. The upstream floor of the undersluices may be kept the same, and thus there will be no raised crest in the undersluices. The crest level of other barrage bays may be kept 1.0 to 1.5 m higher than the crest level of undersluices. Let us keep it 1.3 m, say 257.0 + 1.3 = 258.3 m.

Waterway: The waterway, as per Lacey's wetted perimeter equation, is given by

$P = 4.75\ Q^{1/2}$

$= 4.75\ (8100)^{1/2} = 4.75 \times 90 =$ **427.5 m.**

Now let us provide a waterway approximately equal to 1.2 P by trial, in such a way that approximately 15 to 20% of the discharge is passed through the undersluices and the total provided waterway should be able to pass the entire discharge.

Assume the waterway as below

(a) Undersluice portion :

5 bays of 15 m each	75 m
4 piers of 2.5 m each	10 m
Overall waterway	85 m

(b) Other barrage bays portion

27 bays of 12 m each	324.00 m
25 piers of 2 m each	50.00 m
Overall waterway	374.00 m

Assume a divide wall of 3.0 thicknesses. Hence, total overall waterway provided between abutments = 85+374+3 = **462 m.**

Now, let us check whether the maximum flood can pass through this waterway with the maximum permissible afflux of 1.0 meter or not.

HFL before barrage construction = 262.2 m.

Permissible afflux = 1.0 m.

Now , u/s HFL = d/s HFL + Afflux

d/s HFL = HFL before weir construction = 262.2 m

So, u/s HFL = 262.2 + 1.0 = 263.2 m

Average discharge density = q = 8,100/462 = 17.6

Scour depth R

$R = 1.35(q^2/f)^{1/3}$

Assume Lacey's silt factor f = 1.0

$R = 1.35[(17.6)^2 /1.0] = 1.35 (17.6)^{0.667} = 9.20$ m.

Velocity of approach, V

$V = q /R = 1.90$ m /sec.

Velocity Head = $V^2/2g = (1.90)^2/(2 \times 9.81) = 0.19$ m.

u/s TEL= u/s HFL + Velocity Head = 263.2 + 0.19 = 263.39 m.

Head (i/c velocity head) over the undersluice crest

= u/s TEL – Undersluice crest level = 263.39 – 257.0 = 6.39 m.

Head (i/c velocity head) over the crest of other barrage bays

= u/s TEL – Crest level of barrage bays = 263.39 – 258.3 = **5.09 m**.

Discharge passing through undersluices is given by the discharge formula for a broad crested weir; since the crest and u/s floor are at the same level, and the width of the crest is sufficient, it will behave as a broad crested weir. So,

$Q_I = 1.7(L - K\, n\, H)\, H^{3/2}$

where L is the clear waterway

Q_I = Discharge through undersluices

$= 1.7\ [75 - 0.1 \times 10 \times 6.39]\ (6.39)^{3/2}$

$= 1.7\ [75 - 6.39]\ (6.39)^{3/2} = 1.7 \times 68.61 \times 16.1$ = **1.880 cumecs**.

Let us keep the width of the crest of other barrage bays portion as 2.0 m. Since the head over the other barrage bays crest is 5.09 m., which is more than 1.5 times the width of the crest, it shall behave like a sharp crested weir. The discharge is then given by :-

$Q = 1.84(L - 0.1\ n\ H)\ H^{3/2}$

Q_2 = Discharge through other barrage bays

$= 1.84(312.0 - 0.1 \times 52 \times 5.09)(5.09)^{3/2}$

$= 1.84(324.0 - 26.4)(5.09)^{3/2}$

$= 1.84 \times 297.6 \times 11.4 =$ **6,260 cumecs.**

Total discharge that can pass through the barrage

$= Q_1 + Q_2 = 1{,}880 + 6{,}260 = 8{,}140$ cumecs

$= 8{,}140$ cumecs $> 8{,}100$ cumecs.

Hence, the assumed waterway and crest levels are in order.

Actual overall waterway provided = 462 m against Lacey's wetted perimeter of 427.5 m.

So, Looseness factor = 462 / 427.5 = **1.08**

The design of undersluice section and that of other barrage bays section is carried out separately.

2.Design of undersluice Portion

There are two major flow conditions: (i) When high flood is passing; and (ii) When flow is at Pond Level (with all gates open). Let us calculate q and H_L for these two conditions.

2.1 High flood condition

(a) Assuming no concentration and retrogression

u/s TEL = d/s HFL + Afflux + Velocity head = 262.2 +1.0 +0.19 = 263.39 m.

d/s TEL = d/s HFL + Velocity head = 262.2 + 0.19 = 262.39 m.

Head Loss = H_L = 263.39 – 262.39 = **1.0 m**

Discharge intensity between piers = q

$= CH^{3/2} = 1.7(6.39)^{3/2} = 1.7 \times 16.1 = 27.4$ cumecs/meter

2.2 Pond Level Flow Condition

(a) With no concentration and retrogression

Pond Level (given) = 260.6 m.

Head over the crest of undersluices under this condition

= 260.6 – 257.0 = 3.6 m

Head over the crest of other barrage bays

= 260.6 – 258.3 = 2.3 m

Neglecting velocity of approach for this flow condition, the total discharge passing down the barrage –

$Q = Q_1 + Q_2$

$=1.7[75 - 0.1x10x3.6]\ (3.6)^{3/2} + 1.84[324 - 0.1x52x2.3](2.3)^{3/2}$

$=1.70 \times 71.4 \times 6.81 + 1.84 \times 312 \times 3.26$

= 825 + 1865 = **2690 cumecs.**

Average discharge intensity = 2690 / 462 = 5.82 cumecs/meter

Normal scoured depth = $R = 1.35\ (q^2 / f)^{1/3}$

$=1.35 \times [(5.82)^2 /1]^{1/3} = 1.35 \times (5.82)^{0.667} = 4.45$ m

Velocity of approach, V

$V = q / R$ = 5.82 / 4.45 = 1.31 m/sec.

Velocity head = $V^2 /2g = (1.31)^2 / (2 \times 9.81) = 0.088$ = **say 0.09 m.**

So, d/s TEL = 260.6 + 0.09 = 260.69 m.

The d/s water level when a discharge of 2,690 cumecs is passing can be found from the Stage-Discharge curve of the river. It is found to be 260.2 m.

So, d/s TEL = 260.2 + 0.09 = 260.29 m.

H_L = 260.69 – 260.29 = **0.40 m.**

Discharge intensity between piers = $1.7 \times (3.6)^{3/2}$

= 1.7 x 6.81 =11.54 cumecs/meter.

2.3 Depth of Sheet Pile Lines from Scour Considerations

Total discharge passing through undersluices = 1,880 cumecs

Overall waterway of undersluices = 85 m.

Average discharge intensity = 1880 / 85 = 22.3 cumecs / meter.

Depth of scour

$R = 1.35(q^2 / f)^{1/3}$

$=1.35[(22.3/1)^2]^{1/3} = 1.35(22.3)^{2/3} = 1.35 \times 8 = 10.8$ m, say 11m.

Let us provide a downstream cut-off at 1.5 R below the d/s water level (which is 261.7 m with retrogression).Hence, the R.L. of bottom of d/s cut-off

= 261.7 – 1.5 x 11.0 = 261.7 – 16.5 = 245.2 m.

Let us provide the d/s cut-off up to a bottom level of 245.2 m, i.e. a depth of 7.5 metres

U/s cut-off. Let us provide u/s cut-off at depth of 1.25 R(i.e. 1.25 x 11.0 = 13.75 m) from top of u/s water level.

Level of bottom of u/s cut-off = 263.20 – 13.75 = 249.45 m.

Let us, therefore, provide the u/s cut-off up to a bottom level of 249.5 m, i.e. 7.5 m deep.

2.4 Total Floor length and Exit Gradient

Safe–exit gradient (G_E) = 1/ 6

Maximum Static Head *(H)* = 260.6 – 252.7 = **7.9 m**

Depth of d/s cut-off (*d*) = 252.7 – 245.2 = **7.5 m**

$G_E = (H / d)\ (1/\pi \times \lambda^{1/2})$

So, $1/6 = (7.9 / 7.5)\ (1/\pi \times \lambda^{1/2})$

$1/(\pi \times \lambda^{1/2}) = (7.5 / 7.9) \times (1/6) = 0.158$

Value of α for a value of $1 / (\pi \times \lambda^{1/2})$ as 0.158, comes out to be approximately 8.0.

So, $b = \alpha . d = 8 \times 7.5 =$ **60 m.**

Hence a balance of 18.1 m length can be provided as u/s floor length so as to make the total floor length equal to 60.0 meters.

2.5 Uplift Pressures

To calculate uplift pressures from Khosla's theory, let us first assume floor thickness at u/s cut-off as 1.0 m and at d/s cut-off as 1.5 m. No intermediate cut-off is necessary and hence not provided.

Upstream Pile No. (1)

$b = 60$ m

$d = 7.5$ m

$1 / \alpha = d / b = 7.5 / 60 = 0.125$

Therefore,

$\Phi_{E1} = 100\%$

$\Phi_{C1} = 100 - \Phi_E = 100 - 32 = 68\%$

$\Phi_{D1} = 100 - \Phi_D = 100 - 22 = 78\%$

D/s Pile Line

$d = 7.5$ m

$b = 60$ m

$1 / \alpha = d / b = 7.5 / 60 = 0.125$

Therefore,

$\Phi_{C2} = 0\%$

$\Phi_{E2} = \Phi_E = 32\%$

$\Phi_{D2} = \Phi_D = 22\%$

$\Phi_{C1} = 68\%$

$\Phi_{E2} = 32\%$

2.6 Corrections

Corrections to Φ_{C1} :

(i) Effect of sheet pile No. (2) on pile No. (1) of depth d

Correction = 19 x $(D / b')^{1/2}$ x $(d + D) / b$

Where D = depth of pile (2) below the point C_1, i.e. the point at which

Interface is desired = 256.0 – 245.2 = 10.8 m

d = 256.0 – 249.5 = 6.5 m

b' = 58.5 ; b = 60 m

(+ve) Correction = 19 x $(10.8 / 58.5)^{1/2}$ x (6.5 + 10.8) / 60 =19 x 1/2.33 x 17.3/60

= 2.35%

(ii) Correction for depth ;

Correction = (78%-68%) /(257.0-249.5)x 1.0 = 10 /7.5 x 1.0 = 1.33% (+ve)

Φ_{C1} (corrected) = 68% + 2.35% + 1.33% = 71.68%.

Corrections to Φ_{E2}

(i) *Effect of sheet pile No. (1) on pile No. (2) of depth d :*

Correction = 19 x $(D / b')^{1/2}$ x $(d + D) / b$

where $D = 251.2 - 249.5 = 1.7$ m

$d = 251.2 - 245.2 = 6.0$ m

$b' = 58.5$ m

$b = 60$ m

$$\text{Correction} = 19 \times (1.7 / 58.5)^{1/2} \times \frac{(6.0 + 1.7)}{60.0} = 19 \times \frac{1}{5.86} \times \frac{7.7}{60} = 0.42\% \text{ (-ve)}$$

(ii) Correction due to thickness of floor :

Correction = (32% - 22%)/(252.7-245.2) ×1.5

= 10 /7.5 x 1.5 = 2.0% (-ve)

Φ_{E2} (Corrected) = 32% - 0.42% - 2.0% = **29.58%**

3. Design of Other Barrage Bays Portion

Taking crest level as: 258.3 m.

