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" THE EFFECT OF ANGLE ON SEDIMENT DISTRIBUTION IN CANAL OFF-TAKES"

was submitted by

Sri Ram Swaroop Gupta (Secondus)

and accepted for the award of Degree of Master of Engineering in

DAM DESIGN, IRRIGATION ENGINEERING & HYDRAULICS

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(S.S.Srivastava)
Assistant Registrar (Exam.)

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THE EFFECT OF ANGLE ON SEDIMENT DISTRIBUTION IN CANAL OFF-TAKES

By

RAM SWAROOP GUPTA

M.E. THESIS

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF ROORKEE,
ROORKEE, INDIA
OCTOBER 1962

-: CERTIFICATE :-

Certified that the dissertation entitled "THE EFFECT OF ANGLE ON SEDIMENT DISTRIBUTION IN CANAL OFF-TAKES" which is being submitted by Sri R.S. Gupta, as a partial fulfilment of the requirement for the degree of Master of Engineering in Dam Design, Irrigation Engineering and Hydraulics of the University of Roorkee is a record of bonafide work carried out by him under my supervision and guidance. The results embodied in this dissertation have not been submitted for award of any other degree or diploma.

This is to certify further that he has worked for a period of about six months from April 20, to October 17, 1962 for preparing the dissertation at the University.

20/10/62

Dated October 17, 1962.

(A.G. Mirajgaoker)
Reader in Civil Engineering,
Civil Engineering Department,
University of Roorkee,
ROORKEE, U. P.

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-: SYNOPSIS :-

This thesis reports the experimental studies conducted to investigate the effect of the angle of offtake on sediment distribution in channels. The main channel flume was 3 feet wide and 20 feet long and the offtake channel was 15 in. wide. Five different offtake angles 30°, 60°, 90°, 120° and 150° were studied with a fixed quantity of sediment fed at the head of the parent channel for three channel discharges. At very low discharge when the sediment movement was insignificant, red beads were used to get an idea of sediment distribution pattern.

It was found that the 30° offtake angle was the most efficient in comparison with the other angles studied. It was also observed that the sediment shared by the offtake channel was not in proportion to the quantity of water allowed in the offtake. In all the cases, the sediment share in offtake was more than the discharge shared by the offtake. The existance of a centrifugal force at the offtake has been verified which was least for the angle of 30° at 10% discharge of the parent channel.

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LIST OF FIGURES.

LIST OF FIGURES.

LIST OF SYMBOLS.

Symbol.		Definition.	Dimension(MLT)
b	-	bed width of offtake.	L
d	-	depth of flow.	L
F	-	Centrifugal force	$ML^{-3}T^{-2}$
G	-	Sediment charge	-
G_b	-	% bed load in offtake	-
G_m	-	% bed load in parent channel	-
g	-	Acceleration due to gravity	LT^{-2}
h	-	difference in elevation	L
r	-	hydraulic mean depth	L
P	-	centrifugal pressure	$ML^{-1}T^{-2}$
Q_m	-	Discharge in ~~offtake~~ parent channel above the point of diversion.	L^3T^{-1}
Q_b	-	Discharge in offtake	L^3T^{-1}
R	-	Radius of curvature of flow filaments at pt. of diversion.	L
R_1	-	Radius of the inner bank from the reference axis.	L
R_2	-	Radius of the outer bank from regerence axis.	L
S	-	Slope of bed	-
V	-	Velocity of flow	LT^{-1}
V_B	-	Velocity on barrage	LT^{-1}
V_P	-	Velocity in pocket	LT^{-1}
V_R	-	Radial velocity	LT^{-1}

LIST OF SYMBOLS.

Symbol.		Definition.	Dimension.
V_t	-	Tangential velocity.	$L T^{-1}$
W	-	Weight of water	$ML^{-1} T^{-2}$
X	-	distance from reference axis	L
Z	-	difference in elevation between inner bank and at entrance a distance X	L
θ	-	Angle of offtake	-
γ	-	Unit weight of water	$ML^{-2} T^{-2}$
ρ	-	Mass density	ML^{-3}
τ	-	Tractive force.	$ML^{-1} T^{-2}$

1
INTRODUCTION

INTRODUCTION.

Diversion of water from alluvial streams into irrigation channels, presents many difficult problems to a hydraulic engineer. The stream water carries lot of sediment with it which is the main source of all the problems. The canal sections have to be designed in such a way that the sediment neither gets deposited nor gets scoured out from bed and banks. At points of diversion, the branch channels should take water as well as proportionate sediment from the parent channel, otherwise if the sediment taken by branches is less, the channel capacities get reduced and the supply of downstream users gets affected. The design and orientation of channels should be such that the quantity of sediment entering a canal system should be carried forward, get proportionately distributed in branches and finally ejected through out let works.

When the canal draws heavy silt load, it tends to become shallow, and thereby its water carrying capacity is substantially reduced. To maintain, the water carrying capacity of the channels, it is necessary to remove the coarse bed load deposits by dredging. The cost of removal is one of the largest items in operation and maintenance of canals. It can be seen that the cost of silt removal from such canals, will substantially be reduced if some effective methods are employed for preventing the entry of silt in offtakes.

The design of silt controlling devices at diversions is being studied since many years in India, Egypt, and America, but no perfect method has yet been deviced. Model studies at various hydraulic and irrigation research stations have given solutions to particular problem, which have been found to be fairly effective.

One of the several methods of controlling the entry of sediment in an offtake channel is its proper orientation to the parent channel. The canals taken off from the sukkar barrage, have shown that the orientation of an offtake, can have a great influence in silt carrying capacity. It is established from model studies and field experience that an offtake at right angles to the parent channel does, in no way, help in preventing or excluding the sand.

