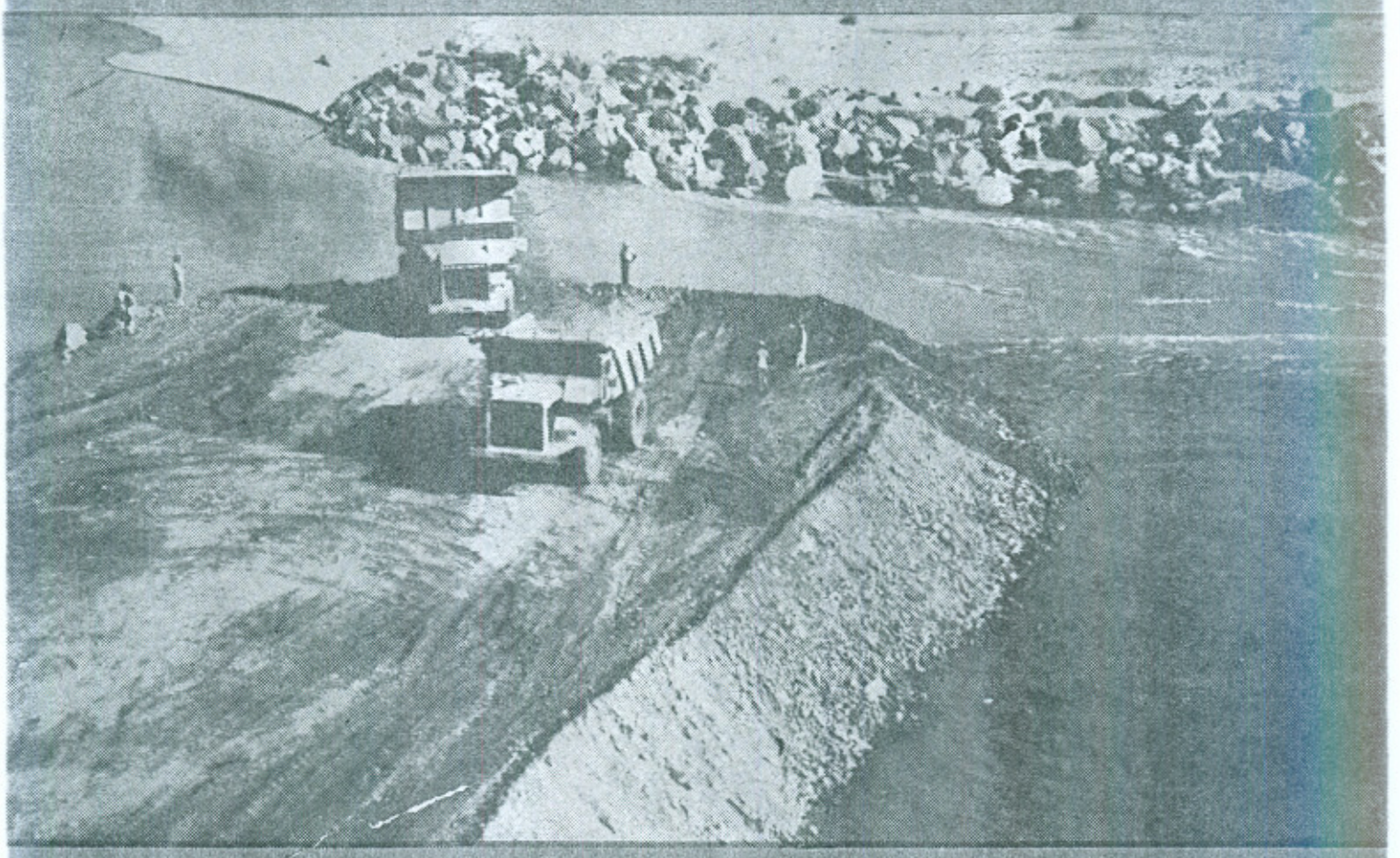
15th Annual

Engineering News



Quarterly Journal of West Pakistan Engineering Congress

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PUBLICATION OF ENGINEERING NEWS

Members are requested to forward technical papers for publication in the Engineering News. There are five broad sections viz :

a. Irrigation and Power Section.
b. Buildings and Highways Section.
c. Industry Section.
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e. General Section.

Other interesting features are news pertaining to Engineering Professions, abstract of papers and other relevant material.

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All the relevant diagrams must be properly traced on transparent paper with Chinese Black Ink. Photographs should be on glossy paper. The diagrams and photographs must be properly labelled and numbered.

News in Pictures with brief introduction will be appreciated in every section of this publication.

Articles, news and notes and other suggestions are earnestly requested to make the Engineering News regular and useful for the profession.

FIFTEENTH YEAR OF PUBLICATION

ENGINEERING NEWS

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• Contributions to this journal in the form of articles, news of engineering works, news about engineers, photographs and technical data etc. are cordially invited.

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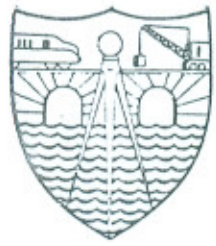
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TITLE COVER

River Indus diverted at Tarbela

Photograph : Courtesy Tarbela Joint Venture.

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CYCLONES IN EAST PAKISTAN
A CHALLENGE FOR THE ENGINEERS

Never has been under the dome of these blue heavens, the calamity so catastropic. Never has the surging waves of the Bay of Bengal staged the dance of Death so furiously as this time in the off-shore islands of our Eastern Wing. Never has the human eyes been afflicted to watch such a panorama of destruction and never was the human heart so anguished at being helpless in the face of elements of Nature. Here was the Man created in the image of God—the best of His creations—lying prostrate, naked, motionless, all dead with a swollen and decaying body. The cruel hand of death has snatched the smile of innocents, but even if it had been spared there was none left to exchange it with the warmth of his heart. There was no mother to wail for his lost child and no son to respectfully bury his dead mother. The eyes of sisters were still open in death painfully searching for the brothers swallowed by the expanse of sea. The 'henna' coloured hand of the beloved was empty under the open sky and there was no youthful 'boatman' to allure her out of this Eternal sleep. It was death, havoc and destruction on every side—the very flood of Noah has engulfed the land.

All this happened in the seventh decade of the twentieth century when the science and technology has a claim to have touched the Zenith. On this very day when a million souls went down the grave of water without their cry for help having touched the ears of their companions, the humanity elsewhere was rejoicing at its feat to have launched a

crawling robot on the surface of the moon. Such was the appalling gap of technology between the haves and have-nots and such was the defiance of the elements of nature, boisterously ridiculing the man's claim to have conquered the nature. The nature struck and struck very hard to demonstrate:

ڈھونڈنے والا ستاروں کی گذر گاھوں کا
اپنے افکار کی دنیا کا سفر کر نہ سکا

جس نے سورج کی شعاؤں کو گرفتار کیا
زندگی کی شب تاریک سحر کر نہ سکا

But the tragedy had a silver lining too. Although the elements of nature killed the human bodies but the human soul triumphantly elevated itself. Never was the human sympathy so widely evoked and never were so many eyes welling with tears. The solidarity of human race was established through the sublimation of the good within human nature which came forward in a large way to succour the survivors of this tragedy, the magnitude of which was unknown in human history.

The tragedy has confronted the 'engineers' and the engineering profession with a great challenge. The engineers owe an onerous duty to the nation. The nation is not merely to bury its dead and count its survivors. It demands of us to devise protective mechanism to prevent the recurrence of such a colossal loss to life and property. Primarily the responsibility rests on our engineer brothers of the East, but we sitting in the West are keen to offer all the possible assistance moral and material, as humble workers and colleagues. The task is tremendous but certainly not beyond the grasp of engineering ingenuity. Let us be clear that within the presently available span of technology, perhaps we cannot stop the floods and cyclones from visiting us, but we can certainly blunt their destructive strike. Let us concentrate on this aspect. Devise protective mechanisms of eliminating the sorrow and misery coming in the wake of these havocs. God has granted us tremendous resources in the form of human labour. We will have to device our own ingenious measure and not look towards the technological 'haves' to come to our rescue. Let the engineers proclaim their determination for self-reliance, and their cyclone and flood protection be the starting point of it. The nation is looking towards us expectantly and eagerly. Let us rise to the occasion.

River Diversion at Tarbela Dam Site

By **S. M. AYOOB**[1]
and
CH. MOHAMMAD ALI[2]

With the completion of river diversion at Tarbela on 9-10-1970 *this huge project has entered a new phase of its construction. Indus River Valley where the mighty Indus has been flowing for centuries has dried up and there will start rising up the gigantic Tarbela Dam which will hold the water* 450 *feet above the existing river bed and will open a new era of progress and prosperity for West Pakistan.*

The river Indus was diverted during October, 1970 *into a diversion channel excavated at the right bank during the* 1*st stage of works by closure of three river channels with earth rock dams. The maximum total river discharge during closure was* 90,000 *cusecs and the maximum partial discharge was* 20,000, 22500 *and* 26800 *cusecs in right, middle and left channels respectively. The necessary information about height of the closure dams and cofferdams, the material to be dumped and the technique of closure and sequence of operations was obtained from the Hydraulic model tests made by Irrigation Research Institute.*

It can be surmised from model tests and actual closure at site that if opposite bank is adequately protected, river bed in final gap is revetted with sizable stone, u/s edge of advancing cofferdam is advancing as a spur and dumping rate is excessive, the heavy boulders are available and in final gap the stone is bull-dozed from both ends and the river closure does not pose any particular problem.

Description of the Project

The dam, shown in Figure 1, consists of an embankment across the 9,000 feet width of the main river valley, a group of 4 tunnels in the rock on the right abutment to provide for irrigation releases and future power, two saddle spillways cut through the rock on the left bank and discharging into a side valley, and two auxiliary embankment dams to close the upstream end of the side valley.

The Tarbela reservoir will have an ultimate gross storage capacity of 11.1 MAF at elevation 1550 and a capacity at the assumed minimum drawdown of 1.8 MAF at elevation 1300, leaving a net usable capacity of 9.3 MAF. The full reservoir depth will be 450 feet after completion of the project.

The main embankment dam (resting on a foundation of alluvial gravel having a maximum depth of 600.0) will be constructed

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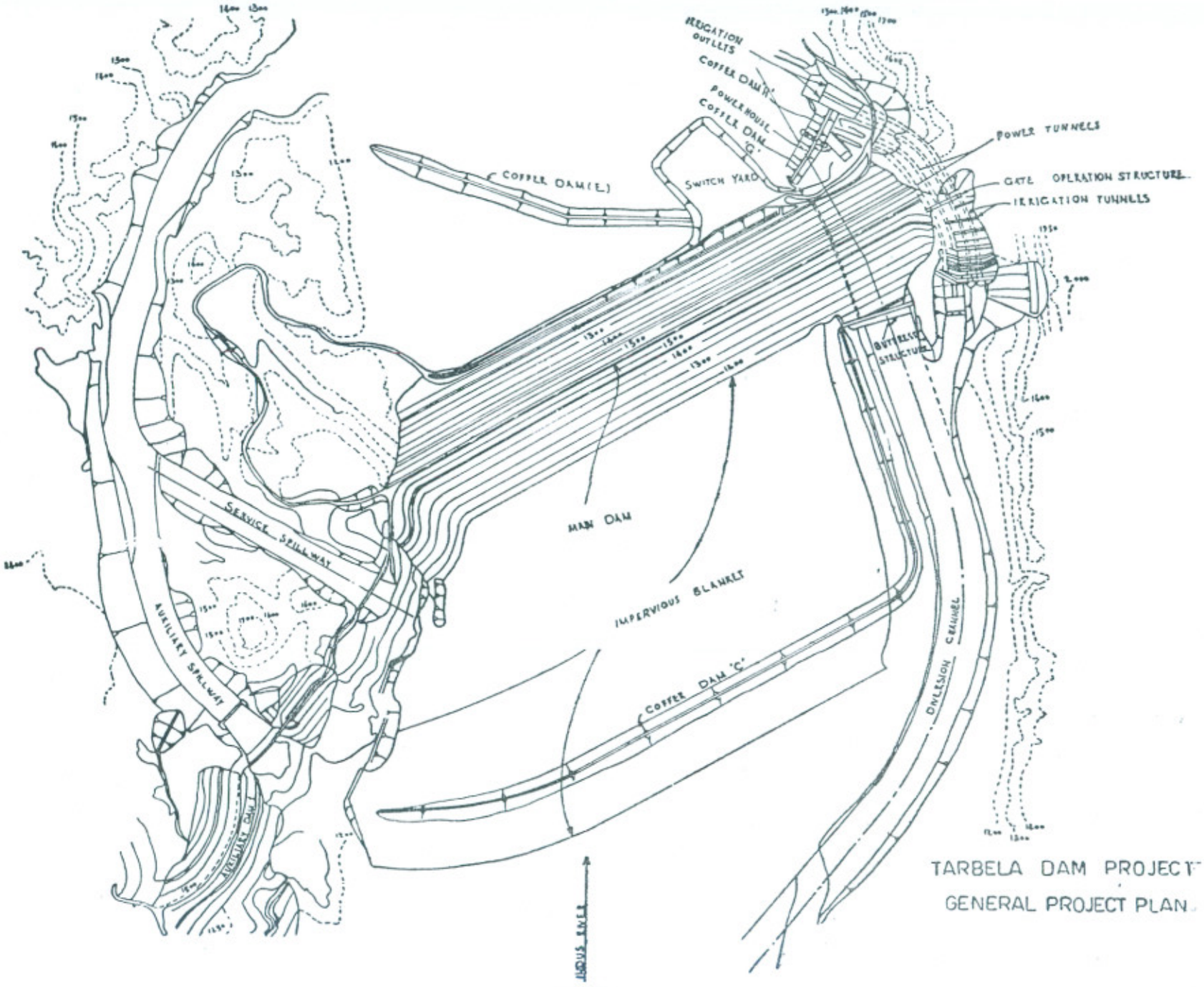