Condition 1 (a): High flood flow with no concentration and retrogression.

u/s water level = 263.2 m

d/s water level =262.2 m

u/s TEL =263.39 m

d/s TEL =262.39 m

$H_L = 263.39 - 262.39 = 1.0$ m.

Head, including velocity head, over the crest

= 263.39 – 258.3 = 5.09 m

Discharge intensity

$q = 1.84\,(5.09)^{3/2} = 1.84 * 11.4 = 21$ cumecs/meter.

Condition 2 (a): Pond level flow with no concentration and retrogression.

u/s water level = Pond level = 260.6 m

d/s water level = 260.20 m

u/s TEL = 260.69 m

d/s TEL = 260.29 m

$H_L = 260.69 - 260.29 = 0.4$ m

Head, including velocity head, over the crest

= 260.69 – 260.29 = 2.39 m

Discharge intensity = 1.84 $(2.39)^{3/2}$ = 1.84 * 3.69 = 6.78 cumecs/meter.

3.1 Depth of Sheet Piles from Scour

Discharge passing = 6,260 cumecs

Overall waterway = 374 meters

Average Discharge intensity = 6,260/374 = 16.8 cumecs/meter

$R = 1.35[(16.8)^2/1]^{1/3} = 1.35 * 6.6 = 9.07$ m.

Let us provide a downstream cutoff up to depth 1.5 R below the d/s water level which is 261.7 m retrogression. Hence, the R.L. of bottom of d/s cut-off

= 261.7 – 1.5 × 9.07

= 261.7 – 13.6 = 248.1 m.

Let us provide d/s cut-off up to a bottom level of 248.1 m, i.e. depth of 6.1 m.

U/s cut-off. Let us provide 1.25 *R*, i.e.

1.25 × 9.07 = 11.4 m for u/s cutoff.

Therefore, the level of bottom of u/s cutoff = 263.2 – 11.4 = 251.8 m.

Let us provide u/s cutoff up to a bottom level of 251.8 m, i.e. for a depth of 5.2 m.

3.2 Total Floor Length and Exit Gradient:

$G_E = 1/6$

Maximum Static Head = H = 260.6 – 254.2 = 6.4 m

Depth of d/s cutoff = d = 254.2 – 248.1 = 6.1 m

$G_E = (H/d) \times (1/(\pi\times\sqrt{\lambda}))$

$1/6 = (6.4/6.1) \times (1/(\pi\times\sqrt{\lambda}))$

Or $(1/(\pi\times\sqrt{\lambda})) = 1/6 \times (6.1/6.4) = 0.159$.

From Plate 11.2, value of α for a value of $(1/(\pi\times\sqrt{\lambda}))$ as 0.159 comes out to be approximately 8.0.

Therefore, $b = \alpha d = 8 \times 6.1 = 48.8$ m ; say provide $b = 49$ m.

Therefore, Balance length of 49 – 1.3 – 2.0 – 26.0 = 49 – 41.6 = 7.4 m is provided as upstream floor.

3.3 Uplift Pressures

Let us assume floor thickness as 1.0 m at u/s cutoff end and 1.5 m at d/s cutoff end.

Upstream Pile No. (1):

$b = 49$ m

$d = 5.2$ m

$1/\alpha = d/b = 5.2/49 = 0.106$

From Plate 11.1 (a)

$\phi_{E1} = 100\%$

$\phi_{C1} = 100 - \phi_E = 100 - 29 = 71\%$

$\phi_{D1} = 100 - \phi_D = 100 - 20 = 80\%$

Downstream Pile No. (2):

$d = 6.1$ m

$b = 49$ m

$1/\alpha = d/b = 6.1/49 = 0.125$

From Plate 11.1 (a)

$\phi_{C2} = 0\%$

$\phi_{E2} = \phi_E = 32\%$

$\phi_{D2} = \phi_D = 22\%$

Let us correct these pressures

$\phi_{C1} = 71\%$

$\phi_{E2} = 32\%$

Correction to ϕ_{C1}

(i) Effect of sheet pile No. (2) on Pile No. (1) of depth d

Correction = $19 \times \sqrt{(D/b')} \times [(d + D)/b]$

where $d = 256 - 251.8 = 4.2$ m

$D = 256 - 248.1 = 7.9$ m

$b' = 47.5$ m

$b = 49$ m

Correction $=19 \times \sqrt{(7.9/47.5)} \times [(4.2 + 7.9)/49]$

$=19 \times (1/2.45) \times (12.1/49) = 1.49\%$ (+ve).

(ii) Correction for depth of floor

Correction $= (80\% - 71\%)/(257 - 251.8) \times 1.0 = (9/5.2) \times 1.73\%$ (+ve)

ϕ_{C1} (corrected) $= 71\% + 1.49 + 1.73\% = 74.22\%$

Correction to ϕ_{E2}

(i) Effect of sheet pile No. (1) on Pile No. (2) of depth d

Correction $= 19 \times \sqrt{(D/b')} \times [(d + D)/b]$

where $d = 252.7 - 248.1 = 4.6$ m

$D = 252.7 - 251.8 = 0.9$ m

$b' = 47.5$ m

$b = 49$ m

Correction $=19 \times \sqrt{(0.9/47.5)} \times [(4.6 + 0.9)/49] = 0.29\%$ (-ve)

(ii) Correction due to thickness of floor

Correction $= (32\% - 22\%)/(254.2 - 248.1) \times 1.5 = 2.46\%$ (-ve)

ϕ_{E2} (corrected) $= 32 - 0.29 - 2.46 = 29.25\%$

3.4 Protection works:

1) Downstream protection

Normal scour depth

$R = 9.07$ m

$D = 2R - y = 2 \times 9.07 - (261.7 - 254.2)$

$= 18.14 - 7.5 = 10.64$ m

Provide a launching apron equal to 1.5D i.e. say 16 m in length and of thickness say 1.5m.

Let us provide C.C. blocks of size 1.2 m × 1.2 m × 0.75 m over a graded filter of 0.75 m thickness for a length equal to 1.5 D i.e. approx 16m. 13 rows of C.C. blocks of size 1.2 m × 1.2 m × 0.75 m having 10 cm gaps filled with bajri shall hence, be provided in length equal to 16.8 m.

1.Upstream protection

Normal Scour depth,R

= 9.07 m

$D = 1.5R\text{-}y$

= 1.5×9.07 – (263.2-257)

= 13.6-6.2 = 7.4 m

Provide a launching apron to thickness 1.5 m in a length = (2.25×7.4)/1.5 = 11.1m (11m)

Let us provide C.C. blocks of size 1.2 m×1.2 m×0.75 m over packed stone of 0.75m thickness for a length equal to say 1.5D i.e. 13.6m. Hence, provide 11 rows of C.C. blocks of size 1.2 m×1.2 m×0.75 m having 10 cm jhories (i.e. gaps filled with bajri), in length equal to 14.2 m.

The above design calculations including the calculation of reference levels, uplift pressures in under sluice portion, uplift pressures in barrage bay portion, section of under sluice portion, section of other barrage bay portion for has been shown in figure 16,17,18,19,20 respectively

4. VARIABLES USED

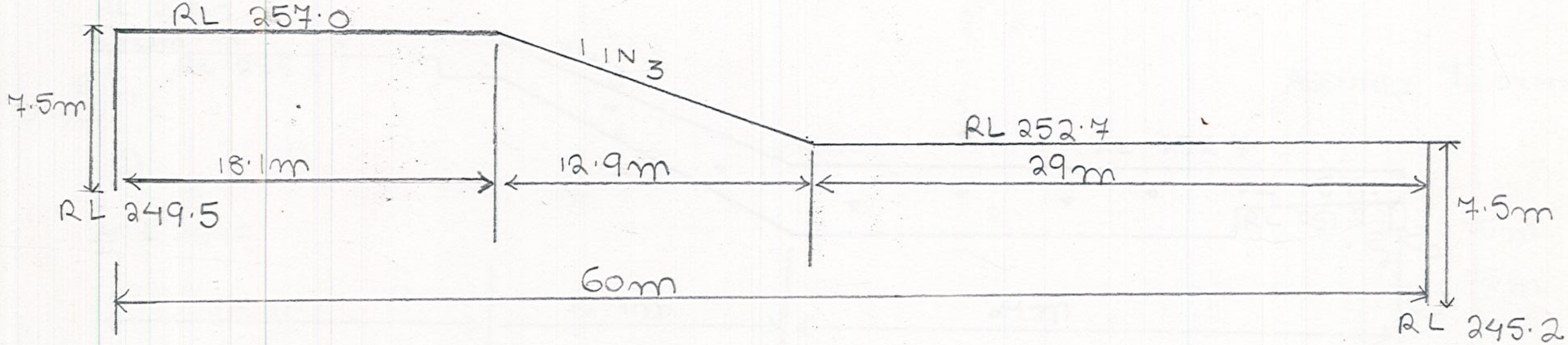
CREST LEVEL

1. *abl* = average bed level
2. *h* = height difference
3. *hbl* = height of other barrage bay

WATERWAY

4. *q* = discharge
5. *p* = wetted perimeter
6. *b1* = no of bays in undersluice portion
7. b2 = no of bays in other barrage bay