The problem, as such, recognizes that the proper orientation of an offtake at diversion will be a guiding factor in controlling the undesirable entry of silt into canals.

The objectives of the present investigation are :-

1. to report all the suitable methods employed for sediment ejection, and exclusion from canal offtakes.

2. to conduct experiment on five different offtake angles in order to find the effectiveness of the angle of offtake

on silt carriage. The angles adopted for different orientations of the offtake channel were 30°, 60°, 90°, 120° and 150°.

3. to study the effect of discharge variation on the division of the bed load.

4. to study the effect on the distribution of bed load with the change in the properties of bed material.

The study was conducted under the following conditions:-

1. The discharge in the flume was limited upto a maximum of 0.96 cusec and varied from 0.46 to 0.96 cusec.

2. Two types of materials, sand and red beads were used as bed load. The non-cohesive sand of the median dia. of 0.69 mm and the red beads of dia., 1 mm. to 2 mm. were used.

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2
REVIEW OF LITERATURE

REVIEW OF LITERATURE

Several attempts have been made both with the aid of model studies as well as by theoretical investigations to analyse the problem relating to the proportional distribution of bed load at canal diversion or offtake. Much criticism has been labelled on the obliquity of an offtake, because of the traditional way of putting them at right angles. More recently, the engineers realized that the proper orientation of an offtake plays an important role in preventing the undesirable entry of sediment into diversion works.

The problem of excluding the coarse bed load at diversion with suitable orientation of an offtake has received the attention of a few field workers and investigators. This is probably due to the large number of variables influencing the problem of sediment entering into canal offtakes.

A careful study of all the available information on the subject shows that enough attention has not been devoted by the earlier research workers on the angle of offtake,* theory. Concentrated efforts aided by modern laboratory technic has yielded a little information towards this approach.

The Arab engineers were probably the first to realise the effect of angle of offtake on the sediment entry in diversion works. In a report dated 1891, Colonel Ross(6) wrote that the Arab engineers kept the following rules in mind while alligning their canals.

~~Numbers in parenthesis refer to numbers in the References.~~

1. The offtake should be at the point on the outside of the curve where deep channel flows.
2. Wherever the course is curved the channel head should be aligned tangential to the general curve of the main current. This means the downstream inclined offtake.
3. Where the river course is straight, the canal head should be at an acute angle. This also means the downstream inclined offtake.
4. The head should not be located at a point where a bar is forming i.e., the silting is taking place.

Bulle , in 1926 .

In 1926, the first attempt of historic interest, has been made in devising methods for preventing sedimentation at intakes of water power plants, The experiments were performed by Bulle (1), in the New Karlsruhe Hydraulic Laboratory in connection with a sedimentation problem at a power plant on the Middle Isar River.

These experiments have been conducted to determine the amount of sediment material diverted into the branch channels at various angles. The percentage of sediment distribution at various angles offtakes with sharp edge entry at the point of diversion are summarized in the following Table.

TABLE No. 1.

Angle of diversion from straight channel.	Percentage of sediment in diversion.	Percentage of sediment in st. channel below diversion.
30	97.3	2.7
60	96.2	3.8
90	90.5	9.5
120	87.5	12.5
150	92.0	8.0

In these experiments the width of the parent channel as well as that of offtake channel was 0.656 feet and bottom slope was 0.003. The length of the flume was 21.15 ft. and the diversion point was at 8.22 ft., from the upstream end. The maximum discharge recorded in these experiments was 0.28 cusec and the discharge shared by both the channels was the same. He used sand as movable material.

Fig. 1 shows the percentages of the sediment distribution that entered the offtake and main channel for different angles of offtakes. Fig. 2 shows the relation between the division of bed load and discharge for an angle of offtake of 30 degree. Fig. 3 shows the manner in which the sediment distributed for an angle of offtake of 150 degree with sharp edge entry while in Fig. 4 the same effect of sediment distribution has been seen for an angle of offtake of 30 degree with rounded