IRRIGATION OUTLETS
COFFER DAM 'B'
POWERHOUSE
COFFER DAM 'D'
POWER TUNNELS
COFFER DAM (E)
SWITCH YARD
GATE OPERATION STRUCTURE
IRRIGATION TUNNELS
BUTTRESS STRUCTURE
MAIN DAM
SERVICE SPILLWAY
IMPERVIOUS BLANKET
AUXILIARY SPILLWAY
COFFER DAM 'C'
OVLESSION CHANNEL
INDUS RIVER
TARBELA DAM PROJECT
GENERAL PROJECT PLAN

Fig 1.

using material excavated from the spillway channel and from the tunnels and diversion channel, additional material required will be obtained from nearby borrow areas. An impervious blanket in continuation with core of Dam will cover the river bed to restrict the underflow through permeable foundations.

The two saddle spillways on the left bank will discharge into channels leading to the large excavated channel along the natural side valley, the Dal Darra, which returns to the main Indus downstream of the dam. The total spillway capacity will be about 1,400,000 c.f.s. at full reservoir level.

The four (half mile long) tunnels will follow a curved alignment through the rock abutment of the dam, will serve initially for river diversion during the final stage of construction, and ultimately for power (tunnels 1 & 2 and eventually 3) and Irrigation releases (tunnels 3 & 4 and eventually only 4).

The discharging capacity of tunnels 1 & 2 during diversion stage will be 200,000 c.f.s. each. Each of three power tunnels will serve four hydro-electric generating units of 175,000 K.W. capacity each. Initial installation will be four sets.

Each irrigation release tunnel (3 & 4) will have a discharging capacity 68,000 c.f.s. at low reservoir level and large flows at higher reservoir level with a capacity of 100,000 c.f.s. at R. L. 1550. Each will be equiped with shut-off gates in a mid tunnel shaft and a Y-branch into two rectangular conduits leading to a pair of radial central gates ($16 \times 24'$) at the outlet. The discharge from each tunnel will pass through a stilling basin and return to the river.

As initially constructed, the tunnels will be concrete lined with a common diameter of 45′, later on when the power units are installed, these will be lined with steel downstream of the gates, located in mid-tunnel shafts with a dia of 43.5 feet for tunnels 1, 2 & 3 and 36′ for tunnel 4.

Particulars of different features of the project:

Location:

40 miles northwest of Rawalpindi.

Construction Period:

Stage I,	River in Natural Bed.	2½ years.
Stage II,	River in Excavated channel.	3 years.
Stage III,	River Diverted through Tunnels.	1 year.
Complete initial power installation.		1½ years.
	Total	8 years.

Project Volumes:

Total embankments and fills.	186,000,000 cu. yds.
Excavation, Required.	96,000,000 cu. yds.
Excavation, Borrow.	98,000,000 cu. yds.
Concrete.	3,320,000 cu. yds.

Reservoir:

Length.		50 miles.
Maximum Depth.		450 feet.
Area.		60,000 acres.
Usable capacity above	El. 1300	9.3 Million. Acre ft.
Dead storage below	El. 1300	1.8 Million. Acre ft.
Gross capacity	El. 1550	11.1 Million. Actr ft.

Main Embankment Dam:

Length at crest (El. 1565).	9,000 feet.
Maximum Height (from lowest foundation point).	470 feet.
Embankment volume.	138,000,000 cu. yds.
Blanket volume.	21,000,000 cu. yds.

Auxiliary Dam No. 1

Length at crest (El. 1565).	2.340 feet.
Maximum height.	345 feet.
Volume, including blanket.	18,000,000 cu. yds.

Auxiliary Dam No. 2

Length at crest (El. 1565).	960 feet.
Maximum height.	220 feet.
Volume.	2,000,000 cu. yds.

Service Spillway:

7 gates 50 feet wide × 58 feet high, discharge capacity.	650,000	c.f.s.
Concrete volume.	416,000	cu. yds.

Auxiliary Spillway:

9 gates 50 feet wide × 58 feet high discharge capacity.	840,000	c.f.s.
Concrete Volume.	475,000	cu. yds.

Tunnels at Right Bank:

Four—2,400 to 2,700 feet long.	
Concrete lined upstream of gate shafts, diameter.	45 feet.
Steel lined downstream of gate shafts.	
Tunnels No. 1, 2 and 3 diameter.	43.5 feet.
Tunnel No. 4 diameter.	36 feet.
Main gates, each tunnel 2 @	13.5 × 45 feet.
Radial irrigation outlet gates,	
Tunnels 3 & 4 each tunnel 2 @	16 × 24 feet.

Power Plant:

Ultimate : 12 units @	175,000 KW	2,100,000 KW
Initial : Units 4 @	175,000 KW	700,000 KW
Inlet valves		4 @ 192 inches.
Cone dispersion bypass valves		4 @ 96 inches.
Transformers		12 @ 1,000 KVA
Concrete Volume.		400,000 cu. yds.

Three Stages of River Diversion

The dam will be constructed in three stages in relation to Indus flows. In the first stage the river is flowing in natural channels in its existing bed. The construction activities are restricted on the right bank enclosed by a cofferdam. These include excavation of diversion channel and building of initial section of the main Dam from the material excavated from diversion channel.

In the second stage the River is flowing through the newly excavated diversion channel on the right bank while the dam is being constructed between the section completed during first stage and left bank of the valley by using material excavated from spillway channel.

In the third stage the diversion channel is closed at buttress structure and the River is flowing through the completed tunnels, while the final section of the dam on the right bank will be completed.

Details of Stage II River Diversion

It is estimated that four years will be required to construct the four power and irrigation tunnels on the right side of the river. During this interval the major portion of the dam in dry bed of river is scheduled for construction, and the river flow must be diverted away from the working area. This will be done through a temporary diversion channel which will be excavated on the right bank of the river as shown in figure 2. The base width of the channel will be 650 feet and it will be approximately 10,000 feet long, skirting the upstream and downstream construction cofferdams.

A gated buttress structure located in the downstream reach of the diversion channel is shown in the figure. The gates on the buttress structure will remain open until the power and irrigation tunnels are completed. At this time the plug blocking the intake channel to the tunnels will be removed and the buttress gates will be closed, forcing the flow to pass through the four tunnels (stage III Diversion).

Prior to forcing the flow through the diversion channel (stage II) a river closure at end of the 1st stage must be effected to dewater the Dam site as specifications require dry foundation of Dam.

After this closure one Coffer Dam u/s of Dam (called Coffer Dam C) and one Coffer Dam d/s of main Dam called Coffer Dam E will be constructed protecting the Dam site against a peak discharge of 750,000 cusecs. Additional temporary cofferdams in the three river channels will be required to divert the flow into the diversion channel while a strip of clay blanket is placed and cofferdam 'C' constructed upon it. At the same time construction can proceed on the downstream cofferdam, designated at "E". Thus the first step to be considered in the stage II Diversion is closure of the river.

Discription of river channels and selection of closure discharge

During low water season River Indus at Tarbela Dam site splits up into three major channels. The discharging capacity of the extreme left channel is maximum whereas the central channel draws minimum of the three channels. The distribution of flow in the three river channels for a total flow of 80,000 cusecs (as recorded on 1/80 scale model with 1964 survey) is 42.3 in left channel, 25.8% in the central channel, 31.9 percent of the total flow in right channel.

The maximum discharge during 100 years of record at Tarbela is 650,000 cusecs and

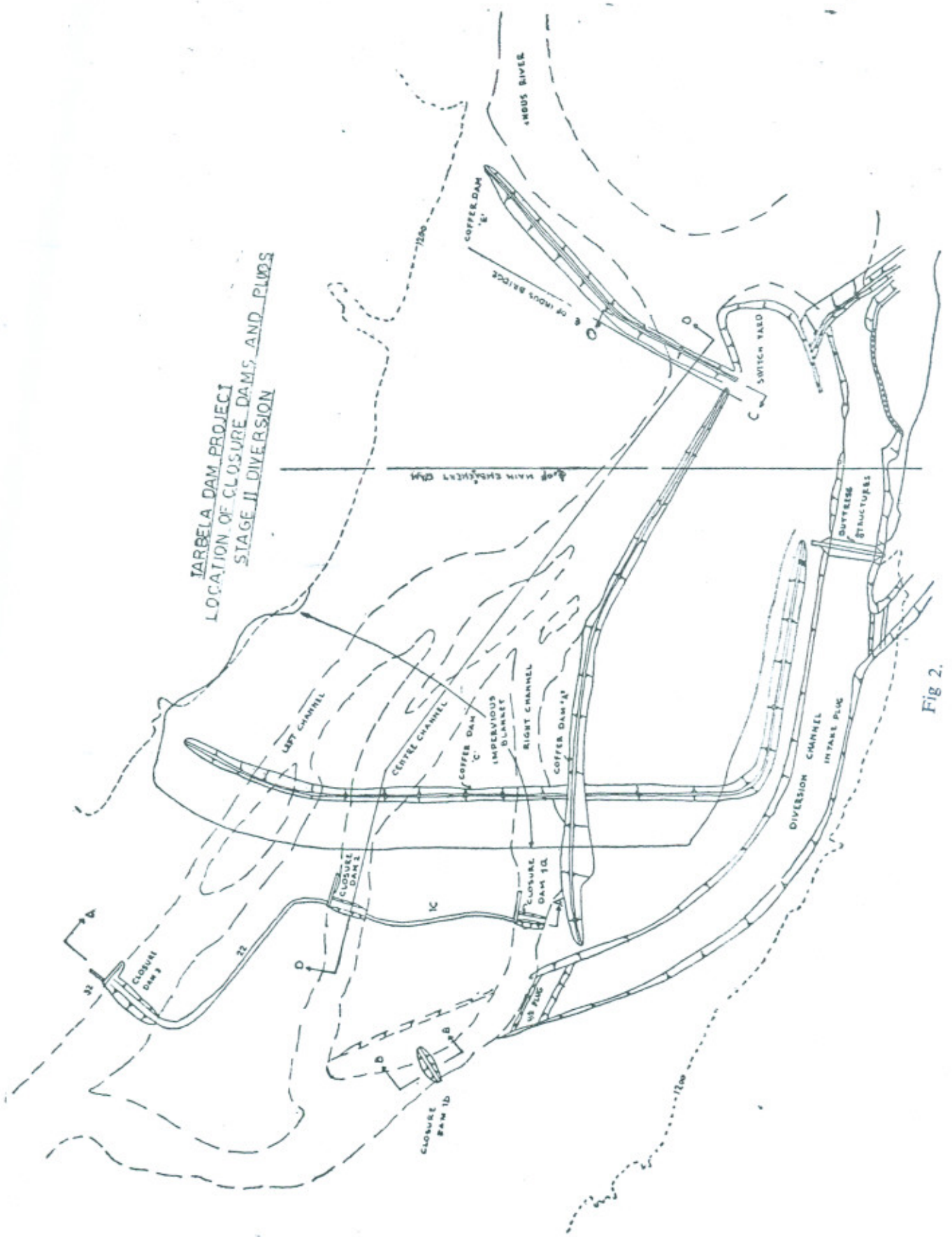

TARBELA DAM PROJECT
LOCATION OF CLOSURE DAMS AND PLUGS
STAGE II DIVERSION
INDUS RIVER
COFFER DAM 'E'
U/S INDUS BRIDGE
SWITCH YARD
MAIN EMBANKMENT DAM
BUTTRESS STRUCTURES
LEFT CHANNEL
CENTRE CHANNEL
COFFER DAM 'C'
IMPERVIOUS BLANKET
RIGHT CHANNEL
COFFER DAM 'A'
DIVERSION CHANNEL
INTAKE PLUG
CLOSURE DAM 2
CLOSURE DAM 1C
CLOSURE DAM 3
CLOSURE DAM 1D
U/S PLUG
1280
1180

Fig 2.