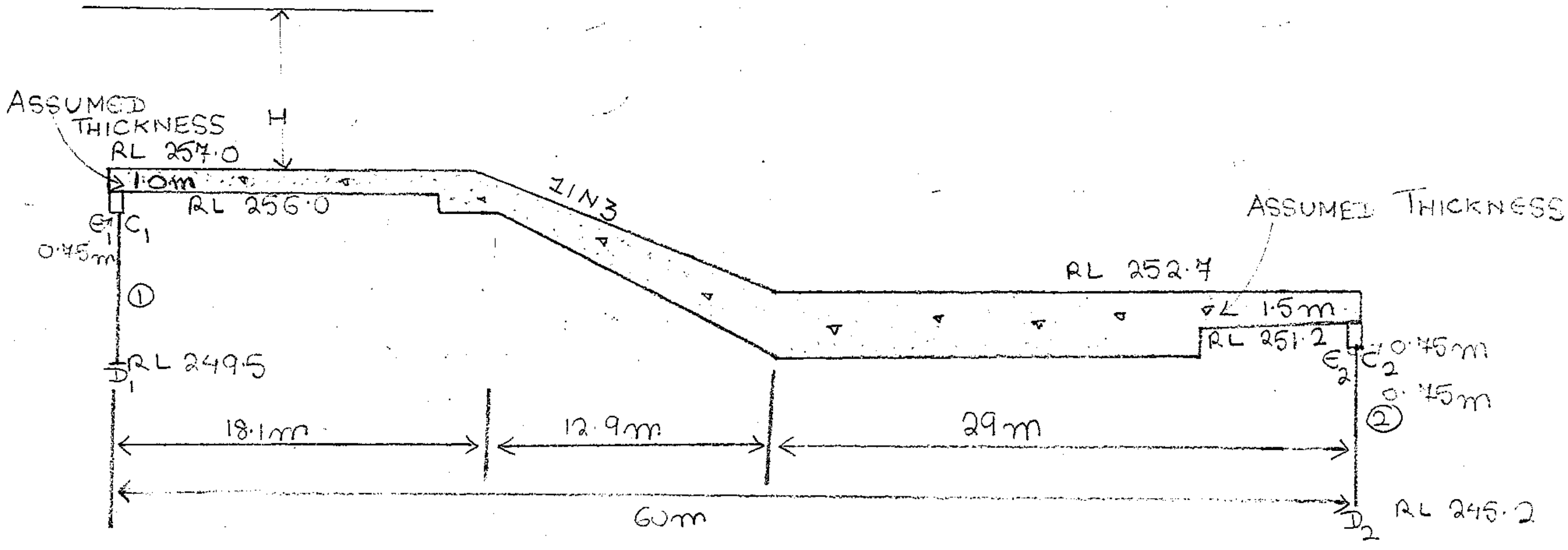
SCALE — 1:3



CALCULATION OF REFERENCE LEVELS

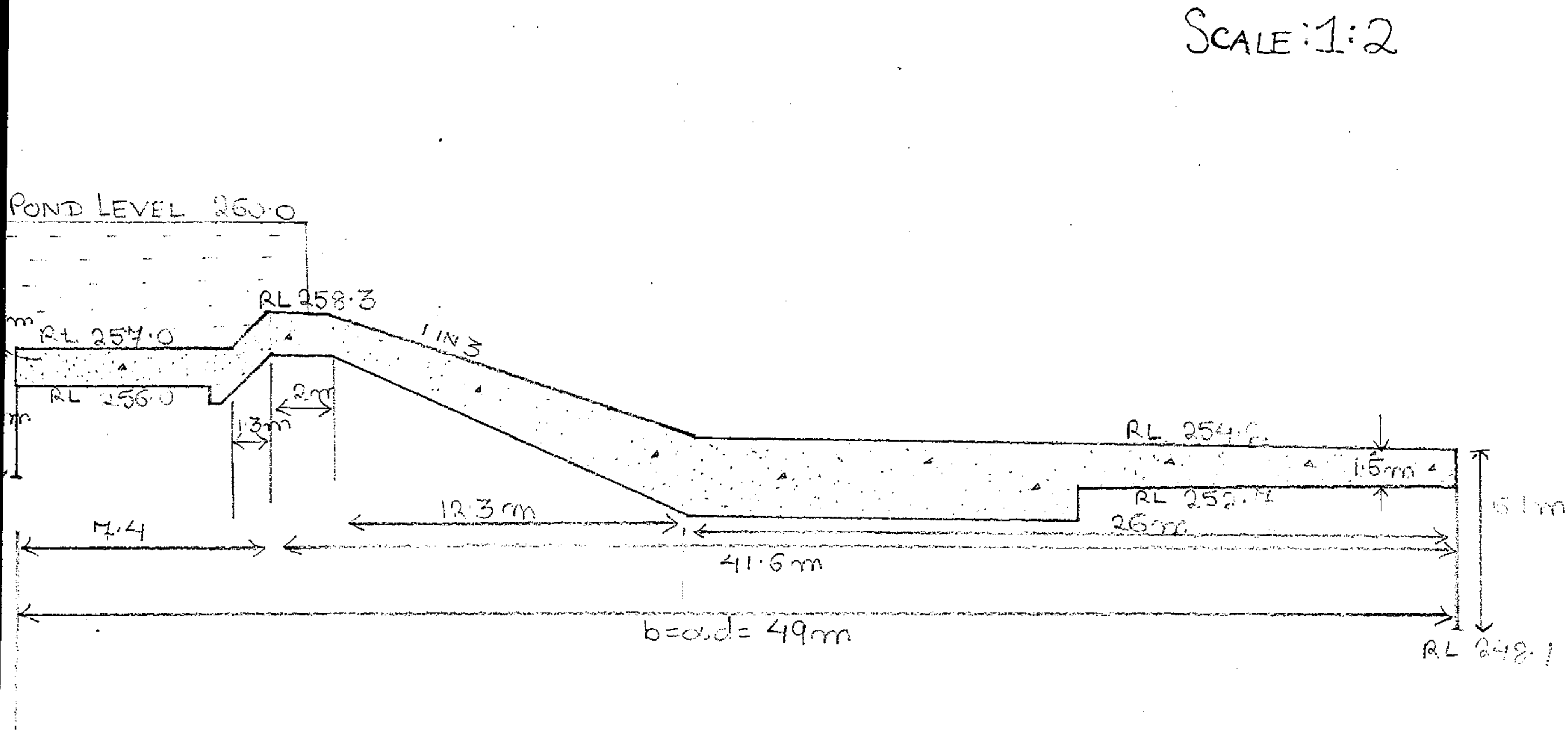
Figure : 16

SCALE : 1:3



UPLIFT PRESSURES IN UNDERSLUICE PORTION

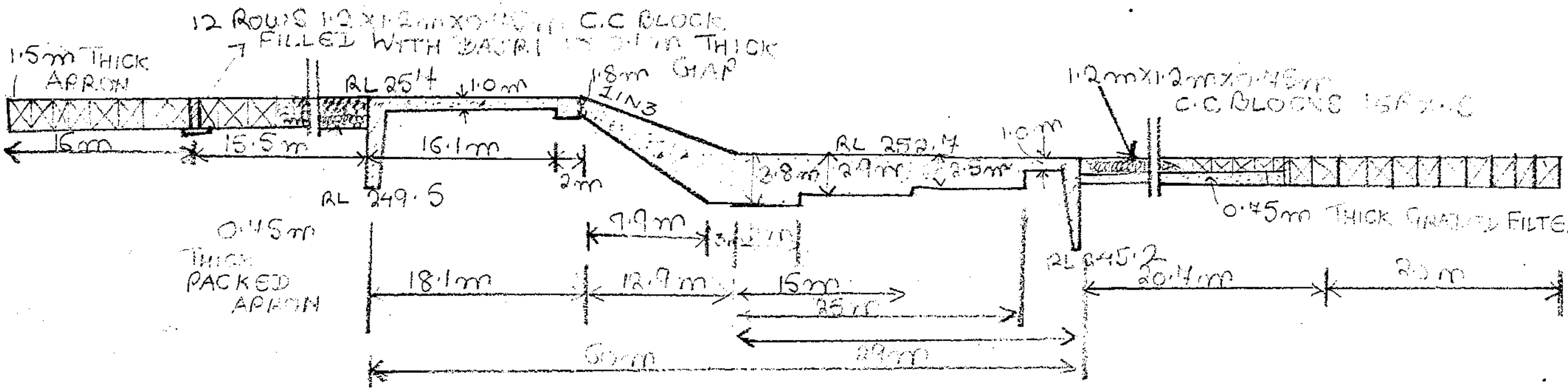
Figure : 17



UPLIFT PRESSURES IN BARRAGE BAY PORTION

Figure : 18

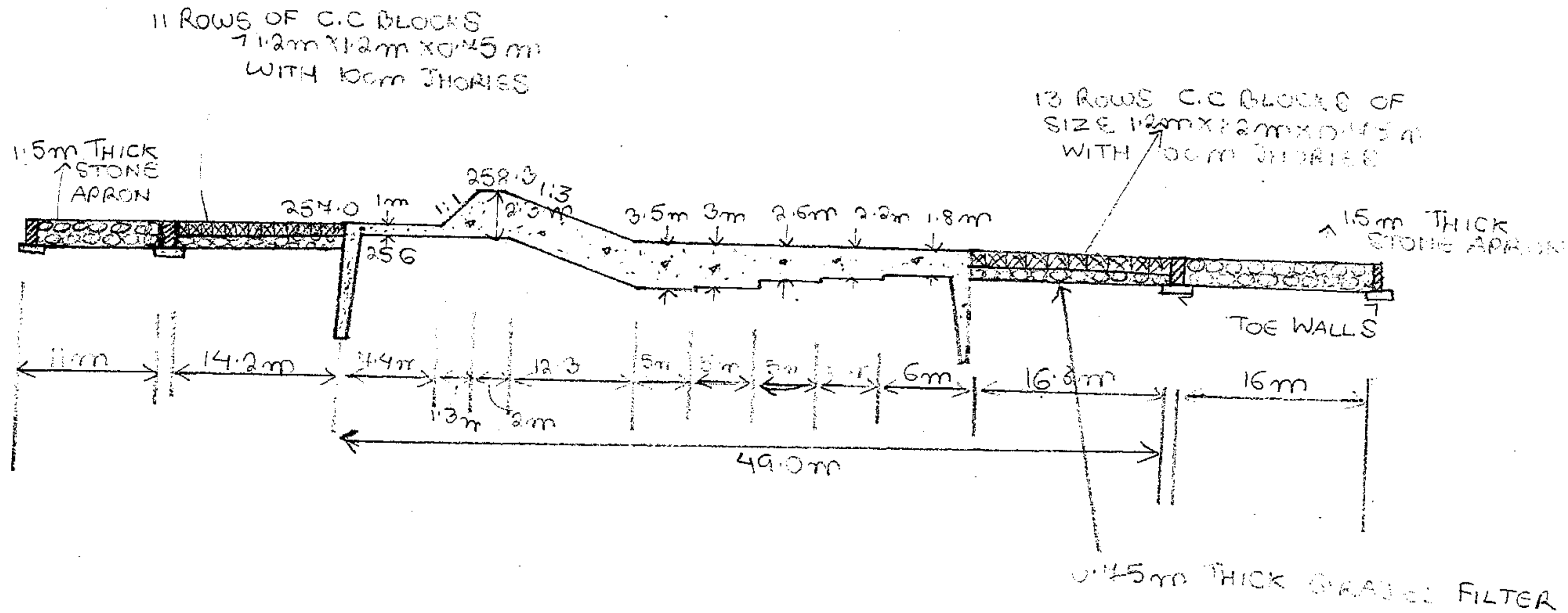
Scale: 1:5



L-SECTION OF UNDERSLUICE PORTION

Figure: 19

SCALE : 1:5



L-SECTION OF OTHER BARRAGE BAYS PORTION

Figure : 20

8. *p1* = no of piers in undersluice portion

9. *p2* = no of piers in other barrage bay

10. *l1* = length of bays in undersluice portion

11. *l2* = length of piers in undersluice portion

12. *l3* = length of bays in other barrage bay

13. *l4* = length of piers in other barrage bay

14. *w1* = overall waterway in undersluice portion

15. *w2* = overall waterway in other barrage bay

16. *dw* = length of divide wall

17. *lf* = looseness factor

18. *ow* = overall waterway

CHECK

19. *dshfl* =HFL (before barrage construction)