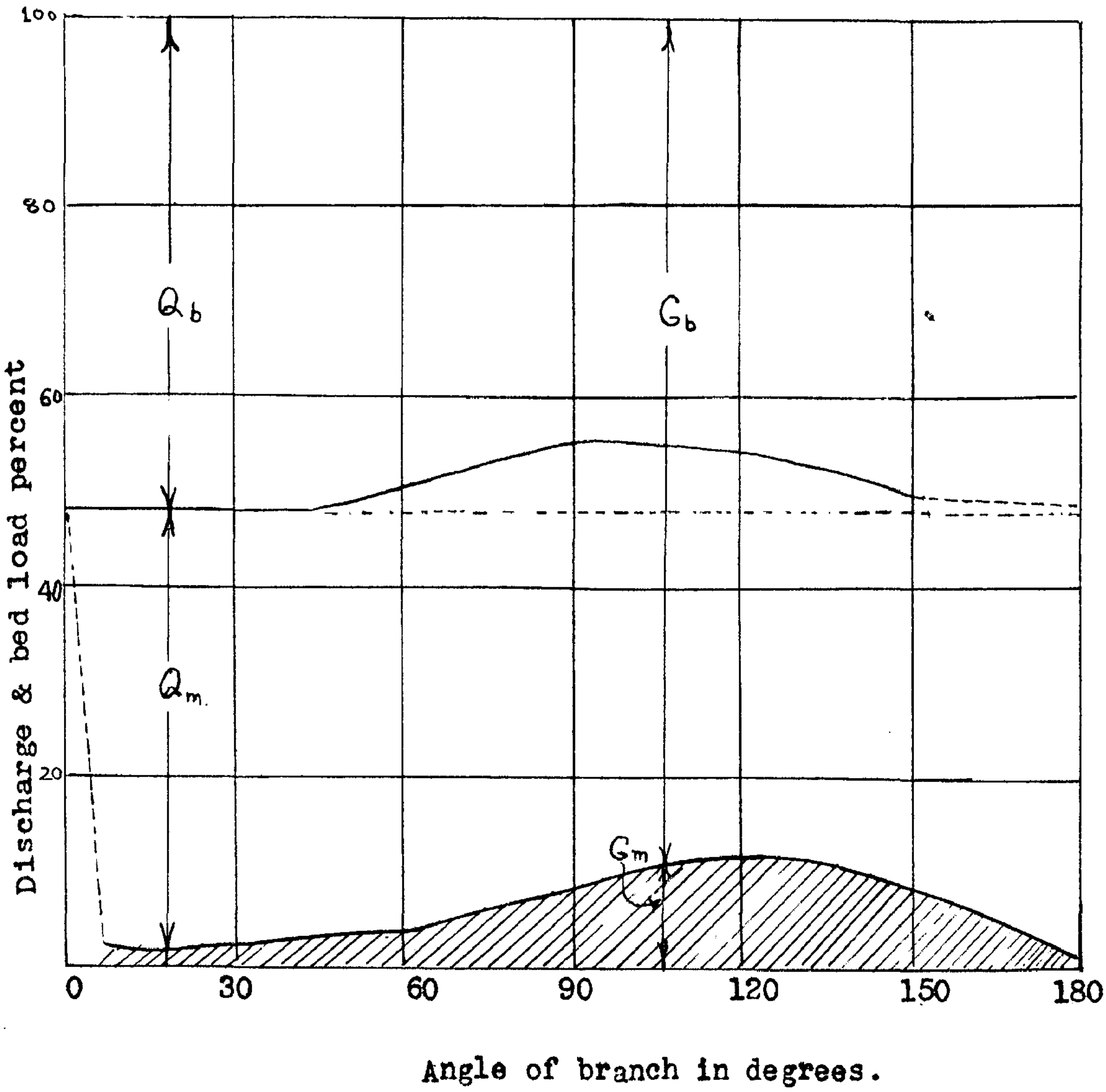


Fig. 1 Relation between division of bed load and angle of branch (Bulle)

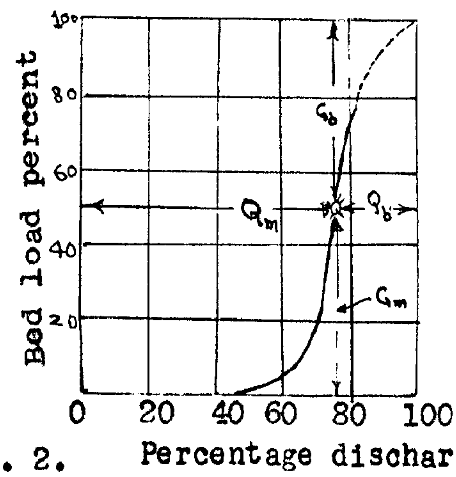


Fig. 2. Relation between bed load and discharge at an angle of 30^o

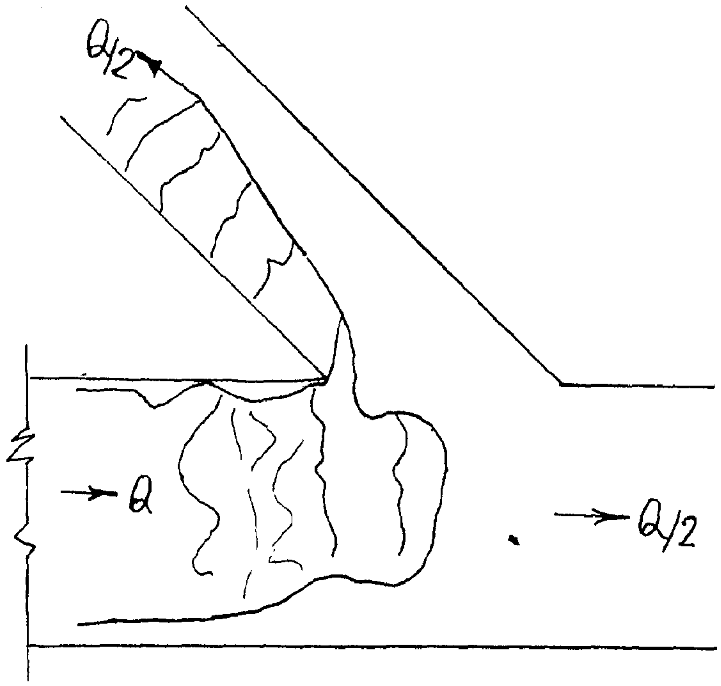


Fig.3. Sharp junction 8% of sediment(coarse) passed into the straight channel and 92% into the offtake (Bulle)

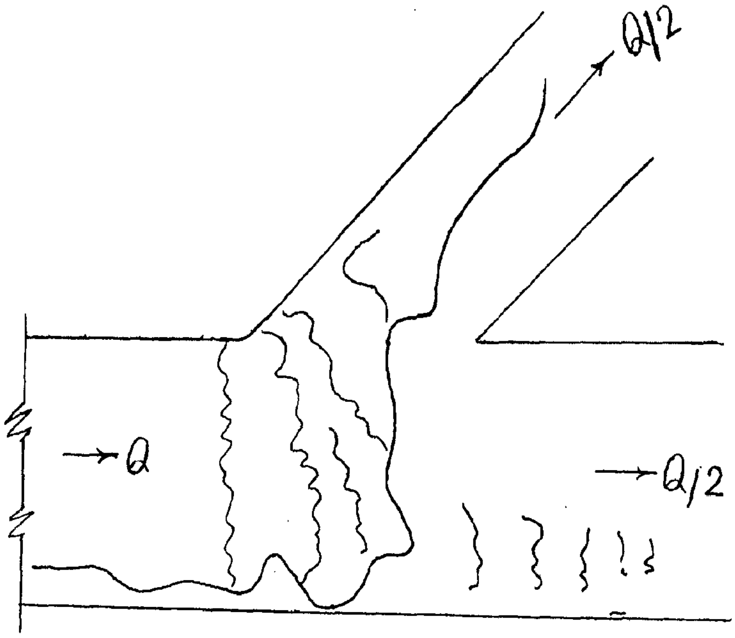


Fig.4 30 deg. rounded junction3% of sediment passed into the straight channel and 97% into the offtake (Bulle) corner at the junction.