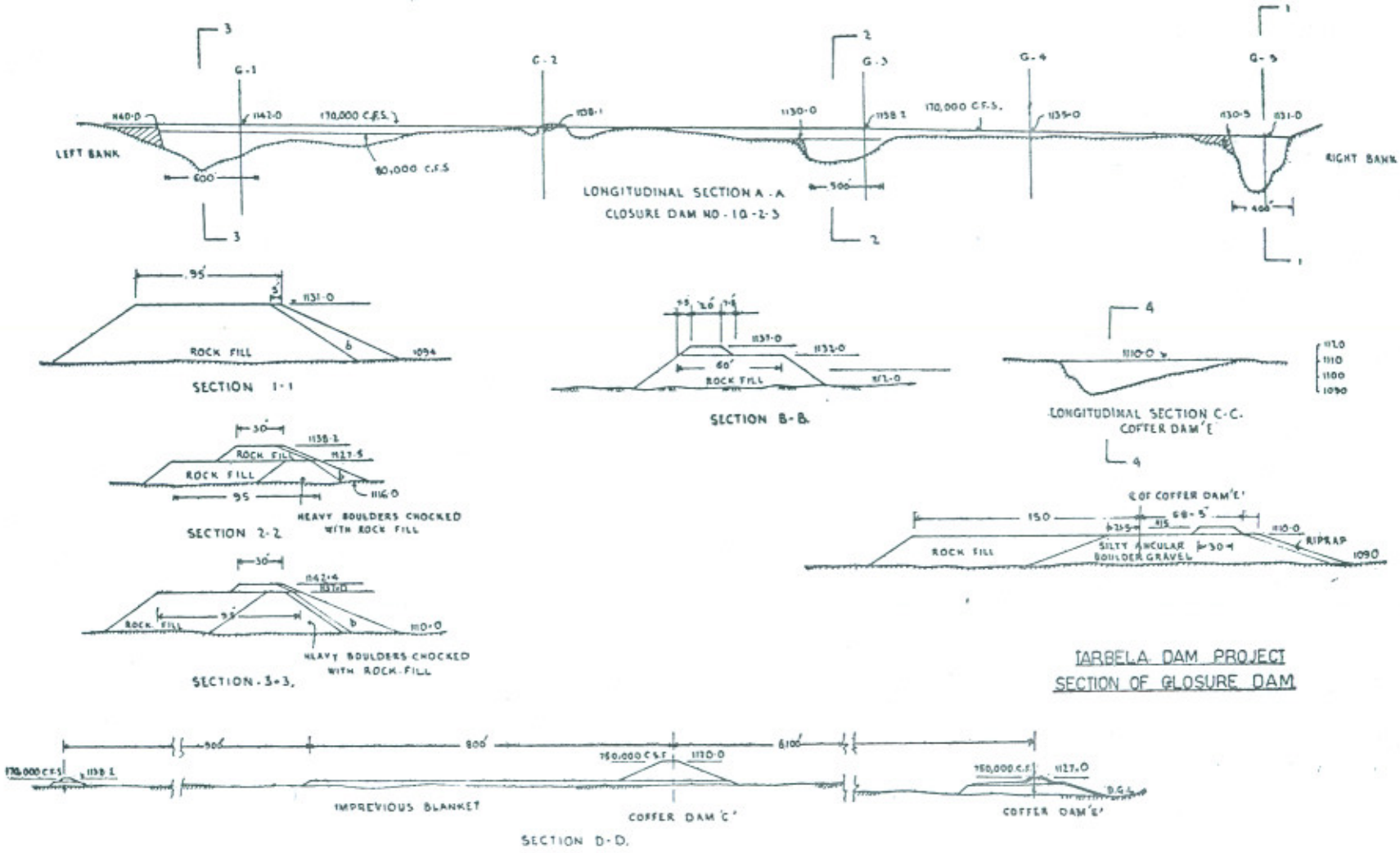

G-1
G-2
G-3
G-4
G-5
LEFT BANK
RIGHT BANK
170,000 C.F.S.
80,000 C.F.S.
LONGITUDINAL SECTION A-A
CLOSURE DAM NO-10-2-3
ROCK FILL
SECTION 1-1
SECTION B-B.
LONGITUDINAL SECTION C-C.
COFFER DAM 'E'
HEAVY BOULDERS CHOCKED WITH ROCK FILL
SECTION 2-2
SECTION-3-3.
IMPREVIOUS BLANKET
COFFER DAM 'C'
COFFER DAM 'E'
SECTION D-D.
RIPRAP
SILTY ANGULAR BOULDER GRAVEL
TARBELA DAM PROJECT
SECTION OF CLOSURE DAM

Fig 2 (*a*)

minimum is at 15,000 c.f.s. The river discharge anticipated during river closure scheduled in October 1970 was between 40,000 to 80,000 cusecs as records indicate that in an average year the river will be flowing at or less than 80,000 cusecs for approximately 240 days (see Fig. 3). The discharge is normally less than 100,000 cusecs from October to March and more than 100,000 cusecs from April to September.

Planning of River Diversion by Scale Models

To investigate the best procedure for closing the three river channel series of tests were conducted on 1/80 natural scale model of River Indus at the Hydraulic Research Station, Nandipur in 1963-64. On the basis of these tests the following procedure of river closure was recommended by M/s TAMS who are responsible for designing the project.

(1) Remove plug, allowing diversion channel to go into operation.

(2) Construct closure dam across right channel.

(3) Equipment can now be moved into the river bed and the diversion channel portion in the river bed from station 0+00 to 20+00 may be excavated.

(4) Close the central channel.

(5) Close the right channel last of all.

As actual closure was being materialized six years after the above testing T.J.V Contractors for Tarbela Dam again requested Irrigation Research Institute, Lahore on 1-1-1970 to set up a 1/60 natural scale model of River Indus for more detailed study relating to river Diversion at Tarbela. The terms of reference set out by T.J.V were :

(1) To determine the most suitable sequence of closure of the 3 river channels.

(2) To investigate the utility or otherwise of excavating the part of diversion channel in the river bed.

(3) To assess the water levels likely to be generated above and below the closure dams.

(4) To estimate the quantity of material required for each closure mound.

Simultaneously Sogreah Hydraulic Laboratory in Grenoble was asked to carry out flume tests to determine the grain size of the material to be used for closure on the basis of water levels observed on Nandipur model in 1964 and to compare different closure methods to find which is the most suitable for Tarbela site.

The Model

A model representing more than 20,000 feet stretch of river Indus located between a point some distance upstream of the trifurcation point of three channels and a point downstream of the outlet of diversion channel into the river, was constructed on 1/60 natural scale. The model river upstream of the main dam axis was moulded to conform to contours supplied by T.J.V. while lower down it was moulded to 1968 cross sections supplied by TAMS. The river bed upstream of the trifurcation point was moulded in accordance with 1964 survey.

The river bed on the model was moulded in Haro Sand specially arranged to simulate the prototype range of the river bed material. It was mainly selected because it has little tendency to form ripples which induce more friction on the model. Boulder bars d/s

of the offtake point, of each channel were duly represented.

Sequence of Closure of the 3 River Channels

In this test series the diversion channel was opened at its intake located just d/s of old Pehur canal head regulator hillock on right bank of the right channel without excavating its portion between station 0+00 to 20+00 in the river bed. Following four sequences of closure :

Right,	Centre,	Left,
Right,	Left,	Centre,
Left,	Centre,	Right,
Left,	Right,	Centre,

were model-tested for river discharges 40,000, 60,000 and 80,000 cusecs. From the model it was observed that :—

(*a*) As the plug in the diversion channel is removed, the maximum drop in water level is in the right channel; whereas the drop in water level in the central and left channel is insignificant.

(*b*) Closure of the right and central channels does not affect the water levels in left channel. Significantly as the back-water effect just reaches the offtake point of left channel.

(*c*) Initial closure of left channel alone results in rise of water level in the central channel by 3.6, 3.9 and 4.5 feet at respective discharges of 40,000, 60,000 and 80,000 cusecs whereas the corresponding rise in the right channel is 2.7, 1.4 and 1.7 feet.

(*d*) Closure of left and central channels results in rise of water level in the right channel by 3.3, 3.6 and 4.3 feet at river discharges of 40,000, 60,000 and 80,000 cusecs.

(*e*) The combined effect of closure of the right & left channels is that the water level in the central channel rises by about 4 feet at the three specific discharges.

(*f*) The stabilized water levels at site of closure dams when the three channels are closed is independent of sequence of closure of the 3 channels.

Excavation of Approach to Diversion Channel

In this set of tests the approach to diversion channel was widened and deepened *i.e.*, diversion channel in river bed from 0+00 to 20+00 was excavated. In the first test right channel was closed and the model was run for the selected discharge of 40,000, 60,000 and 80,000 cusecs. The water levels at the 3 closure dams sites were recorded. In the second test central channel was also closed and the water levels were again observed at the closure dam sites. In the last test left channel was also closed along with right and central channels and water levels recorded at the three closure dam sites.

A comparison of water levels at the three closure dam sites with closure of different channels, with and without excavation of diversion channel between station 0+00 to 20+00 in the river bed showed that with the excavation of diversion channel between station 0+00 to 20+00 the water levels in the central channel get lowered substantially. The water level in the central channel at its offtake point drops by 2 to 2.7 feet, with the closure of right and left channels, 3 to 3.6 feet with closure of right and central and 2.9 to 4.5 with closure dam in all the three channels. Water levels of right channel at closure dam site drop by 0.5 to 1.0 foot whereas the drop in water level in the left channel is insignificant and so widening and