20. *aff* = net permissible afflux

21. *ushfl* = upstream HFL

22. *adi* = average discharge intensity

23. *sd* = Scour Depth

24. *voa* = velocity of approach

25. *vh* = velocity head

26. *ustel1* = upstream TEL

27. *houc* = Head over the undersluice crest

28. *hoco* = Head over the crest of the other barrage bays

29. *dpu* = discharge passing through undersluice

30. *dpo* = discharge passing through other barrage bay

31. *tod* = total discharge

UNDERSLUICE PORTION

32. *dstel1* = downstream tel

33. *hl* = head loss

34. *dip* = discharge intensity between piers

35. *pl* = pond level
36. *hocu* = head over the crest of undersluices
37. *hocob* = head over the crest of other barrage bay
38. *dpu1* = discharge passing through undersluice
39. *dpo1* = discharge passing through other barrage bay
40. *tod1* = total discharge
41. *sd1* = normal scour depth
42. *voa1* = velocity of approach
43. *vh1* = velocity head
44. *ustel2* = upstream TEL
45. *dshfl2* = value of DS HFL from state discharge curve
46. *dstel2* = downstream TEL
47. *hl1* = head loss
48. *dip1* = discharge intensity between piers
49. *ad12* = average discharge intensity
50. *sd2* = scour depth
51. *dshfl3* = downstream HFL
52. *rl0* = RL of the bottom D/S cut off
53. *d* = depth of D/S cut off
54. *rl1* = average bed level of the river
55. *rl2* = U/S cut off bottom RL
56. *d1* = depth of U/S cut off
57. *ge* = exit gradient
58. *msh* = maximum static head
59. *un* = value of constatnt
60. *alpha* = value from plate
61. *b* = total length
62. *alpha1* = 1/ alpha
63. *pe1* = φe1
64. *pe0* = φe0
65. *pc1* = φc1

66. *pd1* = φd1

67. *pd0* = φd0

68. *pc2* = φc2

69. *pe2* = φe2

70. *pd2* = φd2

71. *nrl1* = reference level 1

72. *nrl2* = reference level 2

73. *nrl3* = reference level 3

74. *nrl4* = reference level 4

75. *nrl5* = reference level 5

76. *nrl6* = reference level 6

77. *pt* = pile thickness

78. *cor1* = correction in φc1

79. *cod0* = D

80. *cod1* = d

81. *b3* = b'

82. *cor2* = correction in φc1

83. *cpc1* = corrected φc1

84. *cor3*= correction in φe2

85. *cod2* = D

86. *cod3* = d

87. *b1* = b'

88. *cor4* = correction on φe2

89. *cpe2* = corrected φe2

90. *pwd* = D

91. *pwl* =length of launching apron

92. *pwlt* =thickness of launching apron

93. *pifl* =ength of inverted filter

94. *pwud* =D

95. *pwut* = thickness of launching apron

96. *pwul* =length of launching apron

5. OTHER BARRAGE BAY PORTION

97. odi =discharge intensity
98. *phoc* = head including velocity head over the crest
99. *odi1* =discharge intensity
100. *odi2* = discharge intensity
101. *osd* =normal scour depth
102. *dshfl3* =downstream HFL after retrogression
103. *rldsco* =RL of the bottom of D/S cutoff
104. *dsco* =depth
105. *usco*=U/S cut off bottom RL
106. *dusco* =depth of U/S cutoff
107. *msh1* =maximum static head
108. *un1* =value of constant
109. *jmp* =enter the level were jump is formed

4.2 PROGRAM OUTPUT

```
CREST LEVELS

Enter the average bed level of the river:
257
Enter the height difference of the other barrage:
1.3
The crest level of the other barrage bay is:
258.3m
```

1

```
WATERWAY

The following is calculated by Lacey's Wetted Perimeter eq
Enter the high flood discharge:
8100
The wetted perimeter is:        427.5m
```

2

```
15-20% of the discharge passes through the undersluices and
the rest through the other barrage bays.
The waterway is calculated as:


UNDERSLUICE PORTION
5 bays  of 15m each =75m
4 piers of 2.5m each =10m
               Overall Waterway=85m


OTHER BARRAGE WAYS
27 bays  of 12m each =324
25 piers of 2m each =50
               Overall Waterway=374

Let the divide wall be 3 m thick
       Total Overall Waterways=462
               Looseness factor=1.080702
```

3

```
CHECK
The above waterway will now be checked for the
maximum flood with a maximum given afflux of 1m



Enter HFL(before barrage construction)
262.2
Enter permissible afflux
1
U/S HFL                                                263.2m
Average discharge intensity                            17.532468m^3/s/m
Scour depth                                            9.198322m
Velocity of Approach                                   1.906051m
Velocity Head                                          0.185359m
U/S TEL                                                263.385359m
Head over the undersluice crest                        6.385359m
Head over the crest of the other barrage bays          5.085359m
Discharge passing through the undersluice              1882.104183m^3/s
Discharge passing through other barrage ways           6257.229909m^3/s
Total Discharge                                        8139.334092m^3/s
The waterway and crest level are in order
```

4

```
UNDERSLUIE PORTION
A1.High Flood Condition
Assuming no concentration and retrogression
U/S TEL                                        263.385359m
D/S TEL                                        262.385359m
Head Loss                                      1m
Discharge Intensity between piers              27.430067m^3/s
```

5

```
2.Pond Level Condition
Assuming no concentration and retrogression
Enter the pond level
260.6

Head over the crest of undersluices                    3.6m

Head over the crest of other barrage bays              2.3m

Enter the value of D/S HFL from state discharge curve
260.2
```

6

```
260.2
Discharge passing through the undersluice            829.088487m^3/s
Discharge passing through other barrage bays         1999.765861m^3/s
Total Discharge                                      2828.854348m^3/s
Average Discharge Intensity                          6.123061m^3/s
Normal Scour Depth                                   4.545721m
Velocity of Approach                                 1.346995m/s
Velocity Head                                        0.092571m
U/S TEL                                              260.692571m
D/S TEL                                              260.292571m
Head Loss                                            0.4m
Discharge Intensity between piers                    11.611884m^3/s
```

7

```
B.Depth of sheet pile line from scour considerations
Enter the value of retrogression
0.5
Enter average bed level of the river(D/S)(from figure)
252.7
Total discharge through undersluices                         1882.104183m^3/s
Overall waterway of undersluices                             85m
Average discharge intensity                                  22.142402m^3/s/m
Depth of Scour                                               10.755593m
D/S HFL (after retrogression)                                261.7m
Reference level bottom of D/S cut-off                        245.566611m
Depth of D/S cut-off                                         7.133389m
U/S cut-off bottom RL                                        249.755509m
Depth of U/S cut-off                                         7.244491m
```

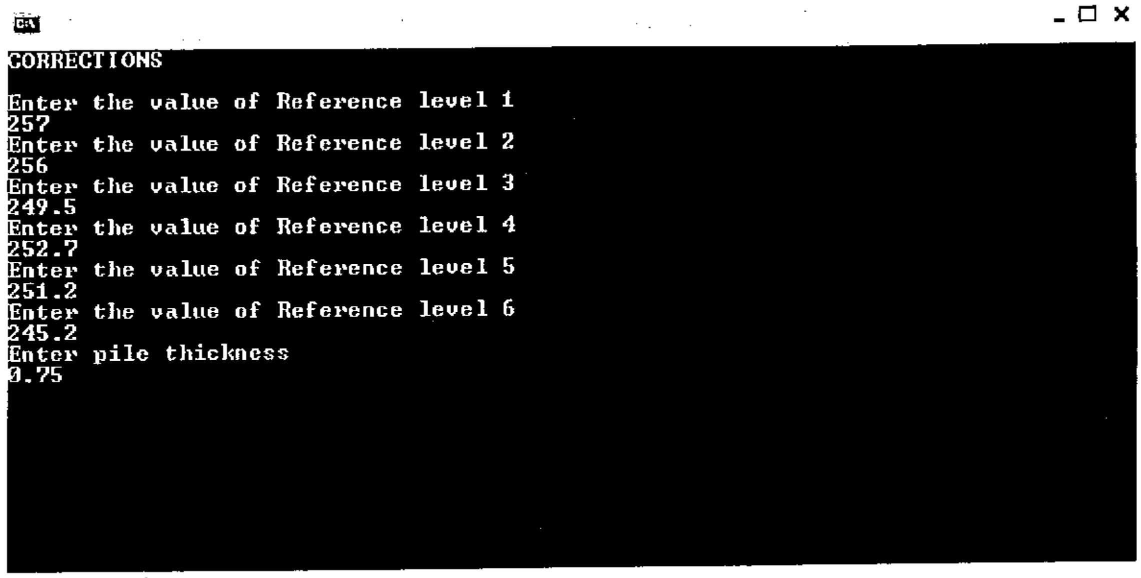
<u>8</u>

```
C.Total Floor length and exit gradient

Enter exit gradient
0.1667
Maximum Static Head                              7.9m

1/π√α=0.152868
Enter the corresponding value ofα
8
total length                             57.955925m
```

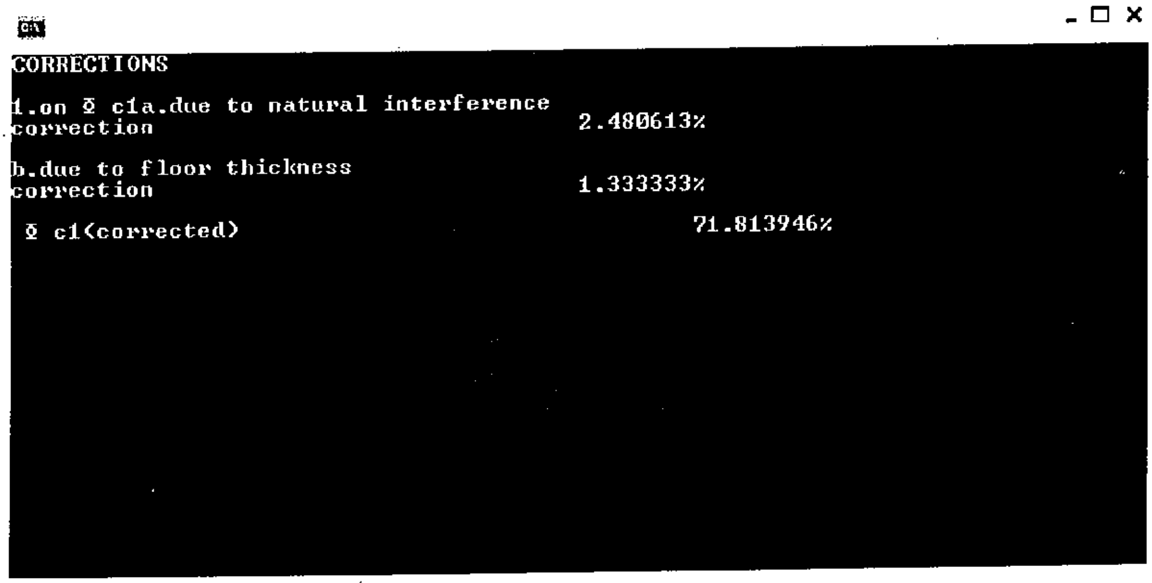
9

```
Depth of U/S cut-off                             7.244491m

1/α=                                             0.125

Enter the value of Φ e0 from plate
32
Enter the value of Φ e1 from plate
100
Enter the value of Φ d from plate
22
Value of Φ e1 is                                 100%

Value of Φ c1 is                                 68%

Value of Φ d1 is                                 78%

D/S pile no.2

Value of Φ c2 is                                 0%

Value of Φ e2 is                                 32%

Value of Φ d2 is                                 22%
```