Model Test of Mississippi River Bend :-

Experiments[8] have been conducted at the U.S. Waterways experiment station to determine the effect of angle of offtake on the amount of bed load withdrawn by using a Mississippi river bend model as shown in Fig. 5. The three angles 45°, 90° and 135° were tested. The diversion at site No. 1, as shown in Fig. 5, was selected for the test, since the greatest amount of sediment was withdrawn in model runs of a 40 feet river stage at this location. The 45° and 135° diversion were inclined to the bank line and continued at those angles into the river. The results are summarized in Table No.2.

TABLE NO. 2.

Angle of diversion in deg.	Percentage of bed load diverted
45	97
90	80
135	85

It should be remembered that these diversions were excavated through the bar at a location that had been found most suitable for the diversion of bed load. At other locations the percentages of diverted bed load would have been less.

In the discussion on the paper based on above study, Leliavsky pointed out that according to the Egyptian engineers

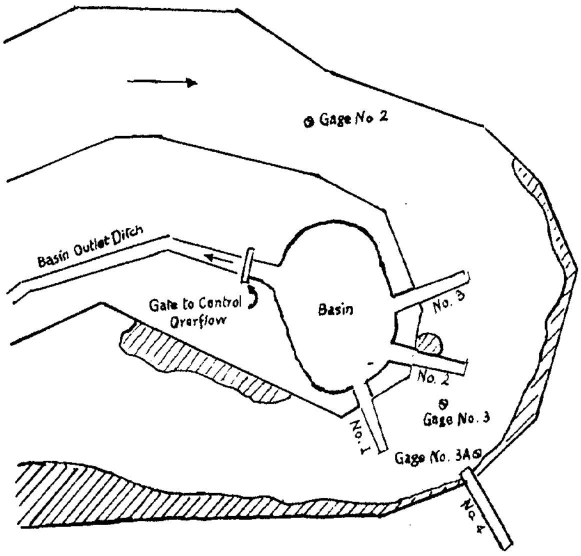


Fig. 5 Location of Diversion of Bed Load movement for model study

the position of the diversion No.4 in Fig. 5 is an anomaly, because they always tend to place their intakes at the concave bank of Nile but with the axis of diversion tangent to that of river. The angle of offtake was thus reduced to nearly zero.

Uppal, 1933.

Uppal[5] in 1933, while discussing on King's paper said that the trouble of silt deposition was experienced in some of the distributaries. He pointed that he had arrived at a significant conclusion that the silt trouble was due to the reason that the offtaking channel did not get help from approach velocity in the parent channel. It could be avoided if the offtakes were placed at an obtuse angle instead of the right angle. He further emphasized that the engineers were so far accustomed to see offtake generally placed at right angles to parent channel, even if the offtake channel was to be ditch channel, and going parallel to parent channel. It was probably due to the fact that an engineer can easily draw out plans of an square head. Stressing the point, he said that wherever possible, it would be more desirable to have offtake at an angle varying from 30 deg. to 60 deg. to the centre line. Such offtakes were proposed by him for ditch distributaries of Gugera Branch of Lower Bari Doab Canal. They were having the following advantages :-

1. The entry from the parent channel to the offtake channel was smooth and there was some velocity of approach into the offtake.

2. The curve in the head reach of the ditch canal was gentle.
3. Less land was required under the offtaking channel, where it was located within the existing land width of the parent channel.

Thus, wherever the alignment permits, engineers should prefer oblique head to the square head.

In his conclusive remarks on the orientation of offtakes Uppal from his own experience, pointed out that the aim should be to distribute the sediment equatably, and suggested that, they can be achieved in the following ways.

1. Wherever possible the offtake should be given oblique head so as to have its proper share of silt from parent channel.
2. As far as possible, the outlet should be at the bed level of the channel so that they may draw their full share of the silt charge.
3. In case of right angled offtakes, the head should be placed so that the approach wings are in line with berm line of the channel thereby ensuring the smooth entry into the offtake.

Nichols and Curran, in 1933.

Nichols and Curran(17) in 1933 have conducted some preliminary experiments to investigate the distribution of sediment at branching channels. The preliminary investigations were carried out along the same general methods as followed by Bulle. In Table No. 3 are shown the dimensions of the flume adopted in these preliminary experiments as well as those used in Bulle's studies.

Table No. 3.

Comparative data on test flumes.

Items.	U.S.W.E.S. Nichols, Curran.	Karlsruhe Bulle.
1. Total length of flume	22.0 ft.	21.15 ft.
2. Dist. from head of flume to point of diversion	10.2 ft	8.22 ft
3. Width of each channel	2.0 ft	0.656 ft
4. Angles of offtakes.	30°	30°, 60°, 90° 120° & 150°.

No sand traps were provided in both the channels and no attempt was made to control the roughness of the channel. Two kinds of bed material were used in these experiments. The experimental results have indicated that the material in suspension was distributed differently than that moved by traction along the bed of the channel. The amount of sediment moved into the off-take was more than the discharge allowed in the off-take.