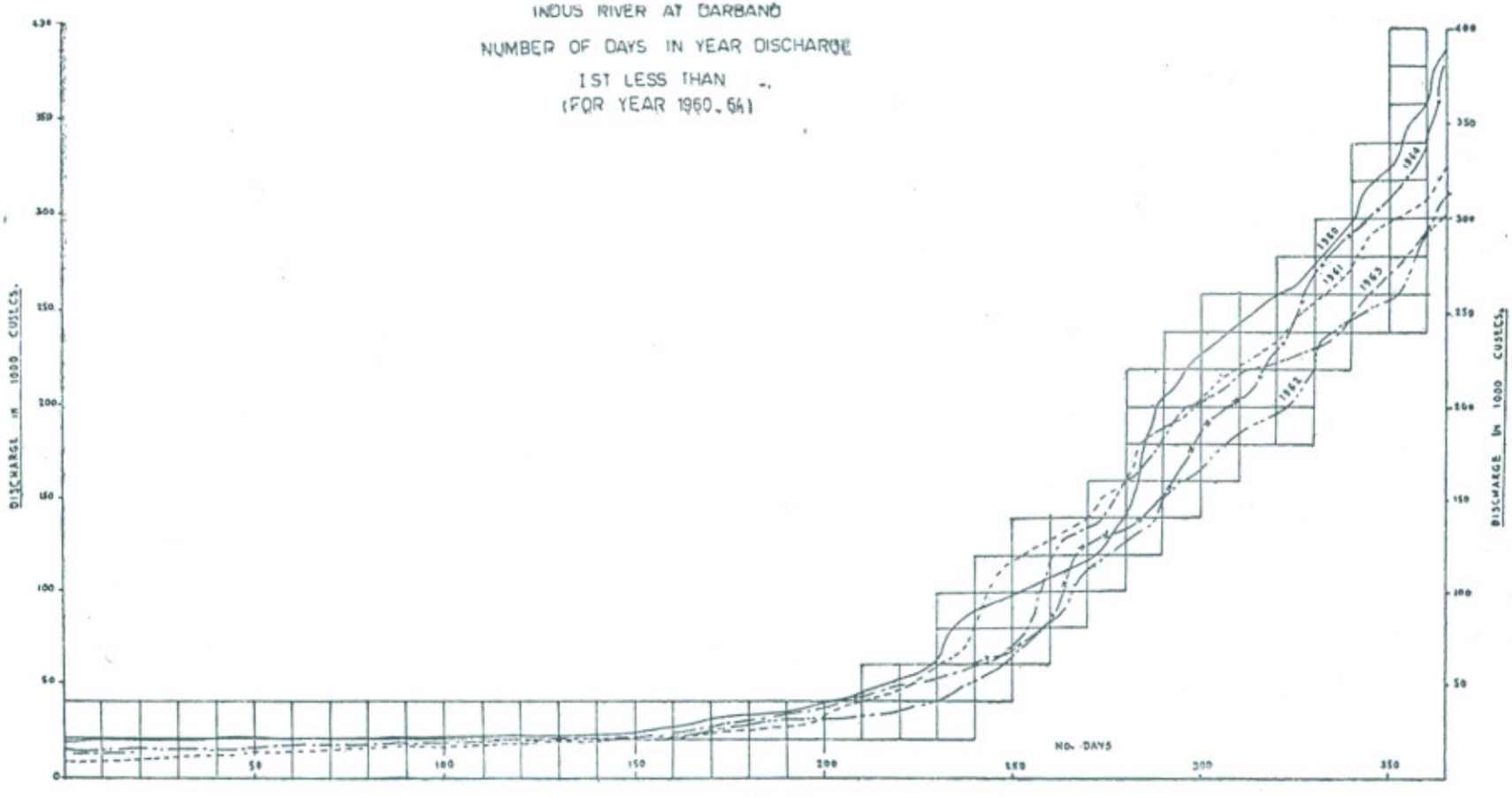

INDUS RIVER AT DARBAND
NUMBER OF DAYS IN YEAR DISCHARGE
1ST LESS THAN -.
(FOR YEAR 1960-64)
DISCHARGE IN 1000 CUSECS.
NO. DAYS
1960
1961
1962
1963
1964

Fig. 3.

deepening of approach channel was not recommended.

Grade and Dumping Rate of Material to be Used for Closure

Sogreah in Grenoble (France) made some erosion tests by using stones of different grades in the closure dam and maintaining different constant head drops in the gap between advancing head of the closure dam and stone protected opposite bank. The head drop was varied from 1 to 4.8 meters which was the maximum head drop recorded on 1/60 scale Nandipur model. From these tests Sogreah recommended the following three grades to be used for river closure at Tarbela.

Grade I = River bed material.
Grade II = Stone for 80 to 400 lbs.
Grade III = Rock not less than 1100 lbs. 50% more than 2200 lbs.

The rate and procedure of dumping the material as planned by TJV was :

1000 cub : yd/hour for Grade I.
500 cub : yd/hour for Grades II & III.

Grades II & III were always to be placed in conjunction with Grade I. Grade I and II and similarly Grade I and III were dumped in ratio of 2/3 to 1/3. The crest width of the three closure dams was fixed as 95 feet to allow turning manœurs of earth moving machinery. The initial crest levels of the three closure dams were kept 1.5 feet above the water levels recorded on the model.

Technique of River Closure

Having decided the sequence of closure of the three river channels and the site of the closure dams (in view of site conditions specially rapids in three channels d/s of there offtake points) next problem was to investigate the most suitable method and technique of closure. From a number of quick tests conducted at Grenoble it was recommended to protect 500 feet length of the left banks of three channels opposite to closure areas and the closure dams to be aligned run to follow a shape of hockey stick. This shape was tested along with other shapes on 1/60 scale comprehensive model at Nandipur.

1. Hockey Stick Shape Closure Dams

The model was remoulded to 1969 survey and the left banks of the three channels against which closure was to be made were protected by grade III rock fill for a length of 500 feet and a thickness of 20 feet at the toe of the bank. The model was run for 80,000 cusecs, the diversion channel was opened and when the flow was stabilised, the closure in the right channel was started by dumping grade I material from the right bank of the channel in a way so that the upstream crest edge of the closure dam was in line with the upstream edge of the stone protection on the opposite bank. The dam was advanced in a straight line till the gap width was 220 feet, then axis of the dam was deflected downstream with continued downward inclination to follow the shape of hockey stick (see Fig. 4). The dumping of grade I material was continued with the specific rate of 1000 cub : yd/hour till the erosion at advancing head of closure dam as well as of the channel bed was excessive and compatible with rate of dumped material and the rate of rise of water level got slackened. At this stage grade II material was introduced. Grade II material was placed at the upstream advancing edge of the closure dam while the remaining portion of closure dam was built by dumping grade I material. The rate of dumping of grade II material was

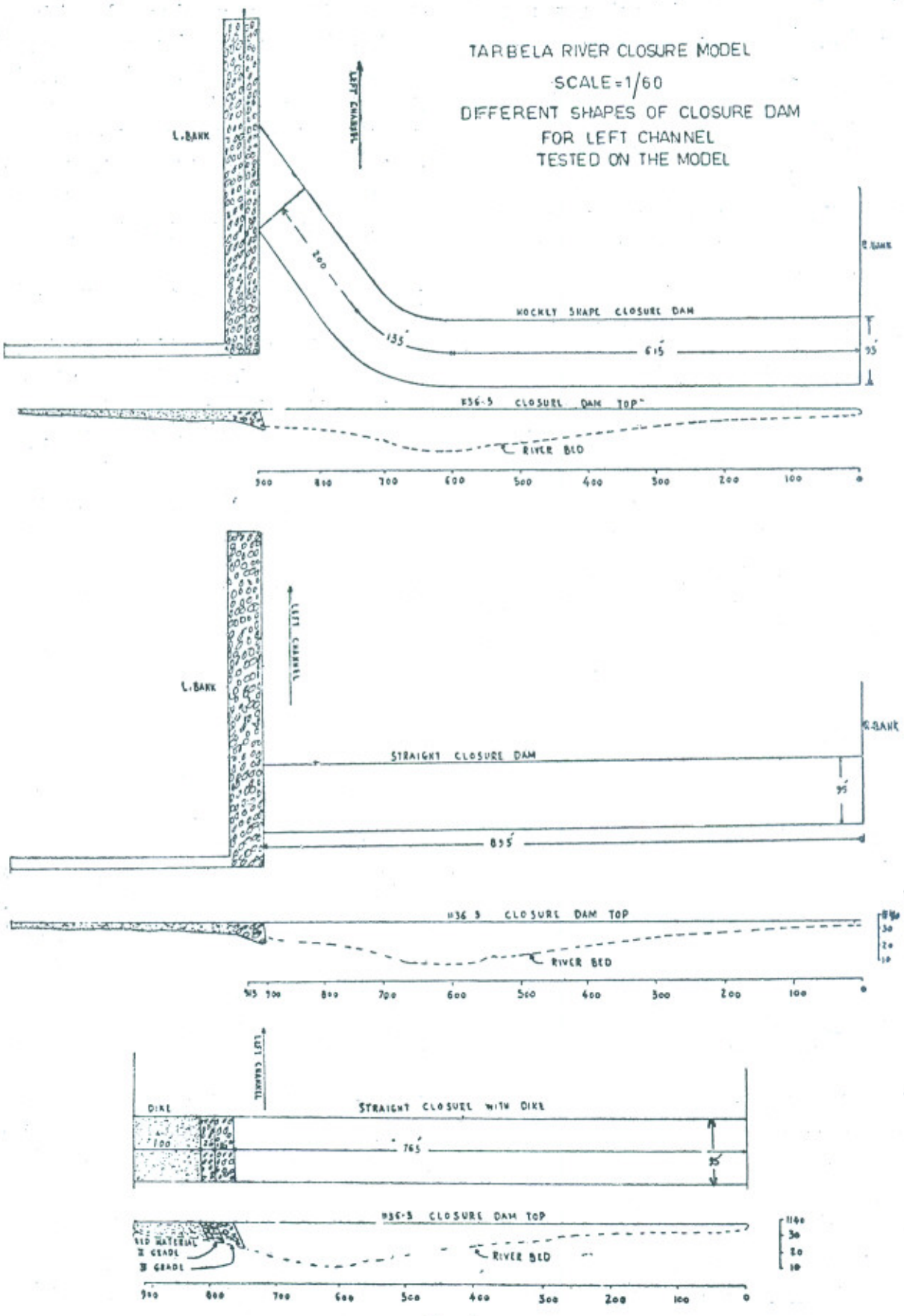

TARBELA RIVER CLOSURE MODEL
SCALE=1/60
DIFFERENT SHAPES OF CLOSURE DAM
FOR LEFT CHANNEL
TESTED ON THE MODEL
L.BANK
LEFT CHANNEL
200
135'
615'
95'
HOCKEY SHAPE CLOSURE DAM
R.BANK
1136.5 CLOSURE DAM TOP
RIVER BED
900 800 700 600 500 400 300 200 100 0
L.BANK
LEFT CHANNEL
STRAIGHT CLOSURE DAM
95'
835'
R.BANK
1136.5 CLOSURE DAM TOP
RIVER BED
30
20
10
DIKE
LEFT CHANNEL
STRAIGHT CLOSUEL WITH DIKE
100
765'
95'
1136.5 CLOSURE DAM TOP
RIVER BED
900 800 700 600 500 400 300 200 100 0

Fig. 4.

half of rate of dumping of grade I material. Water levels generated upstream and downstream of the advancing dam were measured at regular intervals throughout the closure operation. The volume of the material dumped, increment in the dam length as well as the scour at the advancing head of the dam was recorded at fixed intervals. The above test was repeated as assuming that diversion channel is plugged at its entrance point.

After closing the right channel, central channel was also closed in the manner described above. In this case also model data regarding time of closure, quantity of material and water levels upstream and downstream of the closure mound was collected.

After closure of the right and central channels, closure of left channel was started in a way detailed for closure of the right channel. In this case due to more concentrated per foot run discharge and more head drop, placing of grade I material in the wake of grade II was a bit difficult, so the front of u/s advancing spur head built by tipping grade II material had to be kept about 30 to 40 feet in advance of the grade I front. In case of grade III material due to high head drop and big void ratio in the rockfill the excessive percolation in grade III made the placement of grade I material at the back of grade III material difficult and so impervious material had to be dumped on the upstream face of the advancing head of the rockfill. It was observed that when the scour at the advancing head of grade II material becomes excessive the stone removed by high velocity jetting flow goes into scour and paves its bed. Advancing of head of closure dam gets accelerated when the scour hole gets paved up with grade II material. At a certain stage of progression of advancing head of closure dam, the scour becomes larger in depth and extent and the velocity of diverging flow becomes so excessive that the material which goes into scour does not stay there and is moved out of the scour and deposits lower down where the flow diverges out and so at this stage a great percentage of grade II material instead of paving the scour paves the river bed lower down and this is signal for start of dumping of grade III material.

The time taken for closures, the quantity of material dumped, the water levels generated upstream and downstream of the embankment were also recorded.

2. Straight Closure Dam

The bed of the diversion channel being at lower elevation than the bed of the right channel, it was observed that when the diversion channel is opened it draws major portion of the right channel discharge and hence in this case a straight closure dam can be raised without any trouble. Similarly the discharge in the central channel being small here also a closure dam could be advanced in straight line. In this test series, therefore, straight closures were attempted on all the 3 river channels. The model data for the three channels was recorded and have been compared with the data of hockey shape closure dam in Table No. I, which show that straight closure in right and central channel is possible but at left channel it means more wastage of material as it was noticed that hockey alignment of Coffer Dam follows the deep scour alignment and so no extra stone was required to pave or fill the scour hole as in case of straight alignment.

3. Test with Dike Projecting out from Left Bank

In this test the stone protection on the left bank of channel was removed and 150 feet

long dike on alignment of straight closure dam with 95 feet top width, projecting straight from the left bank of the left channel was constructed before starting the closure. The first 100 feet length of this dike was in river bed material followed by 20 feet length of grade II material and ending in grade III rockfill for a length of 30 feet.