<u>10</u>


CORRECTIONS
Enter the value of Reference level 1
257
Enter the value of Reference level 2
256
Enter the value of Reference level 3
249.5
Enter the value of Reference level 4
252.7
Enter the value of Reference level 5
251.2
Enter the value of Reference level 6
245.2
Enter pile thickness
0.75

11


CORRECTIONS
1.on Σ c1a.due to natural interference correction
2.480613%
b.due to floor thickness correction
1.333333%
Σ c1(corrected)
71.813946%

12

```
C.Total Floor length and exit gradient

Enter exit gradient
0.1667
Maximum Static Head                                 7.9m

1/π√α=0.152868
Enter the corresponding value ofα
8
total length                                57.955925m
```

13

```
Depth of U/S cut-off                                7.244491m
                                                    0.125
1/α=

Enter the value of Φ e0 from plate
32
Enter the value of Φ e1 from plate
100
Enter the value of Φ d from plate
22                                                  100%
Value of Φ e1 is
                                                    68%
Value of Φ c1 is
                                                    78%
Value of Φ d1 is

D/S pile no.2
                                                    0%
Value of Φ c2 is
                                                    32%
Value of Φ e2 is
                                                    22%
Value of Φ d2 is
```

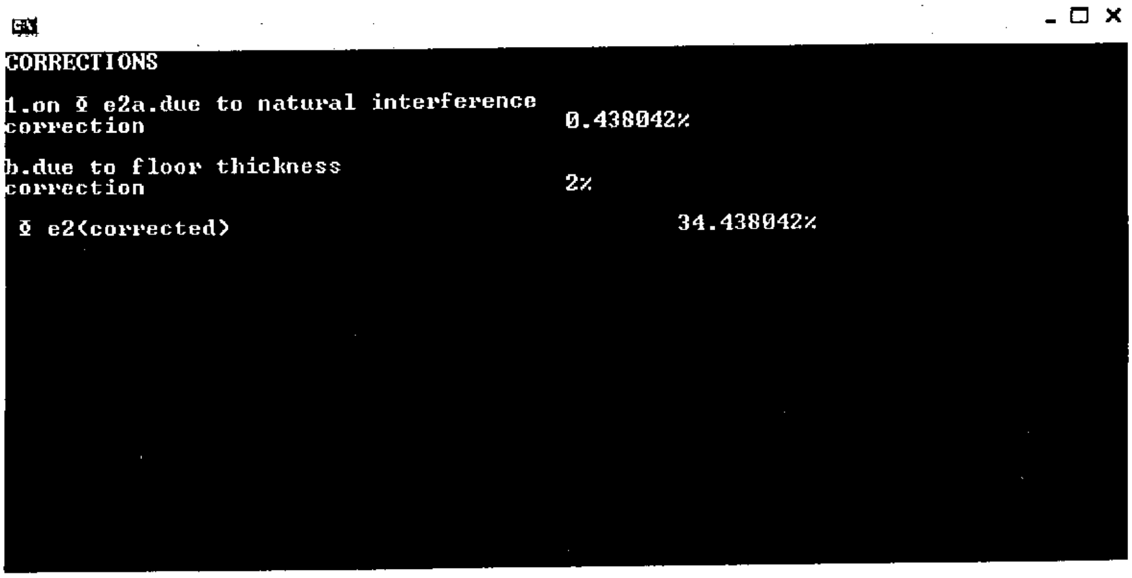
14

```
CORRECTIONS

Enter the value of Reference level 1
257
Enter the value of Reference level 2
256
Enter the value of Reference level 3
249.5
Enter the value of Reference level 4
252.7
Enter the value of Reference level 5
251.2
Enter the value of Reference level 6
245.2
Enter pile thickness
0.75
```

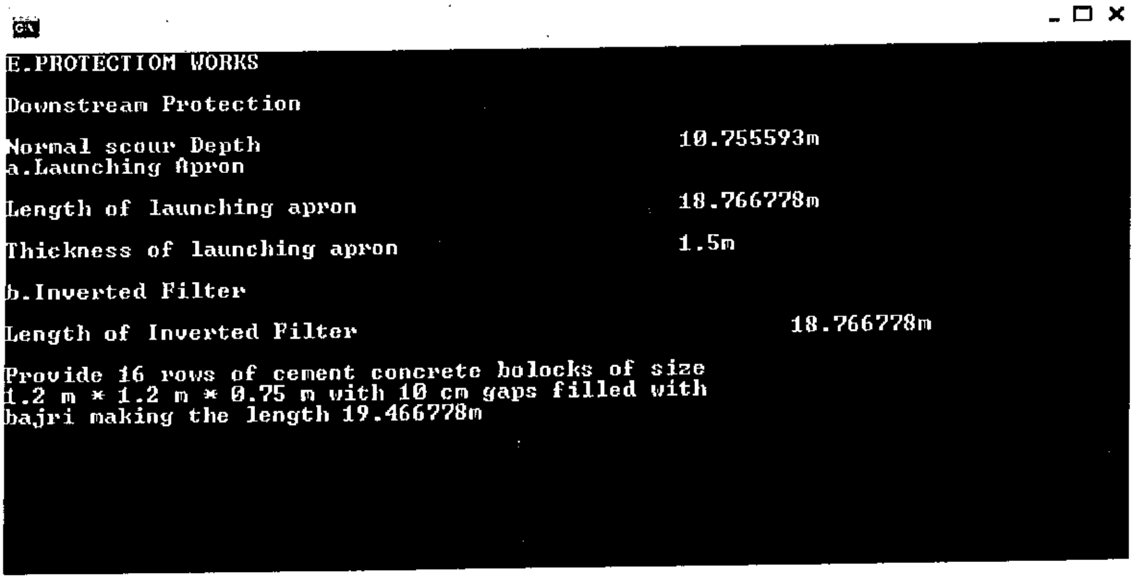
15

```
CORRECTIONS

1.on Φ c1a.due to natural interference
correction                                  2.480613%

b.due to floor thickness
correction                                  1.333333%

 Φ c1<corrected>                                    71.813946%
```

16


CORRECTIONS
1.on Φ e2a.due to natural interference correction
0.438042%
b.due to floor thickness correction
2%
Φ e2(corrected)
34.438042%

17


E.PROTECTIOM WORKS
Downstream Protection
Normal scour Depth
10.755593m
a.Launching Apron
Length of launching apron
18.766778m
Thickness of launching apron
1.5m
b.Inverted Filter
Length of Inverted Filter
18.766778m
Provide 16 rows of cement concrete bolocks of size 1.2 m * 1.2 m * 0.75 m with 10 cm gaps filled with bajri making the length 19.466778m

18

```
Upstream Protection
Launching apron thickness is assumed to be                     1.5m
Length of launching apron                                      14.900083m
Provide cement concrete blocks of size 1.2 m *1.2 m*0.75 m
over packed apron of 0.75 m thickness for a length equal
to      14.400083m
```

19

```
A
1.High flood flow with no concentration and retrogression
Head Loss                                                      1m
Head including  velocity head over the crest                   5.085359m
Discharge Intensity                                            21.100862m^3/s/m
2.Pond level flow with no concentration and retrogression
U/S Pond level                                                 260.6m
D/S Pond level                                                 260.2m
U/S TEL                                                        260.692571m
D/S TEL                                                        260.292571m
Head Loss                                                      0.4m
Head,including velocity head,over the crest                    2.392571m
Discharge intensity                                            6.809498m^3/s/m
```

20

```
B.Depth of sheet piles from scour
Total Discharge                                        6257.229909m^3/s
Overall Waterway for other barrage portion             374m
Average Discharge Intensity                            16.730561m^3/s/m
Normal Scour Depth                                            8.914271m
D/S HFL(after retrogression)                    261.7m
Enter level at which jump is formed
254.2
RL of bottom of D/S cut-off                     248.328594m
Depth (D/S cut-off)                                           5.871406m
U/S cut-off bottom RL                                  252.057162m
Depth of U/S cut-off                                   4.942838m
```

21


```
B.Depth of sheet piles from scour
Total Discharge                                        6257.229909m^3/s
Overall Waterway for other barrage portion             374m
Average Discharge Intensity                            16.730561m^3/s/m
Normal Scour Depth                                            8.914271m
D/S HFL(after retrogression)                    261.7m
Enter level at which jump is formed
254.2
RL of bottom of D/S cut-off                     248.328594m
Depth (D/S cut-off)                                           5.871406m
U/S cut-off bottom RL                                  252.057162m
Depth of U/S cut-off                                   4.942838m
```


22

```
D.Uplift Pressures
U/S Pile no. 1
Total length:                                   46.971246m
Depth of U/S cut-off                            5.871406m
1/α=                                            0.125
Enter the value of Φ e0 from plate
29
Enter the value of Φ e1 from plate
100
Enter the value of Φ d from plate
20
```

23

```
Depth of U/S cut-off                            5.871406m
1/α=                                            0.125
Enter the value of Φ e0 from plate
29
Enter the value of Φ e1 from plate
100
Enter the value of Φ d from plate
20
Value of Φ e1 is                                100%
Value of Φ c1 is                                71%
Value of Φ d1 is                                80%
D/S pile no.2
Value of Φ c2 is                                0%
Value of Φ e2 is                                29%
Value of Φ d2 is                                20%
```

24

```
CORRECTIONS

Enter the value of Reference level 1
257
Enter the value of Reference level 2
256
Enter the value of Reference level 3
251.8
Enter the value of Reference level 4
254.2
Enter the value of Reference level 5
252.7
Enter the value of Reference level 6
248.1
Enter pile thickness
0.75_
```

25

```
CORRECTIONS

1.on Σ c1a.due to natural interference      2.040103%
correction

b.due to floor thickness                    1.730769%
correction
                                                      74.770872%
 Σ c1(corrected)

_
```