Variation of Bed Load Distribution with Discharge :-

The distribution of silt into the offtake depends not only on the angle of the offtake but also on many other factors, which in turn vary with the angle of offtake. For example, the diversion of bed load will be altered with the change of discharge through the offtake.

Vogel[17] in 1933, presented a good number of test results for an angle of 30°. In these tests the rate of discharge in the main channel were kept constant. Both channels were of equal width and rectangular in cross-section. He used in these tests the red river sand. Vogel's results are summarized as under :-

TABLE No. 4.

Flow in offtake channel as a percentage of total discharge	Deposits in branch channel as a %age of total deposits.
65.0	86.1
49.4	75.9
48.8	75.2
34.9	63.6
30.2	45.3
29.9	31.3
24.2	37.1
23.3	38.3
15.9	17.9

The sand traps were not provided so the sand carried beyond the ends of the flumes was lost. If such losses were accounted for, the percentage deposits in the offtake channel would be increased.

Variation of Sediment Distribution into the Offtakes with Particle Size.

Later the experiments [17] were conducted by Vogel utilizing the flumes of semi-circular cross-section laid on the same horiantal planes. The result of these experiments show that the finer sediment is transported in suspension and its division at diversion will be approximately according to the ratio of the water discharges in the offtake and the straight main channel. The approximate average results of his experiments were as under:-

Type of sand.	Discharge in the offtake as %age of total discharge.	Sediment entering the offtake as a %age of total sediment.
Red river sand	38	52
Polk creek sand	36	65

The polk creek sand was coarser than the red river sand, the results indicated that a greater percentage of coarser material will pass in to the offtake than finer materials.

In 1947, Dancy[8] conducted similar experiments at Iowa College, at Ames, in a rectangular channels of 6" x 5" and the offtake was at an angle of 30^{o} to the parent channel. The results are shown in the Table 5 given below and these confirm the concept that suspended sediment as distinguished from bed load divides at a diversion approximately in direct proportion to the division of flow.

In addition to this the table reveals that without exception, as the particle size of the sediment is reduced the percent of size diverted is also reduced. In these tests the slopes were steep except for test No.3, and the outlet were free fall. The slopes of the branch as well as main were the same.

TABLE NO. 5

PERCENTAGE OF TOTAL SEDIMENT PASSING THROUGH A BRANCHING ARM FOR VARIOUS SEDIMENT SIZES*

Test No.	Slope of channel	%age of flow in branch.	Size of Sieve. 3/8"	4	10	20	40	60	80	100	200
1	0.0182	49.1	91.2	84.8	76.1	72.3	68.8	59.6	50.7	49.8	48.1
			186	173	155	147	140	121	103	101	98
2	0.0214	27.8	64.3	60.1	57.2	55.5	42.1	34.1	32.3	28.2	21.0
			231	216	206	200	151	123	116	101	76
3**	0.0214	25.6	61.3	58.4	55.2	47.3	40.6	33.2	30.0	26.4	19.9
			239	228	216	185	159	130	117	103	78
4	0.0346	14.8	24.6	22.7	20.0	19.1	18.8	18.4	18.1	17.8	16.5
			166	153	135	129	127	124	122	120	111

*The first line of values for each test is the percentage of the total sediment of the indicated sieve size passing through the branch. The second line of values is the ratio of that percentage of total flow in the branch.

** Outlet flow was retarded by perforated plates.

<u>Schoklitsch</u>[14] :-

Most of the existing diversions works have an approach channel approximately perpendicular to the river axis. If the flow in such approach is observed, it will be seen that the stream, instead of following the walls of the approach channel enters it at some smaller angle 'α' as shown in Fig. 6. The space between the stream and the channel wall is filled up with vortices. This evidently shows that an intake at right angle (i.e. 90 deg) to the main stream is not correct.

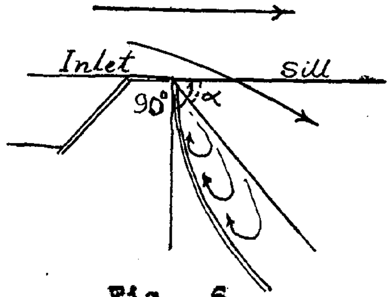
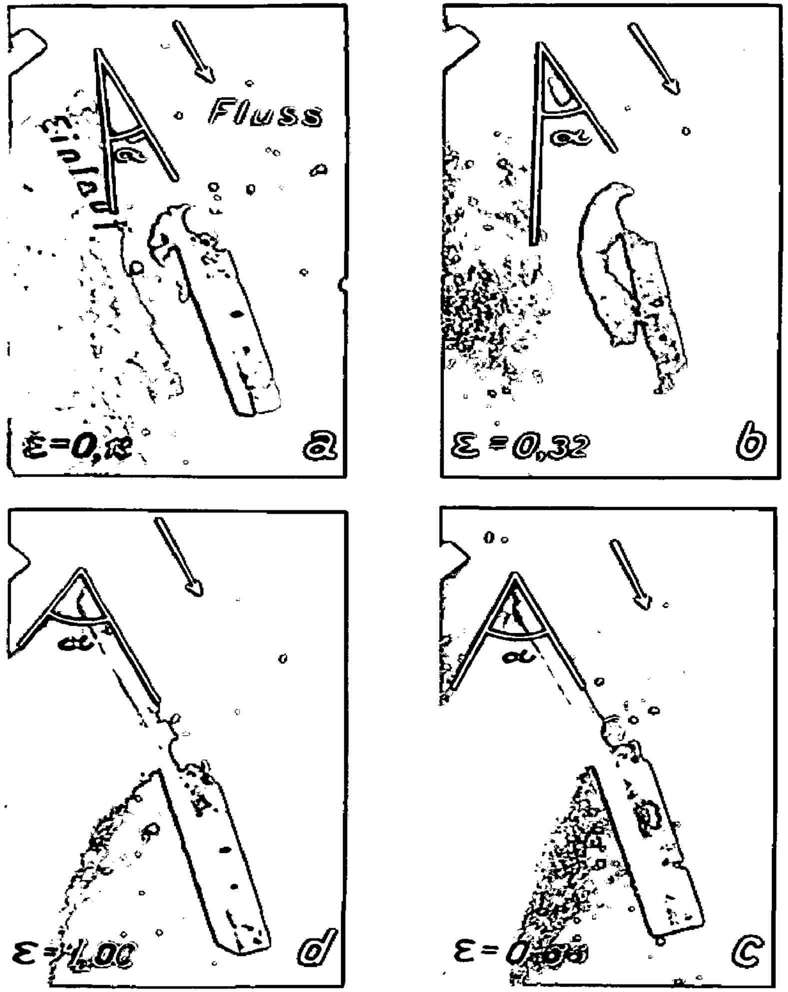