The right and central channel were closed beforehand, the diversion channel was opened and the model was run for 80,000 cusecs river discharge. When the water levels in all the channels were stabilised, closure was started in the last channel by dumping grade I material from the right bank in a way that the axis of closure dam and axis of dike fall in a straight line. The closure dam progressed towards left in the manner described above. The model data regarding time, quantity of material and water levels is compared with the hockey shape and straight closure in Table I.

Water Levels and Material Quantity

The water levels recorded up & D/S of advancing enclosure Dams during closure top Channel for three tests are plotted in Fig. 5 a,b,c.

The water levels observed on the model upstream and downstream of the three closure dams after closure is effected for the

TABLE No. 1

TARBELA RIVER CLOSURE MODEL

Table showing closure time and quantities of material dumped for different shapes of closure dam in channel No. 3.

S. No.	Shape of Closure dam.	Dam length in feet.	Closure time in hours.	Quantity of material in cubic yards.				
				Grade I	Grade II	Grade—III in cl: dam: on bank		Total
1.	Hockey Stick	942	86	96000	19000	11500	15000	141500
2.	Straight	895	90	93000	23000	7000	15000	136000
3-a	Straight	765	66	67000	8000	12500	..	87500
3-b	Dike	150	14.5	4500	1500	2000	..	8000
	3a+3b.	915	80.5	71500	9500	14500	..	95500

Note:

(*i*) In No. 2 (Straight closure dam) 2500 cub. yards of Grade III Material dumped from top to maintain bank protection on left bank.

(*ii*) In No. 3 (Closure with dike) 1000 cub. yards of Grade III material dumped from top to maintain head of the dike.

three selected discharges are tabulated below :—

Closure dam in right channel (diversion channel kept closed).

River discharge in c.f.s.	Upstream water level	Downstream water level
400,000	1126.2	1110.0
600,000	1128.0	1112.6
800,000	1129.0	1114.1

Closure dam in central channel (diversion channel open).

River Discharge in c.f.s.	Upstream water level	Downstream water level
400,000	1123.5	Bed level
600,000	1125.0	1114.4
800,000	1126.0	1116.1

Closure dam in left channel (diversion channel open).

River discharge in c.f.s.	Upstream water level	Downstream water level
400,000	1130.3	..
600,000	1132.8	..
800,000	1135.0	..

The total quantity of material required or each of the closure dams in straight losure with left bank dike as measured from he model is :—

Right channel .. 52500 cubic yards.
Central channel .. 30500 cubic yards.
Left channel .. 95500 cubic yards

Conclusion from 1970 Model Tests

From the model tests conducted at Nandipur and Grenoble the conclusions arrived at from a hydraulic stand-point are as follows:—

1. The plugs at the upstream and downstream ends of the diversion channel be removed *in toto*.
2. The excavation of the portion of diversion in the river bed did not give any added advantage in closure of left channel where final closure is to be effected.
3. The three grades required for effecting the closure are :—
   (*i*) River bed material.
   (*ii*) 80 to 400 lbs stone.
   (*iii*) Heavy stones between 1100-2200 lbs.
4. The closure to proceed from right to left in sequence of right, centre and left.
5. The banks (opposite to closure dams for channel left and middle) protected with heavy rockfill for a length of 500 feet at site before taking up model studies of Nandipur act as rigid barriers.
6. The closure dams to be aligned straight.
7. A dike with sloping nose (preferably at 1 : 4) of about 150 feet length projecting straight from the bank opposite to closure dam may be provided on the left channel as it is most economical and hydraulically sound and practical.

River Diversion at Site

River diversion at site was initially planned according to model findings. The removal of upstream and downstream plugs of the

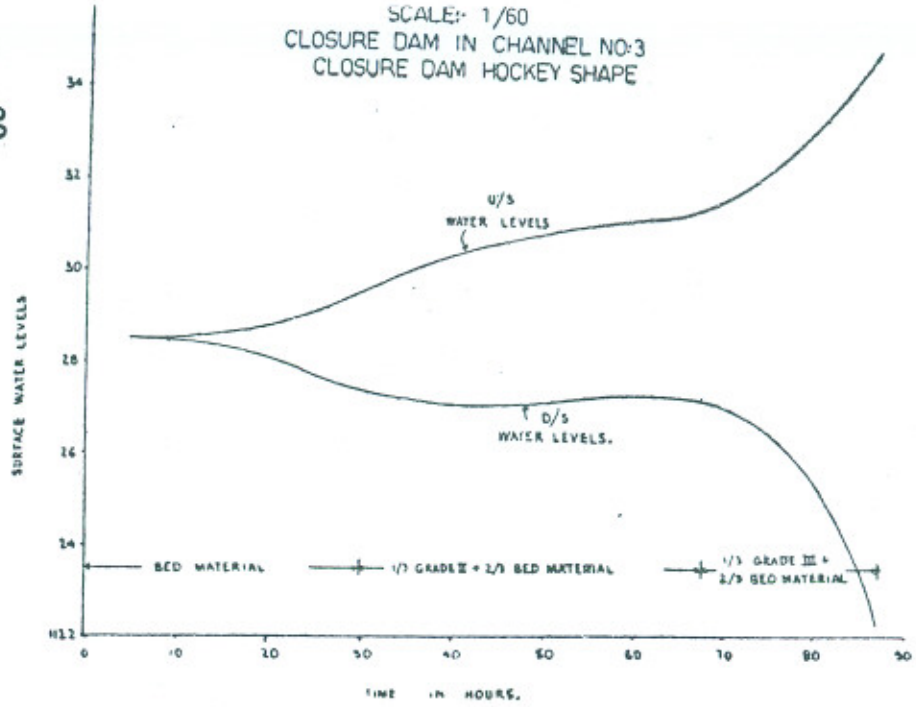


Fig 5. (*b*)

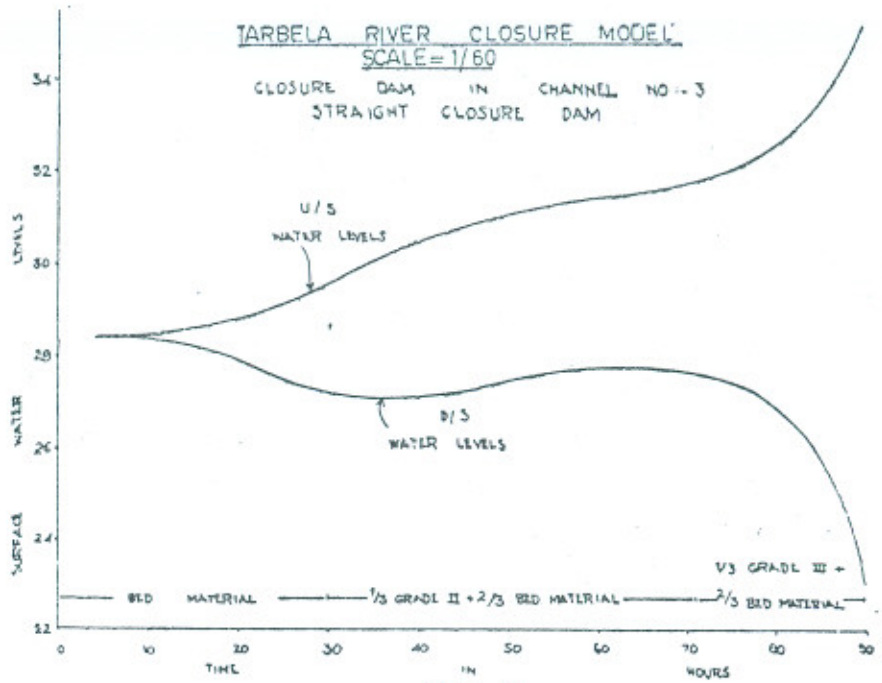


Fig 5. (*a*)

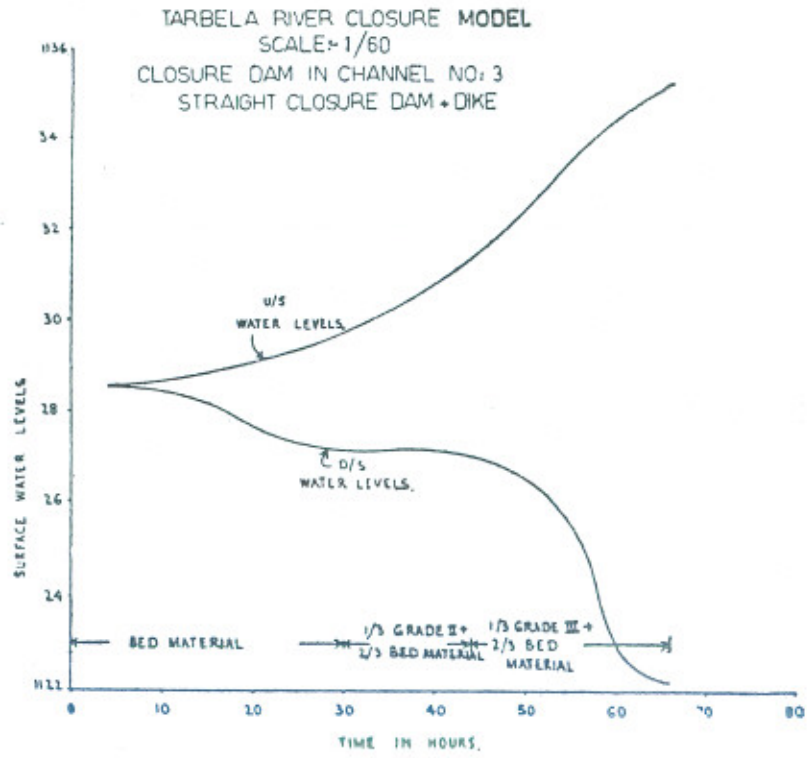


Fig 5 (*c*)

diversion channel was started on 15th September 1970. Unexpectedly a 20 feet thick layer of mud stone was encountered in the plug at entrance of diversion channel which could not be removed with a drag line. It had either to be blasted or removed completely with shovels in dry. Since the blasting was estimated to take more time than available planned, sequence of events had to be modified for removal of plug in dry, by the closure of the right river channel with closure dam 1a downstream and with closure dam 1b upstream of the mouth of the diversion channel as shown in figure No. 2.

Closure of Right Channel

The construction of closure dam 1a started on the 24th of September. The total discharge of the river Indus decreased during closure from 63,300 cubic feet per second to 60,300 cubic feet per second. The partial discharge in the channel to be closed was 20,000 cubic feet per second. The water level upstream of the closure dam rose from El. 1120.0 to El. 1129.7 by 9.7 feet. The opposite bank was protected prior to closure by a length of 500 feet with 11,500 cubic yards heavy boulders. The water level downstream of the closure dam fell from El. 1120.0 to El. 1113.3 by 6.7 feet. The head drop was 16.4 feet. The width of the closure dam measured 95 feet on the crest. The crest elevation measured at R. L. 1130.5 and the length was 400 feet. 69,900 cubic yards rock and 3,600 cubic yards of heavy boulders between 1,100 lbs. 2,200 lbs. were used for the closure. Approximately 30% of the dumped material was washed away because the river bed material consisting of boulder gravel sand contained approximately 15-20% fine materials smaller than 0.15".

Furthermore, impervious material was dumped at the upstream face of the closure dam to increase the water-tightness. The maximum dumping rate was 2600 cubic yards and the closure took 33 hours. After completion the height of the closure dam was increased on a width of 30 feet to a level safe against overtopping due to a flood with the discharge of 170,000 cubic feet per second. (Fig. 2a.) Thereafter closure dam 1a was extended across the island to the middle river channel with cofferdam 1c (see Fig. No. 2) safe against the above flood.

The next step in the operations of diversion was the construction of closure dam 1b upstream of the mouth of the diversion channel in still water, for which 60,000 cubic yards rocks as excavated were used.

After completion of closure dam 1b the closure dam 1a was breached to dewater the area between the closure dams 1a and 1b in front of the upstream plug of the diversion channel. The water level fell from El. 1129.7 to El. 1111.4 by 18.3 feet.

The removal of the upstream plug was completed on the 3rd of October.

For opening the diversion channel a total quantity of 650,000 cubic yards had to be removed within 3 weeks.

On the 5th of October the diversion channel was flooded by breaching closure dam 1b with dozers after closing the breach in closure dam 1a.