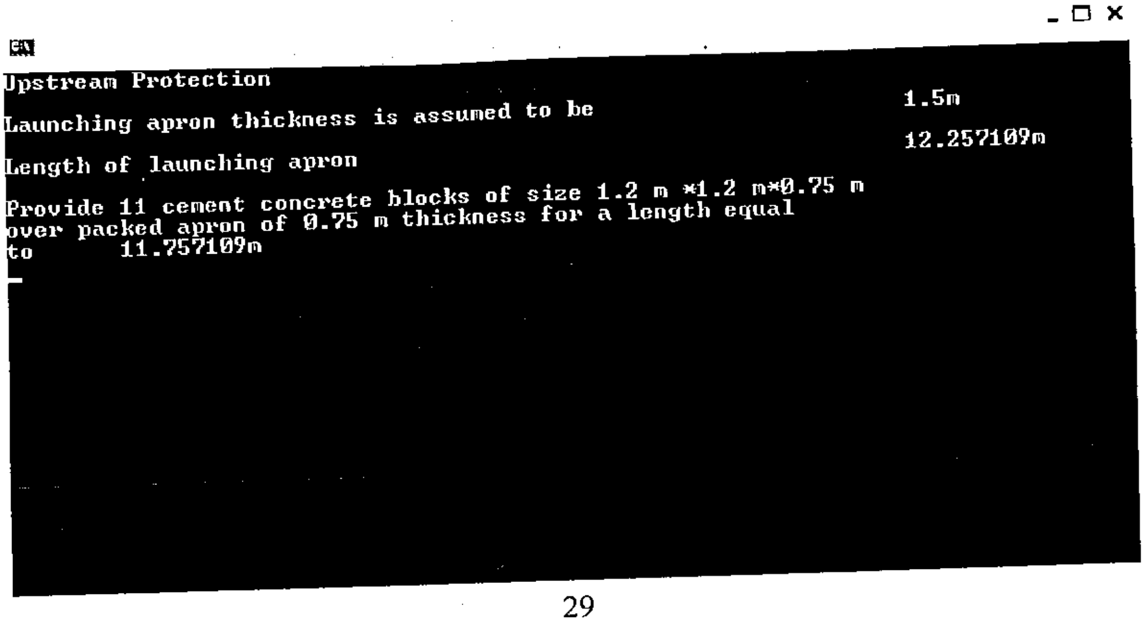
26

```
CORRECTIONS

1.on Φ e2a.due to natural interference
correction                                    0.312995%

b.due to floor thickness
correction                                    2.213115%

 Φ e2(corrected)                                      31.526109%
```

27

```
E.PROTECTIOM WORKS

Downstream Protection

Normal scour Depth                                   8.914271m
a.Launching Apron

Length of launching apron                            15.492812m

Thickness of launching apron                         1.5m

b.Inverted Filter

Length of Inverted Filter                                    15.492812m

Provide 13 rows of cement concrete bolocks of size
1.2 m * 1.2 m * 0.75 m with 10 cm gaps filled with
bajri making the length 16.192812m
```

28


Upstream Protection
Launching apron thickness is assumed to be 1.5m
Length of launching apron 12.257109m
Provide 11 cement concrete blocks of size 1.2 m *1.2 m*0.75 m
over packed apron of 0.75 m thickness for a length equal
to 11.757109m

29

CONCLUSION

The software developed by us satisfactorily designs the following components with user defined input variables:

1. Crest levels
2. Length of waterway for barrage and undersluice portion,
3. Total design for the undersluice portion, and other barrage bay portion for high flood level condition and the pond level condition,
4. Depth of sheet piles under scour considerations,
5. Total floor length for safe exit gradient,
6. Protection works on the upstream and the downstream side of the barrage.

Though the project does not put forward the design of the intermediate pile cut-off, but still the software holds the capacity of giving design results satisfying any designer.