Fig. 6.

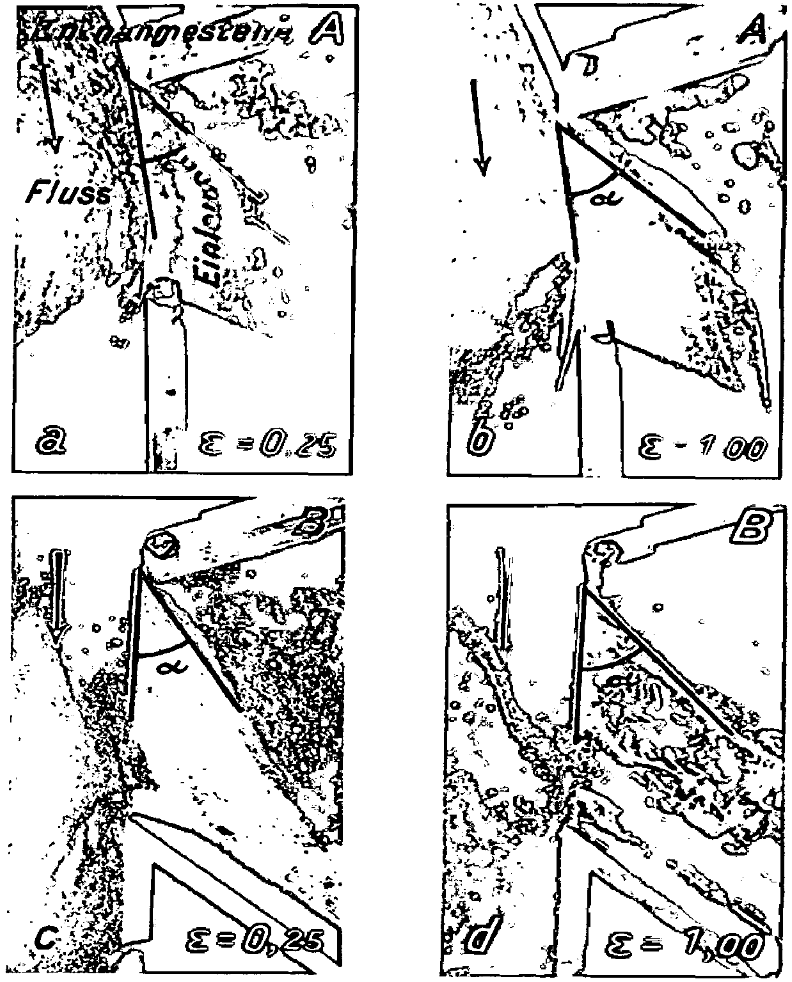
Schoklitsch performed experiments to determine the correct angle of approach. The experiments were carried in a flume from which the water was drawn off at different points. The part of the approach basin in which there was no flow was as certained by strewing fine sand. The sand get settled where there was no flow. The results of these experiments with varieus locations of offtake and different diversion Ratio has been put by him in form of illustration as shown in Fig. 7 & 8. The intake angle 'α' which formed independently of the direction of approach boundaries are also shown in the illustrations.

A comparison of these angles reveals that thereis no correct angle of intake. This angle vary with the diversion ratio and also with the position of the intake in a bend. The value of the intake angle increases as the divertion ratio decreases. The diversion ratio fluctuates continually with the river discharge and the diversion. Thus, accordingly, there is no correct angle of intake for anofftake. The magnitude of the angle varies with the diversion ratio, and there should be selected to suit the condition existing when the bed load is high. This means when diversion ratio is small, the intake angle should



Fluss: River Einlauf: Inlet

FIG. 7 Diversion from straight reach. Variation of intake angle α with the diversion ratio ϵ. Total flow, 6.15 liters per sec. (Model)



Entnahmestelle: Intake Fluss: River Einlauf: Inlet

FIG. 8. Diversion from outside of bend. Variation of intake angle α with the diversion ratio. Total flow, 7.5 liters per sec. A, Intake at beginning of bend. B, At end of bend

be acute. Thus, the foregoing exhibits that the angle of intake of 90° or greater is wrong under all circumstances.

Leliavsky[6] :-

Leliavsky has done much experimental work to investigate effect of angle of offtake on the distribution of bed load at offtakes. He has established a relation between θ, the angle of offtake and R, the radius curvature of the flow filaments at the point of diversion. Fig. 9 shows the physical meaning of θ and R.