Closure of Middle Channel

Starting from evening of 5th October the closure took 18 hours. During closure the total discharge of the river Indus increased from 58,000 cubic feet per second to 90,000 cubic feet per second and decreased after this peak, caused by a heavy rain, to 70,000 cubic feet per second. The maximum partial discharge in the channel to be closed was

TIME IN HOURS.
Fig 5 (c)

22,500 cubic feet per second. The water level upstream of the closure dam rose from El. 1119.5 to El. 1128.6 by 9.1 feet. The water level downstream of the closure dam fell from El. 1119.5 to El. 1116.7 by 2.8 feet. The head drop was 11.9 feet. The crest elevation was increased during closure from El. 1127.5 to El. 1130.0, because the water rose more than expected. The crest width measured 95 feet and the length 500 feet. 35,900 cubic yards rocks as excavated and 440 cubic yards heavy boulders were used for the closure. Approximately 35% of the dumped material was washed away.

After completion the height of the closure dam was increased on a width of 30 feet to a level safe against over-topping by a flood with the discharge of 170,000 cubic feet per second. Fig. 2a.

Closure dam 2 was extended across the island to the left river channel with cofferdam 1a (see Fig. No. 2) safe against the above flood.

Closure dam of middle channel was made watertight in the same way as described for closure dam 1a.

Closure of Left Channel

The opposite bank *i.e.*, left bank of left channel opposite closure bund was paved with 14000, cubic yards of heavy boulders in a length of 500.

The construction of closure dam 3, closing the left river channel, commenced on the 8th. of to October. The closure took 19 hours. The discharge of the river Indus decreased during closure dam 55, 200 cubic feet per second to 51,200 cubic feet per second. The maximum discharge in the channel to be closed was 26,800 cubic feet per second. The water level upstream of the closure dam rose from elevation 1126.0 to elevation 1133.8 by 7.8 feet. The water level downstream of the closure dam fell from elevation 1126.0 to elevation 1121.2 by 4.8 feet. The head drop was 12.6 feet. The crest width measured 95 feet, the length 600 feet and the crest elevation 1136.5, 45,000 cubic yards rocks as excavated and 8,000 cubic yards heavy boulders between 1100 lbs. and 2200 lbs. were used for the closure. Only 6% of the material dumped was washed away, because the river bed in the closure bund area was well paved by nature with closely packed boulders. The average dumping rate was 2,800 cubic yards per hour.

After closure the closure dam 3 and the left bank were increased to a level safe against 170,000 cubic feet per second and made watertight, fig. 2a.

Comparison of Model and Prototype Results

The water level in right channel at closure dam site at start of closure at a total river discharge of 63,300 cusecs was at El. 1120.0 against elevation 1120 observed from model at a total river discharge of 60,000 cusecs.

The initial water level at start of closure in middle channel was observed to be at elevation 1119.5 at a discharge of 58,000 cusecs against 1119.2 observed from model at an incoming river discharge of 60,000 cusecs. The initial water level observed at site of closure in left channel was at elevation 1126.0 at an incoming river discharge of 55,200 cusecs against elevation 1126.6 observed on model at an incoming river discharge of 60,000 cusecs. Thus the agreement between model and prototype was close.

As already mentioned, the sequence of closure originally planned on the basis of model tests had to be changed at the last moment to take out the u/s rock plug at the entrance to diversion channel in dry con-

ditions. The right channel which was originally scheduled to be closed after opening the diversion channel was closed without opening the diversion channel. An additional closure dam 1b had to be placed in the right channel u/s of the diversion channel mouth. The closure dam (1b) was not removed before closing the central channel but was allowed to be washed away by flow and the residual cofferdam resulted in more discharge and higher water levels in the central channel. Moreover the discharge variation in the river during the closure was also excessive. It was 60,000 cusecs during closure of the right channel and increased to 90,000 cusecs during closure of central channel and again dropped to 50,000 cusecs during closure of the right channel.

The dumping rate of the material was 26000 to 2800 cubic yard per hour against anticipated rate of 1000 cubic yard per hour.

The behaviour of the bed of three channel in relation to scouring was also different. The bed of the left channel lined by nature with boulders (Disc shaped placed at a uniform upturned angle) there was almost no scour even at the final stage of closure and the losses of stone were not more than 6%. The roughness of bed of diversion channel was also not truly represented on model.

All these factors had a significant influence on performance of model and the prototype. The model data as regards water levels head drop and material quantity is compared with the prototype data below.

The closure of left channel which was drawing 26800 cusecs at the time of closure (when the total incoming river discharge was 55,200 cusecs) did not present any particular problem as opposite bank was protected with heavy boulders, bed of this channel at this site was ideally paved by nature, average dumping rate was 2800 cubic yards per hour, heavy boulders between 1100—2200 lbs. were used for final gap, heavy stone was bulldozed from both banks when final gap was being closed and the diversion channel had a large capacity (750,000 cusecs) and its bed was at a level lower than bed of river at intake of diversion channel.

	Prototype	Model	Difference
Right channel:			
U/S water level El.	1129.7	1128.1	+1.6 ft.
D/S water level El.	1113.3	1114.0	—0.7 ft.
Head drop elevation	16.4	14.1	—2.3 ft.
Quantity of C : Yard.	69,900	52,000	+17400
Central channel:			
U/s water level El.	1128.6	1126.0	—2.6 ft.
D/s water level El.	1116.7	1116.1	+0.6 ft.
Head drop elevation	11.9	9.9	+2.0 ft.
Quantity of material C : Yard.	35900	30500	+5400
Left Channel:			
U/s water level El.	1133.8	1132.2	+1.6 ft.
D/s water level El.	1121.2	1121.6	—0.4 ft.
Head drop elevation	12.6	10.6	+2.0 ft.
Quantity of material dumped in C : Yards.	53000	95500	—42500

Should Pakistan be enthusiastic About $6\frac{1}{2}\%$ International Loans for Road Projects?

By **R. E. BURNS,**
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This Memorandum was submitted by a foreign consultant while working with Transport Planning Cell of the Planning and Development of the Government of West Pakistan. This article is being published with the express consent of the author and its copyrights are reserved. The article brings out interesting features of strategy of loans for road projects and should serve as a useful guide to the Engineers and Planners for the formulation of future policies.

In the recent past primary emphasis was put on maximizing the amount of foreign financed projects in Pakistan. Not only were proferred loans not refused, but an inordinate amount of effort to develop 'loanable' projects was expended. West Pakistan was reasonably successful in developing such projects and the results are now being felt in terms of repayment of past foreign "aid". The burden of these repayments have come as a surprise to some planners leading to the conclusion that there seems to be some confusion concerning the difference between a grant and a loan. This confusion has recently been cleared up as the consequences of past loans have become apparent particular in the case of India and Indonesia. These countries have reached the point where the inflow of foreign "aid" just covers the repayment of past aid. In theory at least the economic growth stimulated by the earlier investments should easily have covered the repayment requirements. The increasing ratio of foreign exchange indebtedness to foreign exchange earnings indicates that this may not be the case. This means t[illegible] for one reason or another that some of the past "loanable" projects have probably been bad ones.

Macro economists who take a broader more general view of the development process rightly emphasize the importance of loans on foreign exchange from international lending agencies. Implicit in their desire for these loans is the assumption that they are to yield rates of return far in excess of the rate of interest charged on the loan. Since they are not micro economists or practical men in terms of project design and implementation they emphasize the need for 'loanable' projects. Who then is to undertake the mundane task of seeing that loanable projects

are also good ones yielding high rates of return? In the case of roads the highway department is chiefly interested in building roads quickly and making demonstrable progress in doing so. As engineers they have no real expertise in insuring the economic goodness of a project. They are rightly interested in the technical goodness of the design and construction. The lending agencies themselves have taken on the primary task of ensuring the goodness of a project by conducting a formal economic feasibility study before making a loan, and engage consultants to do so. There are however two serious problems with this approach other than the normal uncertainty involved in such an analysis. The first is that the existing system of incentives to consultants strongly encourages that the project be judged a good one. The second is that the representatives of the lending agency who's very job depends on the location of some loanable projects has an incentive to find some. With such a system of incentive the implicit assumption of the marco economist *i.e.*, the project is a good one, is not always fulfilled. There is then no truly independent individual to represent the interests of the future generations who must pay back the loan.

The Transport Planning Cell in the Planning & Development Department have taken on this responsibility among others. In discharging this responsibility they have been able to search for good road investment projects outside the ordinary system of incentives. Perhaps their major accomplishment in the past two years has been the identification of a large amount of extremely good road investment projects which involve the widening and reconditioning of existing roads with largely underutilized domestic resources. The economic goodness of these projects can be established to meet the most exacting economic criteria of the international lending agencies yet they have been met with something less than enthusiasm, both on the part of the lending agencies, the implementing agencies, and in some cases the marco economists in search of more foreign exchange inflows.

The reasons for this reluctance go to the heart of the problem of development. To begin with, the dominance of the marco economists in the planning process in Pakistan has led to a feeling that the important and interesting work has been accomplished once the public sector allocations have been made at the sectoral level. The assumption that good projects have been prepared and more importantly will be implemented is open to serious question. The almost total lack of interest in screening and effectively monitoring development projects is evident by visiting either the projects wing in the central planning commission or its counterpart in the provincial planning departments. This is understandable since it is relatively easy to train a half dozen young men as macro economists, but quite another thing to develop an entire set of sophisticated institutions to see to the actual development and implementation of plans. The use of foreign consultants and advisers to help develop and screen loanable projects is to some extent implicit recognition that this is an important area of endeavour. However, the emphasis on foreign aid inflows generated at the level of the macro economist continues to make its impact felt at the project level with the important assumption of the goodness of the project not receiving the attention it deserves.

The lack of enthusiasm of international lending agencies for a widening and recondi-

tioning program springs from the fact that it is not a "clean" project in the sense that it does not fit their current definition of a loanable project regardless of the potential return on the investment. The very assets that make such a program enormously beneficial to the province mitigates against its being accepted as loanable. Because the existing alignment utilized and the comparison of the improved cross section with existing one makes crude quantity estimates feasible and reduces the engineering required, it does not meet the engineering standards of the international lending agencies. Because the rate of return is so high (usually in excess of 40 percent) it does not require a sophisticated feasibility study, not meeting the requirements of the economic criteria of the lending agency. Because the construction is crude and labor intensive it can best be done by the domestic construction industry, not meeting the requirement of international competitive bidding required by the lending agency. Because of the non-lumpiness of the investment, its flexibility, and immediate benefits proportional to implementation, it cannot be fit into a well defined project. Such a program requires much more sophistication on the part of the lending agency while a clearly defined self liquidating toll road built to high standards requires almost none. Thus what is potentially the best investment strategy receives no support from the agency most capable of making it a good project in the eyes of the macro economists.

The implementing agency, the highway department in this case approaches the issue with somewhat mixed emotions. While widening and reconditioning has been successfully carried out to a relatively minor scale it is not clear that the department can generate the organizational effort necessary to complete say 300 miles of major improvements per year. Such an attempt would require the decentralization of responsibilities. Assistant Engineers would have meaningful responsibilities for a ten or fifteen mile section of major road improvement. Superintending Engineers would have to plan the arrival of inputs on a scale not attempted before in the province except by foreign engineers. Labour would have to be recruited and organized on an equally larger scale. Contractors capable of using basic machinery such as road rollers, lorries, and bitumen sprayers would have to be encouraged. The major foreign exchange input, simple machinery would not likely be forthcoming. For lack of this the entire program could be disastrous. International lending agencies are usually not sophisticated enough to consider the financing of the importation of road rollers and bitumen sprayers for such a program to be a loanable project. On the other hand, far more sophisticated machinery utilizing much less labor quickly comes in under a loanable project organized by foreign engineers. High cost Western standards also come in under the loan. It is small wonder that the highway department is largely organized to generate loanable projects relegating their own engineers to a minor role, and discouraging the development of a labor intensive domestic construction industry. The price for these loans is large, not only in terms of premature investments, high cost Western standards, and high interest rates, but perhaps more importantly they put off the day when local responsibility for successes and failures can be accepted by local engineers and contractors. It is extremely comforting to blame the failures on the foreign consultants and engineers. The price that is being paid for this luxury is becoming very high.