Bibliography

REFERENCES

1. Garg, S.K., '*Irrigation Engineering and hydraulic structures*'. Khanna Publishers, 2004

2. Punmia, B.C., *Irrigation and Water Power Engineering*. Lakshmi Publications, Delhi, 2002

3. Vashney, R.S., S.C. Gupta and R.L. Gupta. '*Theory and design of Irrigation Structures*'. Lakshmi Publications, 1993.

4. www.npccindia.com

5. www.hccindia.com

6. www.pslover.com

7. www.kirupa.com

8. www.index.phtml

9. www.encarta.msn.com

APPENDIX A

Source Code

```
#include<iostream.h>
#include<stdio.h>
#include<conio.h>
#include<math.h>
void main()
{
    //crestlevels
    double abl,h,hbl,q,p,b1,b2,p1,p2,l1,l2,l3,l4,w1,w2,dw,ow,lf,dshfl,aff,ushfl,adi;
    double sd,voa,vh,ustel1,houc,hoco,dpu,dpo,tod,i,dstel1,hl,dip,pl,hocu,hocob;
    double dpu1,dpo1,tod1,adi1,sd1,voa1,vh1,ustel2,dshfl2,dstel2,hl1,dip1;
    double adi2,sd2,dshfl3,rl0,retro,rl1,d,rl2,d1,ge,msh,un,alpha,b;
    double alpha1,pe1,pe0,pc1,pd1,pd0,pc2,pe2,pd2,nrl1,nrl2,nrl3,nrl4,nrl5,nrl6;

    cout<<"C.Total floor length and exit gradient\n\n";
    cout<<"Exit Gradient\t\t\t\t\t"<<ge<<"\n\n";
    msh1=pl-jmp;
    cout<<"Maximum static head\t\t\t\t"<<msh1<<"m\n";
    un1=(ge*dsco)/msh1;
    printf("1/%c%c%c",227,251,166);
    cout<<"="<<un1;
    cout<<"\nEnter the corresponding value of";
    printf("%c\n",224);
    cin>>alpha2;
    b=alpha2*dsco;
    cout<<"total length\t\t\t\t"<<b<<"m\n";
```

```
clrscr();
getch();
cout<<"D.Uplift Pressures\n\n";
cout<<"U/S Pile no. 1\n\n";
cout<<"Total length:\t\t\t\t\t"<<b<<"m\n\n"; double
pt,cor1,cod0,cod1,b3,cor2,cor3,cod2,cod3,cor4,cpc1,cpe2,div1,div2;
double pwd,pwl,pwlt,pifl,pwud,pwut,pwul,odi,odi1,phoc,odi2,osd,rldsco,dsco;
double usco,dusco,jmp,un1,msh1,alpha2;
cout<<"CREST LEVELS\n\n\n";
cout<<"Enter the average bed level of the river:\n";
cin>>abl;
cout<<"Enter the height difference of the other barrage:\n";
cin>>h;
cout<<"The crest level of the other barrage bay is:\n";
hbl=h+abl;
cout<<hbl<<"m\n";
getch();
clrscr();
//waterway
cout<<"WATERWAY\n\n\n";
cout<<"The following is calculated by Lacey's Wetted Perimeter eq\n";
cout<<"Enter the high flood discharge:\n";
cin>>q;
cout<<"The wetted perimeter is:\t";
p=((4.75)*pow(q,0.5));
cout<<p<<"m\n";
getch();
clrscr();
cout<<"Let us assume a waterway of 1.2 p by trial such that about\n";
cout<<"15-20% of the discharge passes through the undersluices and\n";
cout<<"the rest through the other barrage bays.\n";
```

```
cout<<"The waterway is calculated as:\n";
//undersluice portion
cout<<"\n\n\n\n";
cout<<"UNDERSLUICE PORTION\n";
b1=5,l1=15,p1=4,l2=2.5,b2=27,l3=12,p2=25,l4=2;
cout<<b1<<" bays  of "<<l1<<"m each ="<<b1*l1<<"m\n";
cout<<p1<<" piers of "<<l2<<"m each ="<<p1*l2<<"m\n";
w1=b1*l1+p1*l2;
cout<<"            Overall Waterway="<<w1<<"m\n";
//other barrage ways
cout<<"\n\n\n\n";
cout<<"OTHER BARRAGE WAYS\n";
cout<<b2<<" bays  of "<<l3<<"m each ="<<b2*l3<<"\n";
cout<<p2<<" piers of "<<l4<<"m each ="<<p2*l4<<"\n";
w2=b2*l3+p2*l4;
cout<<"            Overall Waterway="<<w2<<"\n";
cout<<"\n\n";
cout<<"Let the divide wall be 3 m thick\n";
dw=3;
ow=w1+w2+dw;
cout<<"      Total Overall Waterways="<<ow<<"\n";
//looseness factor
lf=(ow/p);
cout<<"            Looseness factor="<<lf<<"\n";
getch();
clrscr();
//check
cout<<"CHECK\n";
cout<<"The above waterway will now be checked for the\n";
cout<<"maximum flood with a maximum given afflux of 1m\n";
cout<<"\n\n\n\n";
```

```
cout<<"Enter HFL(before barrage construction)\n";
cin>>dshfl;
cout<<"Enter permissible afflux\n";
cin>>aff;
ushfl=dshfl+aff;
cout<<"U/S HFL\t\t\t\t\t\t"<<ushfl<<"m\n";
//Average discharge intensity
adi=q/ow;
cout<<"Average discharge intensity\t\t\t"<<adi<<"m^3/s/m\n";
//Scour depth
sd=1.35*pow(adi,0.67);
cout<<"Scour depth\t\t\t\t\t"<<sd<<"m\n";
//Velocity of Approach
voa=adi/sd;
cout<<"Velocity of Approach\t\t\t\t"<<voa<<"m\n";
//Velocity Head
vh=(pow(voa,2)/19.6);
cout<<"Velocity Head\t\t\t\t\t"<<vh<<"m\n";
ustel1=ushfl+vh;
cout<<"U/S TEL\t\t\t\t\t\t"<<ustel1<<"m\n";
//HEAD(over the undersluice crest)
houc=ustel1-abl;
cout<<"Head over the undersluice crest\t\t\t"<<houc<<"m\n";
//HEAD(over the crest of the other barrage bays)
hoco=ustel1-hbl;
cout<<"Head over the crest of the other barrage bays\t"<<hoco<<"m\n";
//Discharge passing through the undersluice
dpu=1.7*(b1*l1-0.1*b1*2*houc)*pow(houc,1.5);
cout<<"Discharge passing through the undersluice\t"<<dpu<<"m^3/s\n";
//Discharge passing through other barrage bays
dpo=1.84*(b2*l3-0.1*b2*2*hoco)*pow(hoco,1.5);
```

```
cout<<"Discharge passing through other barrage ways\t"<<dpo<<"m^3/s\n";
tod=dpu+dpo;
cout<<"Total Discharge\t\t\t\t\t"<<tod<<"m^3/s\n";
if(tod>q)
{
        cout<<"The waterway and crest level are in order\n";
        i=1;
}
else
{
        cout<<"The waterway and crest level are not in order\n";
        i=0;
}
getch();
clrscr();
if(i!=0)
//MAIN UNDERSLUICE PORTION
{
cout<<"UNDERSLUIE PORTION\n";
cout<<"A";
cout<<"1.High Flood Condition\n";
cout<<"Assuming no concentration and retrogression\n";
ustel1=dshfl+aff+vh;
dstel1=dshfl+vh;
hl=ustel1-dstel1;
cout<<"U/S TEL\t\t\t\t\t"<<ustel1<<"m\n";
cout<<"D/S TEL\t\t\t\t\t"<<dstel1<<"m\n";
cout<<"Head Loss\t\t\t\t"<<hl<<"m\n";
dip=1.7*pow(houc,1.5);
cout<<"Discharge Intensity between piers\t"<<dip<<"m^3/s\n";
getch();
```

```
clrscr();
cout<<"2.Pond Level Condition\n";
cout<<"Assuming no concentration and retrogression\n";
cout<<"Enter the pond level\n";
cin>>pl;
hocu=pl-abl;
hocob=pl-hbl;
cout<<"\nHead over the crest of undersluices\t\t"<<hocu<<"m\n\n";
cout<<"Head over the crest of other barrage bays\t"<<hocob<<"m\n\n";
dpu1=1.7*(b1*l1-0.1*b1*2*hocu)*pow(hocu,1.5);
dpo1=1.84*(b2*l3-0.1*b2*2*hocob)*pow(hocob,1.5);
tod1=dpu1+dpo1;
adi1=tod1/ow;
sd1=1.35*pow(adi1,0.67);
voa1=adi1/sd1;
vh1=pow(voa1,2)/19.6;
ustel2=pl+vh1;
cout<<"Enter the value of D/S HFL from state discharge curve\n";
cin>>dshfl2;
dstel2=dshfl2+vh1;
hl1=ustel2-dstel2;
dip1=1.7*pow(hocu,1.5);
cout<<"\nDischarge passing through the undersluice\t"<<dpu1<<"m^3/s\n\n";
cout<<"Discharge passing through other barrage
bays\t"<<dpo1<<"m^3/s\n\n";
cout<<"Total Discharge\t\t\t\t\t"<<tod1<<"m^3/s\n\n";
cout<<"Average Discharge Intensity\t\t\t"<<adi1<<"m^3/s\n\n";
cout<<"Normal Scour Depth\t\t\t\t"<<sd1<<"m\n\n";
cout<<"Velocity of Approach\t\t\t\t"<<voa1<<"m/s\n\n";
cout<<"Velocity Head\t\t\t\t\t"<<vh1<<"m\n\n";
cout<<"U/S TEL\t\t\t\t\t\t"<<ustel2<<"m\n\n";
```

```
cout<<"D/S TEL\t\t\t\t\t\t"<<dstel2<<"m\n\n";
cout<<"Head Loss\t\t\t\t\t"<<hl1<<"m\n\n";
cout<<"Discharge Intensity between piers\t\t"<<dip1<<"m^3/s\n\n";
getch();
clrscr();
cout<<"B.Depth of sheet pile line from scour considerations\n\n";
cout<<"Enter the value of retrogression\n";
cin>>retro;
cout<<"Enter average bed level of the river(D/S)(from figure)\n";
cin>>rl1;
cout<<"Total discharge through undersluices\t\t\t"<<dpu<<"m^3/s\n\n";
cout<<"Overall waterway of undersluices\t\t\t"<<w1<<"m\n\n";
adi2=dpu/w1;
cout<<"Average discharge intensity\t\t\t\t"<<adi2<<"m^3/s/m\n\n";
sd2=1.35*pow(adi2,0.67);
cout<<"Depth of Scour\t\t\t\t\t\t"<<sd2<<"m\n\n";
dshfl3=dshfl-retro;
cout<<"D/S HFL (after retrogression)\t\t\t\t"<<dshfl3<<"m\n\n";
rl0=dshfl3-(1.5*sd2);
cout<<"Reference level bottom of D/S cut-off\t\t\t"<<rl0<<"m\n\n";
d=rl1-rl0;
cout<<"Depth of D/S cut-off\t\t\t\t\t"<<d<<"m\n\n";
rl2=ushfl-(1.25*sd2);
cout<<"U/S cut-off bottom RL\t\t\t\t\t"<<rl2<<"m\n\n";
d1=abl-rl2;
cout<<"Depth of U/S cut-off\t\t\t\t\t"<<d1<<"m\n\n";
getch();
clrscr();
cout<<"C.Total Floor length and exit gradient\n\n";
cout<<"Enter exit gradient\n";
cin>>ge;
```

```
msh=pl-rl1;
un=(d1*ge)/msh;
cout<<"Maximum Static Head\t\t\t\t"<<msh<<"m\n\n";
printf("1/%c%c%c",227,251,166);
cout<<"="<<un;
cout<<"\nEnter the corresponding value of";
printf("%c\n",224);
cin>>alpha;
b=alpha*d1;
cout<<"total length\t\t\t\t"<<b<<"m\n";
getch();
clrscr();
cout<<"D.Uplift Pressures\n\n";
cout<<"U/S Pile no. 1\n\n";
cout<<"Total length:\t\t\t\t\t"<<b<<"m\n\n";
cout<<"Depth of U/S cut-off\t\t\t\t"<<d1<<"m\n\n";
alpha1=d1/b;
printf("1/%c",224);
cout<<"=\t\t\t\t\t\t"<<alpha1<<"\n\n";
cout<<"Enter the value of";
printf(" %c",232);
cout<<" e0 from plate\n";
cin>>pe0;
cout<<"Enter the value of";
printf(" %c",232);
cout<<" e1 from plate\n";
cin>>pe1;
cout<<"Enter the value of";
printf(" %c",232);
cout<<" d from plate\n";
cin>>pd0;
```

```
pc1=100-pe0;
pd1=100-pd0;

cout<<"Value of";
printf(" %c",232);
cout<<" e1 is\t\t\t\t"<<pe1<<"%\n\n";
cout<<"Value of";
printf(" %c",232);
cout<<" c1 is\t\t\t\t"<<pc1<<"%\n\n";
cout<<"Value of";
printf(" %c",232);
cout<<" d1 is\t\t\t\t"<<pd1<<"%\n\n";
cout<<"D/S pile no.2\n\n";
pc2=0;
pe2=pe0;
pd2=pd0;
cout<<"Value of";
printf(" %c",232);
cout<<" c2 is\t\t\t\t"<<pc2<<"%\n\n";cout<<"Value of";
printf(" %c",232);
cout<<" e2 is\t\t\t\t"<<pe2<<"%\n\n";cout<<"Value of";
printf(" %c",232);
cout<<" d2 is\t\t\t\t"<<pd2<<"%\n\n";
getch();
clrscr();
cout<<"CORRECTIONS\n\n";
cout<<"Enter the value of Reference level 1\n";
cin>>nrl1;
cout<<"Enter the value of Reference level 2\n";
cin>>nrl2;
cout<<"Enter the value of Reference level 3\n";
```

```
cin>>nrl3;
cout<<"Enter the value of Reference level 4\n";
cin>>nrl4;
cout<<"Enter the value of Reference level 5\n";
cin>>nrl5;
cout<<"Enter the value of Reference level 6\n";
cin>>nrl6;
cout<<"Enter pile thickness\n";
cin>>pt;
cod0=nrl2-nrl6;
cod1=nrl2-nrl3;
b3=b-2*pt;
div1=cod0/b3;
cor1=19*pow(div1,0.5);
cor1=(cor1*(cod0+cod1))/b;
clrscr();
cout<<"CORRECTIONS\n\n";
cout<<"1.on";
printf(" %c",232);
cout<<" c1";
cout<<"a.due to natural interference\n";
cout<<"correction\t\t\t\t"<<cor1<<"%\n\n";
cor2=((pd1-pc1)*(nrl1-nrl2))/(nrl1-nrl3);
cout<<"b.due to floor thickness\n";
cout<<"correction\t\t\t\t"<<cor2<<"%\n\n";
cpc1=pc1+cor1+cor2;
printf(" %c",232);
cout<<" c1(corrected)\t\t\t\t"<<cpc1<<"%\n\n";
cod2=nrl5-nrl3;
cod3=nrl5-nrl6;
div2=cod2/b3;
```

```
cor3=19*pow((div2),0.5);
cor3=(cor3*(cod2+cod3))/b;
getch();
clrscr();
cout<<"CORRECTIONS\n\n";
cout<<"1.on";
printf(" %c",232);
cout<<" e2";
cout<<"a.due to natural interference\n";
cout<<"correction\t\t\t\t"<<cor3<<"%\n\n";
cor4=((pe2-pd2)*(nrl4-nrl5))/(nrl4-nrl6);
cout<<"b.due to floor thickness\n";
cout<<"correction\t\t\t\t"<<cor4<<"%\n\n";
cpe2=pe2+cor3+cor4;
printf(" %c",232);
cout<<" e2(corrected)\t\t\t\t"<<cpe2<<"%\n\n";
getch();
clrscr();
cout<<"E.PROTECTIOM WORKS\n\n";
cout<<"Downstream Protection\n\n";
cout<<"Normal scour Depth\t\t\t\t"<<sd2<<"m\n";
pwd=2*sd2-dshfl3+nrl4;
pwl=1.5*pwd;
pwlt=(2.25*pwd)/pwl;
cout<<"a.Launching Apron\n\n";
cout<<"Length of launching apron\t\t\t"<<pwl<<"m\n\n";
cout<<"Thickness of launching apron\t\t\t"<<pwlt<<"m\n\n";
cout<<"b.Inverted Filter\n\n";
pifl=1.5*pwd;
cout<<"Length of Inverted Filter\t\t\t\t"<<pifl<<"m\n\n";
cout<<"Provide 16 rows of cement concrete bolocks of size\n";
```

```
cout<<"1.2 m * 1.2 m * 0.75 m with 10 cm gaps filled with\n";
cout<<"bajri making the length "<<pifl+0.7<<"m\n";
getch();
clrscr();
cout<<"Upstream Protection\n\n";
pwud=1.5*sd2-ushfl+nrl1;
pwut=1.5;
pwul=(2.25*pwud)/pwut;
cout<<"Launching apron thickness is assumed to be\t\t\t"<<pwut<<"m\n\n";
cout<<"Length of launching apron\t\t\t\t\t"<<pwul<<"m\n\n";
cout<<"Provide cement concrete blocks of size 1.2 m *1.2 m*0.75 m\n";
cout<<"over packed apron of 0.75 m thickness for a length equal \n";
cout<<"to\t"<<pwul-0.5<<"m\n";
getch();
clrscr();
//OTHER BARRAGE BAY PORTION
cout<<"OTHER BARRAGE BAY PORTION\n\n";
cout<<"Crest level of other barrage bay portion\t\t"<<hbl<<"m\n";
cout<<"A\n";
cout<<"1.High flood flow with no concentration and retrogression\n";
cout<<"\nHead Loss\t\t\t\t\t\t"<<hl<<"m\n";
cout<<"\nHead including  velocity head over the crest\t\t"<<hoco<<"m\n";
odi=1.84*pow(hoco,1.5);
cout<<"\nDischarge Intensity\t\t\t\t\t"<<odi<<"m^3/s/m\n";
cout<<"\n2.Pond level flow with no concentration and retrogression\n";
cout<<"\nU/S Pond level\t\t\t\t\t\t"<<pl<<"m\n";
cout<<"\nD/S Pond level\t\t\t\t\t\t"<<dshfl2<<"m\n";
cout<<"\nU/S TEL\t\t\t\t\t\t\t"<<ustel2<<"m\n";
cout<<"\nD/S TEL\t\t\t\t\t\t\t"<<dstel2<<"m\n";
cout<<"\nHead Loss\t\t\t\t\t\t"<<hl1<<"m\n";
phoc=ustel2-hbl;
```

```
cout<<"\nHead,including velocity head,over the crest\t\t"<<phoc<<"m\n";
odi1=1.84*pow(phoc,1.5);
cout<<"\nDischarge intensity\t\t\t\t\t"<<odi1<<"m^3/s/m\n";
getch();
clrscr();
cout<<"B.Depth of sheet piles from scour\n\n";
cout<<"Total Discharge\t\t\t\t\t\t"<<dpo<<"m^3/s\n";
cout<<"\nOverall Waterway for other barrage portion\t\t"<<w2<<"m\n";
odi2=dpo/w2;
cout<<"\nAverage Discharge Intensity\t\t\t\t"<<odi2<<"m^3/s/m\n";
osd=1.35*pow(odi2,0.67);
cout<<"\nNormal Scour Depth\t\t\t\t\t\t"<<osd<<"m\n";
cout<<"\nD/S HFL(after retrogression)\t\t\t"<<dshfl3<<"m\n";
rldsco=dshfl3-1.5*osd;
cout<<"Enter level at which jump is formed\n";
cin>>jmp;
dsco=jmp-rldsco;
usco=ushfl-1.25*osd;
dusco=abl-usco;
cout<<"\nRL of bottom of D/S cut-off\t\t\t"<<rldsco<<"m\n";
cout<<"\nDepth (D/S cut-off)\t\t\t\t\t\t"<<dsco<<"m\n";
cout<<"\nU/S cut-off bottom RL\t\t\t\t\t"<<usco<<"m\n";
cout<<"\nDepth of U/S cut-off\t\t\t\t\t"<<dusco<<"m\n";
getch();
clrscr();
cout<<"Depth of U/S cut-off\t\t\t\t"<<dsco<<"m\n\n";
alpha1=dsco/b;
printf("1/%c",224);
cout<<"=\t\t\t\t\t\t"<<alpha1<<"\n\n";
cout<<"Enter the value of";
printf(" %c",232);
```