He correlated 'θ' and 'R' and presented in a graphical representation as shown in Fig. 10. From this graph he established relation as given below :-

$$R = b/2. \tan \frac{\pi - \theta}{2}$$

In establishing this form of correlation between the 'θ' and 'R', model tests were conducted at Delta Barrage Laboratory in Egypt. These tests confirmed that the channel formation at the entrance to the offtake was unsymmetrical and was in fact found to be similar to that occuring in a bend of an alluvial river.

The lack of this symmetry depends mainly upon the angle of offtake. Thus, the angle of offtake 'θ' determines the magnitude of centrifugal force developed by the curvature of flow filaments. According to Egyptian Engineers the division of bed load at offtakes is a function of this angle.

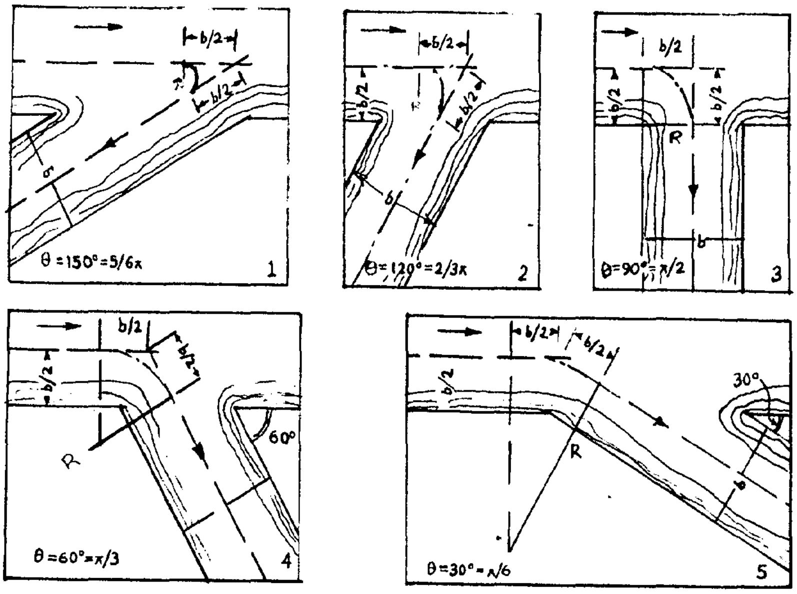


Fig. 9

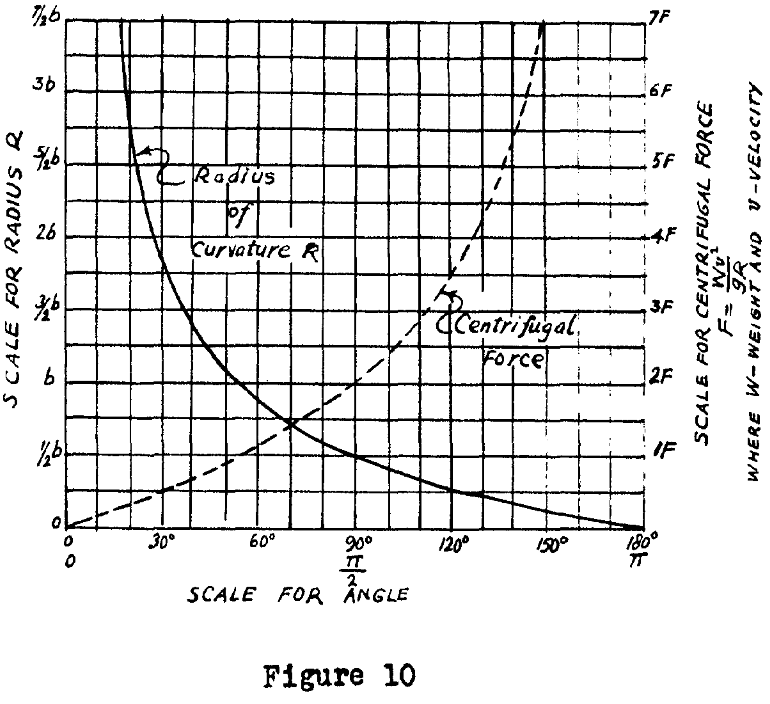


Figure 10

Leliavsky, based on his experimental results plotted a relation between centrifugal force and angle of offtake, which is shown in Fig. 10.

The centrifugal force, thus is a guiding factor which governs the behaviour of the sediment at the mouth of the offtake.

In addition to above, it appears almost essential that comparative study of the different methods employed for silt exclusion and ejection would provide a clear understanding of their relative importance.

Extensive records are now available for many canal systems in India, Egypt and U.S.A., where different measures have been taken to keep off the sand entering the offtake channel.

Various methods have been adopted for controlling sand entering a channel taking off from analluvial river or parent channel. All such methods can broadly be divided into the following classes, aiming respectively at :-

a) Adjusting the canal section in such a way as to increase within required limits, the silt carrying capacity of the water.
b) Preventing the coarse material from entering the canals.
c) Removing the bed materials after its entry into the Canal section.

Design of channels with adequate silt carrying capacity has first been suggested in India by Kennedy and followed by Lacey[15].

Prevention and exclusion of silt can be achieved by designing elaborate diversion works, and varified before hand by exhaustive model studies.

Till recently no clear line of demarcation can be drawn, however, between bed load and suspended load, no efficient method to work out the percentages of charge moving along the bed, and held in suspension is available. The methods of exclusion discribed below are generally effective against coarser particles only and do not apply to finer silt held in suspension.

PREVENTIVE METHODS .

The object of reducing the coarse material entering the canal offtake can be best accomplished by designing an elaborate diversion work. Their success depends on the proper operation and control. The most reliable methods usually adopted for preventing the undesirable entry of coarser bed material in canal offtakes, are discussed as under :-

PROPER LOCATION OF AN OFFTAKE:-

Amongst the preventive methods, the proper location of an offtake is the most important. While planning the diversion works, the first consideration usually kept in view is the location of an offtake with respect to the stream or parent channel.