Recognizing these problems the government of West Pakistan had moved to deal with them by setting up the Transport Planning Cell, by making widening and reconditioning a major investment in the Fourth Plan, and by requesting the international lending agencies to increase their loan sophistication by financing the importation of crude road building equipment. Perhaps even more important the highway department has recently completed some widening and reconditioning to quite high standards on the road between Sheikhupura and Lyallpur. The general highway consultants in co-operation with the highway department has recently carried out an extremely important experiment on the road between Bahawalpur and Multan. They have prepared engineering estimates and drawings for widening and reconditioning to a standard acceptable by the international lending agencies. This has been done entirely by domestic resources in a few weeks time. This experiment should receive the highest support and encouragement.

While macro economists may not be interested in the details of the argument they are familiar with the concept of import substitution *i.e.*, the substitution of domestic goods for those previously imported. Road engineering and construction have a great potential here since roads in West Pakistan are relatively simple to construct and a large corps of underemployed engineers exist in the field. The road transport revolution is only beginning and unless the highway department and the domestic construction industry are forced to play their roles the importation of roads will become a major foreign exchange cost to the country. While widening and reconditioning will serve many of the road investment needs now, the next ten years will see the need for major new construction of multi lane facilities, especially in the Lahore-Rawalpindi corridor. If the finance department can be persuaded to give the highway department a fraction of the cooperation that foreign engineers and contractors receive, there is no reason that a domestic road engineering and construction capability cannot be developed. By developing on a widening and reconditioning program the industry will be ready for the larger, more sophisticated program to come.

In answer then to the question posed in the subject heading it would seem that any loan preferred by an international lending agency at commercial terms should be scrutinized by asking the following questions :

1. Has the alternative of widening and reconditioning been considered. If so what is the return on such an investment?
2. How objective has the analysis been? Has it been scrutinized by a competent outside analyst?
3. What is a realistic estimate of the rate of return on the investment? Can a 15 percent rate of return be safely assumed?

Even more important is the necessity to consider the loan in terms of the present credit worthiness of the government concerning its outstanding loans taken in the past. A case could however be made that it will soon be acceptable internationally to default on the debt repayments as seems likely for some countries. In that case Pakistan should get its share also when past loans do indeed become grants.

But even this strategy must be viewed in the light of its impact on the engineering and

road construction industry that is retarded in its growth due to a willingness to take the easy road in the short run. Such a strategy has external diseconomies associated with it that don't appear in the formal feasibility studies.

This does not mean that loans for road construction should not be accepted. It means that the nature of the loan should be such that it will have a favourable impact on the development of a domestic capability. In this respect equipment loans would rate the highest. Loans for widening and reconditioning open to international competitive bidding with engineering done locally would rate second. This might be the best strategy for the Hyderabad-Multan section which desparately needs improvements but not to Western standards. Last of all would be the conventional package loans of the past with imported technologies standards, and engineering.

Design of Louvers by Sunbreak Protractor

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INTRODUCTION

Sunshades and louvers are a common sight in modern buildings in tropics. Although they appear to be of mere aesthetic value to a layman but in actual fact they are required to perform a definite function, especially in tropics where thermal comforts of inmates is of primary importance in building design. In the cold regions of tropics, the buildings must admit sunshine into the rooms throughout the year which generally does not call for any kind of louvers; while in Hot Arid zones, it is necessary to exclude the summer sun from entering the building and to allow the winter sun to enter the rooms for better thermal comforts. The louvers design for equatorial humid zones where Winters are only but mild, have to be such as to exclude the Summer as well as the winter sun. Fortunately, the Solar Path at the Equator is symmetrical and does not change its hemisphere from North to South or vice versa on any particular day and therefore the problem of excluding the sun from entering the building is somewhat easy to tackle. But as we approach tropics, the Solar Path changes its hemisphere in a day. For instance, in the Northern hemisphere, the summer sun is Northerly in the mornings and evenings and southerly throughout the day. Therefore, louver design becomes more difficult in tropics.

The method of designing louvers developed about twenty years ago involves using of Shadow Angle Protractor with Solar Charts to get horizontal and vertical shadow angles of the sun from which the depth of projection is calculated by trignometry. The Architects' work becomes laborious when he has to consult trigonometric functions to work out depth of projections for various dimensions of windows and verandahs. Consequently, the Architects usually tend to skip over this labour and rely on guess work leaving the users to face the consequences. In view of higher expense involved in construction of louvers, it is important to see that they really perform the function for which they are meant. This must be ensured while the building is in a design stage. In other words,

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there is a need for simplifying the work of the Architect and Designer so that he can quickly and easily check the efficiency of design to give the best value for the money proposed to be spent.

It is in recognition of the above need that the Building Research Station, Lahore, has introduced a new type of Protractor called "Sunbreak Protractor" which, instead of shadow angles, gives directly the trace of shadow a particular overhang casts, thus eliminating all calculations. The dimensions of overhangs on the Protractor are given in terms of 'rating' which is defined as the projection that would shade a unit length. The horizontal rating is used for horizontal overhangs and vertical rating for vertical projections. The Sunbreak Protractor is shown in Fig. 1.

Louver Design

Take appropriate Solar Chart representing the latitude of the place under study and place the Protractor concentrically on the chart so that the arrow on the Protractor points towards the orientation of wall as read on the Solar Chart. The vertical rating line and horizontal rating curve which together (or independently) envelop the Sun Path of desired seasons and required hours within its base can be read on the transparent protractor to get the dimensions of projection. For instance, the vertical and horizontal rating to eliminate summer sun from a window facing 30° west of south at a place having a latitude of 28°N, comes to

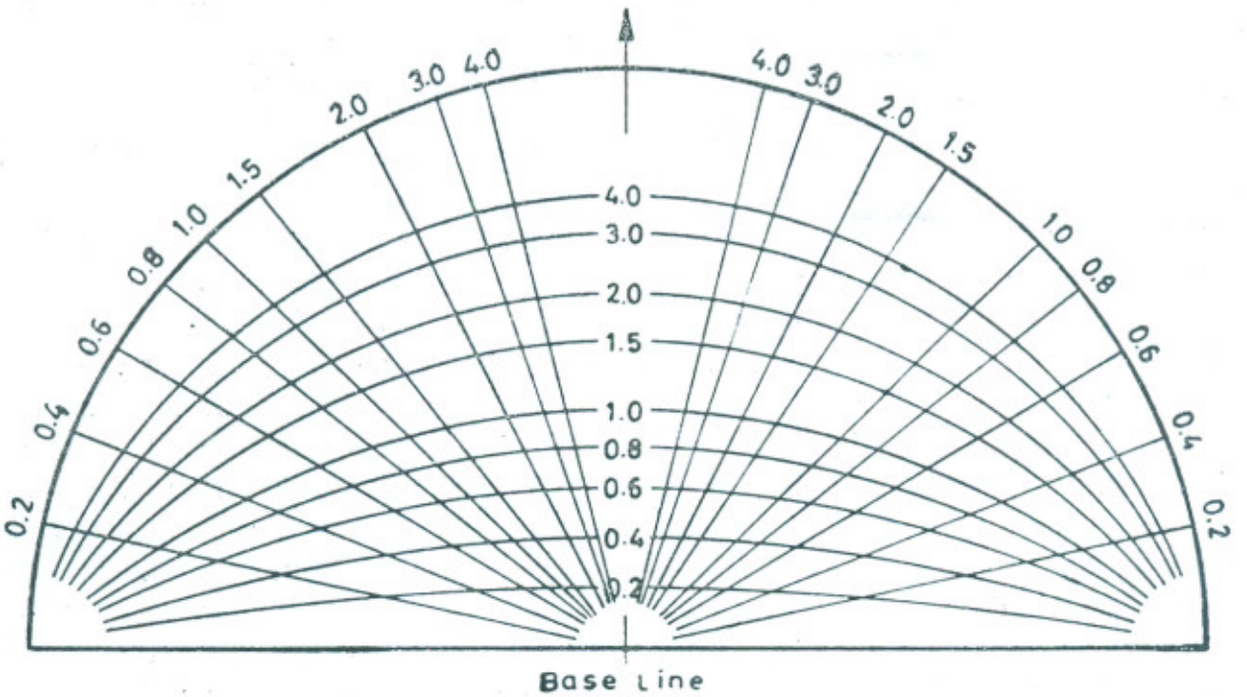


Fig. 1 Sunbreak Protractor — To be placed concentrically on the appropriate solar chart so that the arrow points towards the orientation of wall as read on the solar chart. The radial lines indicate the vertical rating and curved lines give horizontal rating of overhangs. The rating line which envelops the sun path of desired month during desired hours within its base line can be read off.

1.0 and 0.75 respectively as shown in Fig. 2. If the size of window is $4\frac{1}{2}$ ft.$\times 4\frac{1}{2}$ ft., the vertical louver required will be 4.5 ft. (=4.5×1.0) deep, while the horizontal overhang will be 3.5 ft. (=4.5×0.75) wide. Such a combination of louvers having different projection for vertical and horizontal overhangs may be unsightly for an individual window and can be avoided by placing intermediate louvers. Furthermore, the depth of overhangs being on the high side, the construction cost will be extremely high which too can be reduced by placing intermediate louvers. If the depth of projection

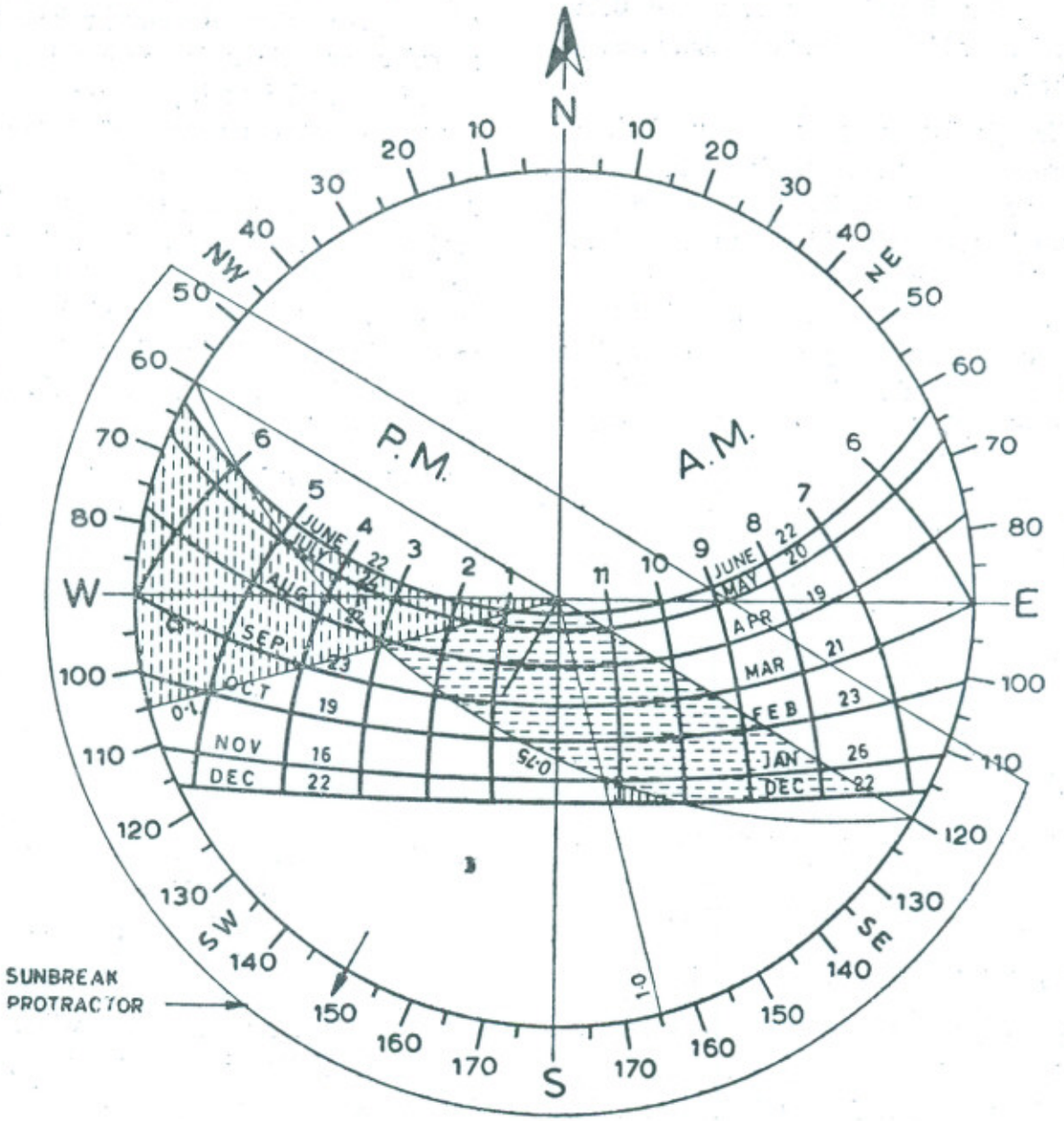


Fig. 2 Sunbreak Protractor placed in the orientation of 30° West of South on solar chart of 28°N. The vertical and horizontal hatchers respectively indicate times during which a vertical or horizontal overhang will obstruct the Sun. It will be seen that rating 1.0 (vertical) and 0.75 (horizontal) is required to eliminate summer sun.

is restricted to 1.75 ft., it will shade a width of 1.75 and a height of 2.33 ft. (=1.75÷0.75). In order to fully shade the window $4\frac{1}{2}$ ft. wide and $4\frac{1}{2}$ ft. deep, one would require two intermediate vertical louvers and one intermediate horizontal louver. This will give a box type louver system having vertical and horizontal rating of 1.16 and 0.78 respectively which is better than that actually required.