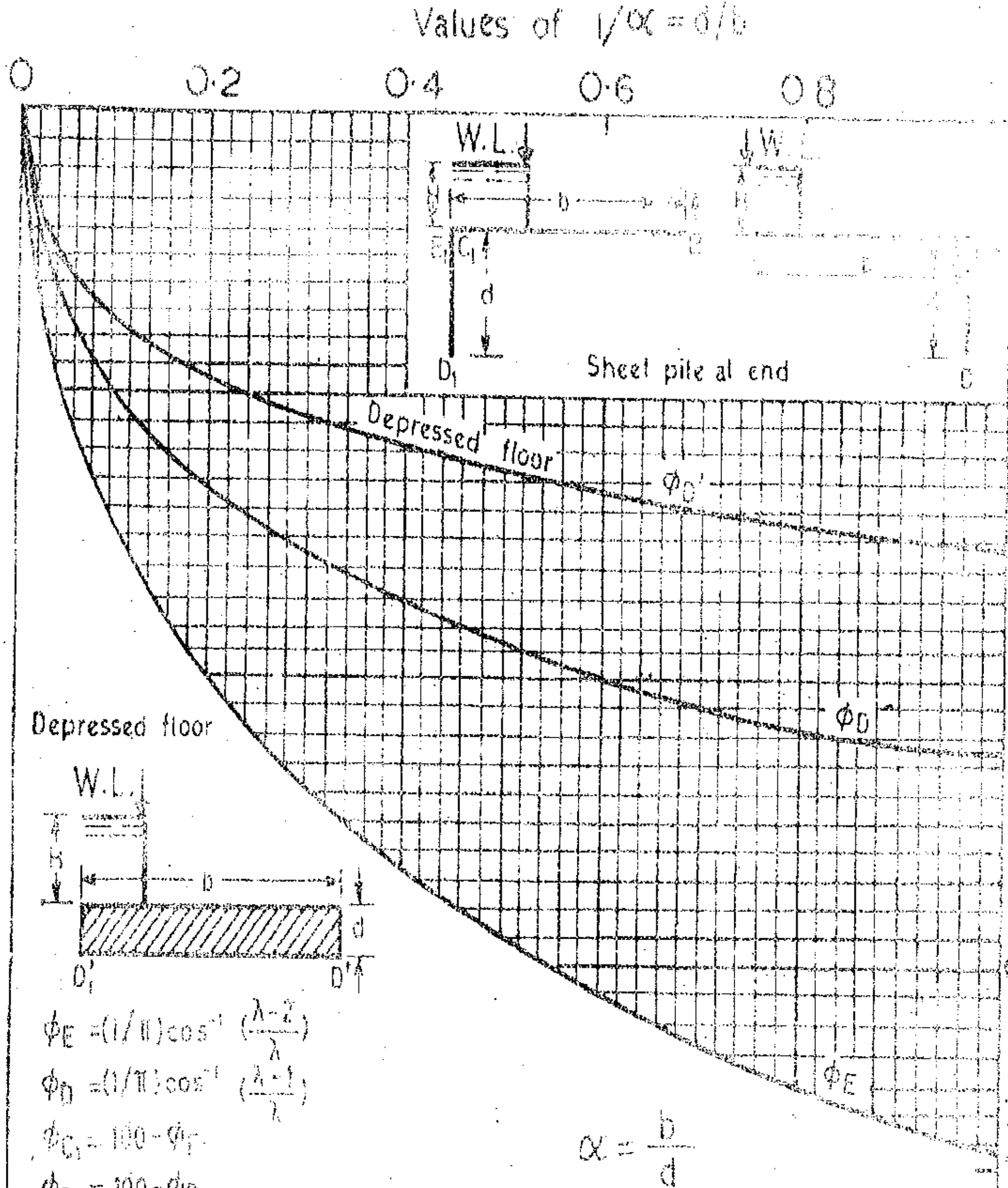
```
cout<<" e0 from plate\n";
cin>>pe0;
cout<<"Enter the value of";
printf(" %c",232);
cout<<" e1 from plate\n";
cin>>pe1;
cout<<"Enter the value of";
printf(" %c",232);
cout<<" d from plate\n";
cin>>pd0;
pc1=100-pe0;
pd1=100-pd0;

cout<<"Value of";
printf(" %c",232);
cout<<" e1 is\t\t\t\t"<<pe1<<"%\n\n";
cout<<"Value of";
printf(" %c",232);
cout<<" c1 is\t\t\t\t"<<pc1<<"%\n\n";
cout<<"Value of";
printf(" %c",232);
cout<<" d1 is\t\t\t\t"<<pd1<<"%\n\n";
cout<<"D/S pile no.2\n\n";
pc2=0;
pe2=pe0;
pd2=pd0;
cout<<"Value of";
printf(" %c",232);
cout<<" c2 is\t\t\t\t"<<pc2<<"%\n\n";cout<<"Value of";
printf(" %c",232);
cout<<" e2 is\t\t\t\t"<<pe2<<"%\n\n";cout<<"Value of";
```

```
printf(" %c",232);
cout<<" d2 is\t\t\t\t"<<pd2<<"%\n\n";
getch();
clrscr();
cout<<"CORRECTIONS\n\n";
cout<<"Enter the value of Reference level 1\n";
cin>>nrl1;
cout<<"Enter the value of Reference level 2\n";
cin>>nrl2;
cout<<"Enter the value of Reference level 3\n";
cin>>nrl3;
cout<<"Enter the value of Reference level 4\n";
cin>>nrl4;
cout<<"Enter the value of Reference level 5\n";
cin>>nrl5;
cout<<"Enter the value of Reference level 6\n";
cin>>nrl6;
cout<<"Enter pile thickness\n";
cin>>pt;
cod0=nrl2-nrl6;
cod1=nrl2-nrl3;
b3=b-2*pt;
div1=cod0/b3;
cor1=19*pow(div1,0.5);
cor1=(cor1*(cod0+cod1))/b;
clrscr();
cout<<"CORRECTIONS\n\n";
cout<<"1.on";
printf(" %c",232);
cout<<" c1";
cout<<"a.due to natural interference\n";
```

```
cout<<"correction\t\t\t\t"<<cor1<<"%\n\n";
cor2=((pd1-pc1)*(nrl1-nrl2))/(nrl1-nrl3);
cout<<"b.due to floor thickness\n";
cout<<"correction\t\t\t\t"<<cor2<<"%\n\n";
cpc1=pc1+cor1+cor2;
printf(" %c",232);
cout<<" c1(corrected)\t\t\t\t"<<cpc1<<"%\n\n";
cod2=nrl5-nrl3;
cod3=nrl5-nrl6;
div2=cod2/b3;
cor3=19*pow((div2),0.5);
cor3=(cor3*(cod2+cod3))/b;
getch();
clrscr();
cout<<"CORRECTIONS\n\n";
cout<<"1.on";
printf(" %c",232);
cout<<" e2";
cout<<"a.due to natural interference\n";
cout<<"correction\t\t\t\t"<<cor3<<"%\n\n";
cor4=((pe2-pd2)*(nrl4-nrl5))/(nrl4-nrl6);
cout<<"b.due to floor thickness\n";
cout<<"correction\t\t\t\t"<<cor4<<"%\n\n";
cpe2=pe2+cor3+cor4;
printf(" %c",232);
cout<<" e2(corrected)\t\t\t\t"<<cpe2<<"%\n\n";
getch();
clrscr();
cout<<"E.PROTECTIOM WORKS\n\n";
cout<<"Downstream Protection\n\n";
cout<<"Normal scour Depth\t\t\t\t"<<osd<<"m\n";
```

```
pwd=2*osd-dshfl3+nrl4;
pwl=1.5*pwd;
pwlt=(2.25*pwd)/pwl;
cout<<"a.Launching Apron\n\n";
cout<<"Length of launching apron\t\t\t"<<pwl<<"m\n\n";
cout<<"Thickness of launching apron\t\t\t"<<pwlt<<"m\n\n";
cout<<"b.Inverted Filter\n\n";
pifl=1.5*pwd;
cout<<"Length of Inverted Filter\t\t\t\t"<<pifl<<"m\n\n";
cout<<"Provide 13 rows of cement concrete bolocks of size\n";
cout<<"1.2 m * 1.2 m * 0.75 m with 10 cm gaps filled with\n";
cout<<"bajri making the length "<<pifl+0.7<<"m\n";
getch();
clrscr();
cout<<"Upstream Protection\n\n";
pwud=1.5*osd-dshfl+nrl1;
pwut=1.5;
pwul=(2.25*pwud)/pwut;
cout<<"Launching apron thickness is assumed to be\t\t\t"<<pwut<<"m\n\n";
cout<<"Length of launching apron\t\t\t\t"<<pwul<<"m\n\n";
cout<<"Provide 11 cement concrete blocks of size 1.2 m *1.2 m*0.75 m\n";
cout<<"over packed apron of 0.75 m thickness for a length equal \n";
cout<<"to\t"<<pwul-0.5<<"m\n";
getch();
clrscr();
}
}
```

PLATE – 1



$\phi_E = (1/\pi)\cos^{-1}\left(\frac{\lambda-2}{\lambda}\right)$

$\phi_D = (1/\pi)\cos^{-1}\left(\frac{\lambda-1}{\lambda}\right)$

$\phi_{C_1} = 100 - \phi_E$

$\phi_{D_1} = 100 - \phi_D$

$\phi_{D_1'} = 100 - \phi_{D'}$ (Depressed floor)

$\phi_{D'} = \phi_D - 2/3\ (\phi_E - \phi_D) + 3/\alpha^2$ (Depressed floor)

$\lambda = \frac{1+\sqrt{1+\alpha^2}}{2}$

PLATE – 2