Although for more accurate work it is necessary to convert magnetic North to true North and standard time to local time but in actual practice it will be seen that these corrections may not materially alter the design of louvers. It may be remarked here that the Sunbreak Protractor does not give only one particular dimension of overhang for a given orientation ; it gives a wide choice while the judgement of selection rests with the Engineer or Architect. The cardinal point in selection of an overhang lies in the fact that it should have the smallest rating value merely for economic considerations because larger rating requires deeper projection at higher construction expense. The Sunbreak Protractor is expected to be a useful addition to Architect's tools of designing buildings. The difference between the diameter of Protractor and the Solar Charts is due to differential shrinkage of the paper and polythene which can be ignored.

Preferred Orientations in West Pakistan

The use of Sunbreak Protractor will show that East and West orientations are extremely difficult to treat and solar heat cannot be completely eliminated even with very deep overhangs due to low altitude of Sun. The only way to eliminate the Summer Sun is to provide louvers that are inclined at 45° with the face of building towards South, besides horizontal overhangs. This gives rise to a complicated louver system but cannot be avoided. It will still be cheaper than providing deep verandah in the hope of eliminating the hot Summer Sun which infact it does not.

North orientation is tolerable but it will allow penetration of summer sun in the mornings as well as in the evenings which must be cut off by adequate vertical projections. During the course of the day (say from 9 a.m. to 3 p.m.), the Sun dips towards South and does not require any horizontal projection in North orientation. Therefore, North face will be quite cool in Summer if vertical Sunbreakers are used but it may tend to be very cold in Winter due to Northerly winds and complete elimination of sun during winter.

The South orientation is probably the best for upper regions of West Pakistan (where Summers are hot and Winters cold) but horizontal overhangs will be found necessary to keep the wall or window under shade during middays of Summer. Fortunately, the Winter Sun is not interrupted by the horizontal overhangs in the South orientation due to its lower altitude and as such South orientation should be preferable for living and bed rooms. It will also be seen that within 5° East or West of South, the dimension of overhang required are quite small and therefore economical to treat.

The North-West orientation will be most uncomfortable during summer especially between 13.00 hours to sunset which is the hottest portion of the day and unfortunately this hot Sun can only be stopped by vertical louvers with a rating of 3 or above which will also eliminate the much wanted Winter Sun besides increasing expense. On the

contrary, the South-East orientation will admit Summer Sun from sunrise to about 13.30 hours which can be partially interrupted by horizontal overhang of rating 0.75 but for complete elimination it will be necessary to provide vertical louvers of rating 2 in addition to the horizontal overhang. This orientation is better than North-West in the sense that it will provide some warmth in Winter mornings even with the louvers.

The South-West orientation is equally warm in Summer between 11.00 hours to Sunset but it can be substantially improved by adding vertical louvers of rating 1.5 and horizontal overhangs of rating 1.0. As regards North-East orientation, it will admit summer sun up to 11.00 hours which can be substantially eliminated with vertical louvers of rating 2 or more but this will also eliminate Winter Sun. However, if only a horizontal overhang of rating 1 is pr ovided, substantial improvement will be possible without interrupting the early morning Sun in Winter as well as Summer.

Summing up, North-South orientation should be preferred for houses in all the dry regions of West Pakistan. The least used rooms *i.e.*, drawing and dining, may be located in the Northern side with a series of vertical projections to protect the wall or windows. The most frequently used rooms *i.e.*, bed rooms and living rooms, should be located on the south side with a series of horizontal overhangs for protection. The south verandah on the back side will be extremely useful to protect during Summer and serve as a sun room during winter. The North-West orientation must be avoided even if it may mean placing of a building diagonally in a plot. The recommended louvers for some of the cities in West Pakistan for eight cardinal directions are given in Table 1.

TABLE 1

Louvers required for various orientations in Lahore (*also applicable to Bannu, D. I. Khan, Gujrat, Gujranwala, Jhang, Jhelum, Lyallpur, Mianwali, Sargodha, Sheikhupura and Sialkot*).

Orientation	Type of louvers required
North ..	Vertical louvers 1 ft. wide and 2 ft. apart.
South ..	Horizontal overhang 1 ft. wide and 3 ft. apart.
East and West ..	Vertical louvers (but pointing towards South-East or South-West), 1 ft. wide and 13½ in. apart along with horizontal projections 1 ft. wide and 2½ ft. apart.
North-East ..	Horizontal overhang 1 ft. wide and 1 ft. apart.
South-East ..	Vertical louvers 1 ft. wide and 6 in. apart along with horizontal louvers, 1 ft. wide and 15 in. apart.
North-West ..	Vertical louver 1 ft. wide and 4 in-apart.
South-West ..	Horizontal louver 1 ft. wide and 1 ft. apart along with vertical louver 1 ft. wide and 8 in. apart.

NOTE :—All projections are measured from plane of window and distances between louvers are given as clear distances irrespective of thickness of louvers.

The Functional Requirements of Windows with Particular Reference to the Prediction and Control of Sunlight Penetration

By **PETER R. SMITH***

The multiple functions traditionally associated with a window are discussed in the light of modern building services and constructional techniques. Research in several countries concerned with the requirements of windows in relation to view, light, sunshine and privacy is described, and a similar project concerned primarily with sunshine, proposed by the author, is introduced.

In an Appendix, current methods for predicting sunlight penetration are described. A computer program developed by the author for presenting the information on sun penetration into a room in graphical form is described.

The Functions of a Window

Of all the functional elements of a building fabric, the window is the one whose function is least clearly defined. In hot climates it seems to have developed as an opening for light and ventilation, often covered with an opaque shutter; in the colder climates windows were of limited value until the introduction of glass, to admit light while controlling ventilation.

The invention of transparent glass and the means of assembling it into large transparent sashes opened the way for the use of windows as part of the aesthetic of the interior, bringing abundant light into a room and adding the view of outside gardens or courtyards to the interior visual scene. At the same time, the use of transparent glass broke the technical interdependence of light and ventilation, which was a product of the hole-and-wooden-shutter technology. Yet these two functions are still linked in the use of most conventional opening windows, and in many building regulations which specify the requirements for windows to supply light and ventilation.

If we put light and ventilation as the principal functions of a window, what happens when we have a modern building in which both these functions are also performed by parts of the building's services? The idea of parallel systems performing the same function is not new, since it is common to

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use elevators, escalators and stairs in the same building.

While these three systems of vertical transportation can be expected to share the total load, the same is not usually true for the windows and air conditioning systems, and only partly true for the natural and artificial lighting. Which of the systems performs the job best will depend largely on our definition of "best".

A system of artificial lighting and air conditioning, if it is elaborate enough, can reproduce or improve upon just about any set of natural conditions. In practice it would have been designed to produce fairly steady conditions which are designed to be comfortable for most of the occupants. At the same time it permits the use of good thermal and acoustic insulation to keep out the variations of outside heat, noise, gusts of wind and the like. In contrast, an openable window provides a variety of these phenomena as well as a view outside, sunshine penetration and "visual contact" with the outdoors.

The Application to Architecture

Where does all this leave the architect, faced with the least understood of all decision-making processes: the necessity to make some decision, whether there is information to use in making it or not, simply to complete the design?

The chances are, he will choose to put in windows because a windowless building does not appeal to him. He may proportion them on the basis of appearance, either outside or inside, and add sunshades or blinds or curtains to provide for some adjustment.

To tackle the question more scientifically, than this, is not easy. In the absence of a direct-design method, the usual trial-and-error procedure is a circular one, using the performance criteria as a basis for proposing a solution; analysing the performance of the proposal; comparing this with the criteria and accepting or modifying the solution. In the case of the window it is soon realised that many tools exist for the analysis (and research is still being directed toward improving them—some are outlined in the Appendix) but the acceptance criteria are largely undefined.

What do we know about these criteria?

In any but very cold climates, the air conditioning engineer will ask for external protection from sun penetration. This is not an absolute requirement but it is one that can be clearly stated, and is therefore likely to be honoured if the building is air conditioned. If there is air conditioning or heating, good insulation (such as double-glazing) is an advantage for both heat and sound control. To compare the extra capital cost with the saving in fuel bills is an accounting exercise and is often done. The advantage of quietness is difficult to evaluate and therefore is not often considered.

The window must be resistant to water penetration, wind penetration, and unauthorised entry in its closed position. The architect is familiar with these things and takes account of them automatically in his construction detailing.

If natural light is to be relied upon for all or a substantial part of the working illumination, then means exist to calculate daylight factors and probable levels of illumination in the room. In this case the windows can be "designed". If natural ventilation is to be relied upon, the means for designing the openings for it are much less satisfactory than in the case of lighting, but a design is

possible. It is often found that the window, in its usual form, is an inappropriate opening for letting air in and out.

Since something is known about the matters listed above, they are likely to be weighted more heavily in any conscious design decision than the matters about which less is known—sunlight, view, and privacy. The arguments in favour of a rational design process rather than an intuitive one stand on the grounds of factual knowledge, in both qualitative and quantitative senses, about all aspects of the subject. When knowledge exists about only some aspects but not about others, then the intuitive design may have a lower probability of error than a design based solely on the rational use of the available knowledge. There is a case, then, for pursuing the question of the functional requirements of windows so that some criteria can be established in the less-known fields.

Sunlight, View and other Uses of Windows

These questions are now beginning to receive attention. The work of Bitter and van Ireland in the Netherlands (Ref. 1) in 1960 sought the opinions of housewives on the insolation of their houses, and found that most valued sunlight highly, preferring sunlight to a fine view from their living room. These results are sufficiently interesting to suggest that similar studies should be undertaken in warmer climates.

In the U. K., attention has been given to these problems by Markus (Ref. 2), Keighley at the Building Research Station, Cuttle at Pilkington Bros., and Brierley at the Building Performance Research Unit at Strathclyde (Ref. 3). Professor Markus has pointed out the importance of the "information content" of the view through a widow, which depends on the relative positions of the observer, the window, and interesting parts of the view outside. He also demonstrates the different patterns of sunlight received through windows of different shapes.

Brierley's work is concerned with low-rise, high-density housing, and one of the indications is that a reasonable spacing of these buildings for privacy will automatically allow sufficient sunshine in most cases. However, he describes the highly complicated interactions of sunshine, daylight, privacy, view and situation on overall occupier-satisfaction in this type of housing.

The Building Research Station and Pilkington Bros. are both investigating preferences for window size, shape and location in large landscaped office layouts, using models of about 1 : 12 scale into which the observer can look from one side. Preferences can be determined by allowing the observer to vary or choose one of several parameters. The view is back-projected on a screen a little way outside the windows, and several different views are available; the size or shape or location of the windows may be varied (in the case of the B. R. S. model, this is done by the subject at the press of a button); the intensity of the interior lighting can be controlled.

At present, there is no provision for sunlight penetration into these model offices, although the outside "view" could easily represent a sunlit or shaded or overcast condition.

The author is planning a complementary project, to be carried out in Australia, in which a survey will be made of both domestic and commercial buildings to investigate the attitudes of the occupants towards the sun penetration and view provided by their windows. At the same time observations will be made of the use which is being made