It must be confirmed whether, the preference should be given to locate the intake on straight stretch of the river or to the curved approach. In the case of a straight channel, the sand charge decreases from the mid-stream towards the banks.

It is well known that flow round a bend is subject to centrifugal forces resulting in a transverse slope of the water surface from inner bank towards the outer as shown in Fig. 11. Thus at ~~outer bank the~~ any level, there is greater pressure near the outer bank than near the inner bank. Water tends, therefore, to flow from higher free level to lower free level. However, this movement is prevented, along the surface by the centrifugal force. At the bottom, velocity is considerably low than at the top and, enough centrifugal force is not available, to counteract the tendency of water at the top to move inwards. Water dives in from the top at the concave bank and flows along the bottom, carrying sand and silt to the inner bank, where it is deposited. The cross section is deep at the concave side with a transverse current from concave side to convex as shown in Fig. 11. Engels[13] investigations have indicated that sand particles move from one convex bank to another, crossing the intermediate shoals diagonally which is indicative from Fig. 12.

a) <u>OFFTAKE FROM STRAIGHT REACH</u> :-

In case, where the parent channel, having axial flow, a small channel taking off with a raised sill, does not draw a considerable proportion of sediment, but where the offtakes draw a large proportion of the parent discharge, an unfavourable curvature

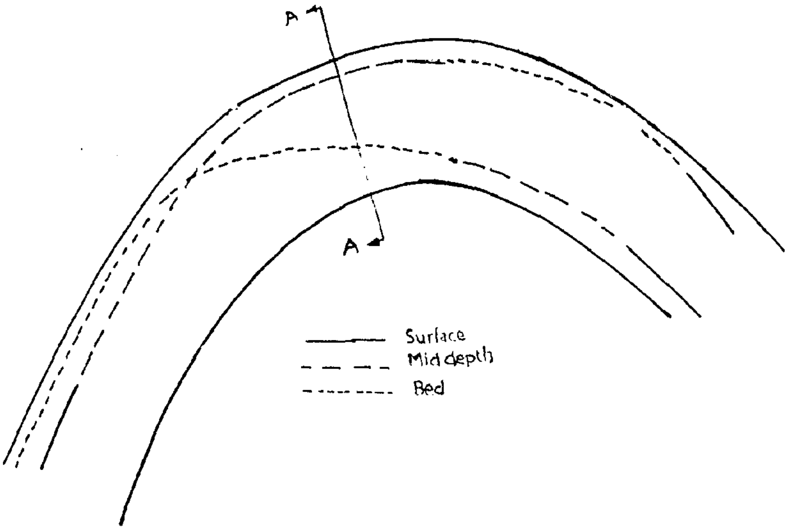
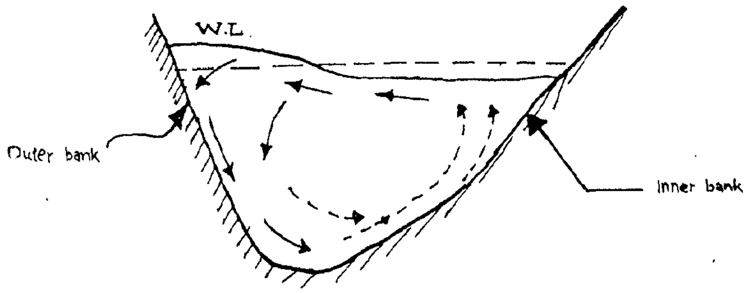


Fig.11 Cross & diving flow at bends



Section at A-A

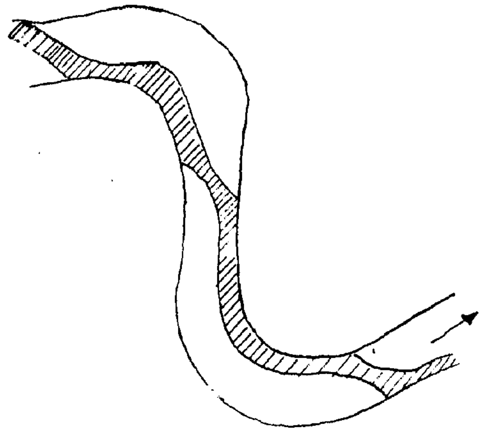


Fig. 12. Path of sediment movement in alluvial channel.

of flow develops towards the offtakes and thereby, causing more bed load to move into the canal.

b) <u>OFFTAKE FROM CURVED APPROACH</u> :-

The effect of curvature on sand exclusion is so dominant that a canal taking off from an outside bend will draw top water, and will function without any trouble, while a canal taking from the inside of a bend will draw excess coarse bed material. A location of an offtake on the outside bend slightly downstream the point of contraflexure, shares much silt free top water and remain free from the undesirable effects of the sediment.

c) <u>ORIENTATION OF OFFTAKE</u> :-

Orientation of an offtake helps in excluding the sand. A detailed account of the authoritive data derived from previous experiments have already been given in the earlier pages.

d) <u>SHIFTING OF AN OFFTAKE</u> :-

An offtake from a straight channel works satisfactorily, provided the discharge shared by the offtake is small as compared to the main channel discharge. In nature, xxxxly a sufficiently long straight and stable reach rarely exists. Canals drawing heavy discharges should then be located on a concave curve, so as to ensure satisfactory sand exclusion. The meander curves tend to move downstream. As a result of that the canal head which has excluded sand for many years may, in the course of time, begin to draw bed sand, when the curvature of flow becomes unfavourable. Under such conditions, the offtake should then have to be shifted upstream so that it takes off from concave curve. This was done

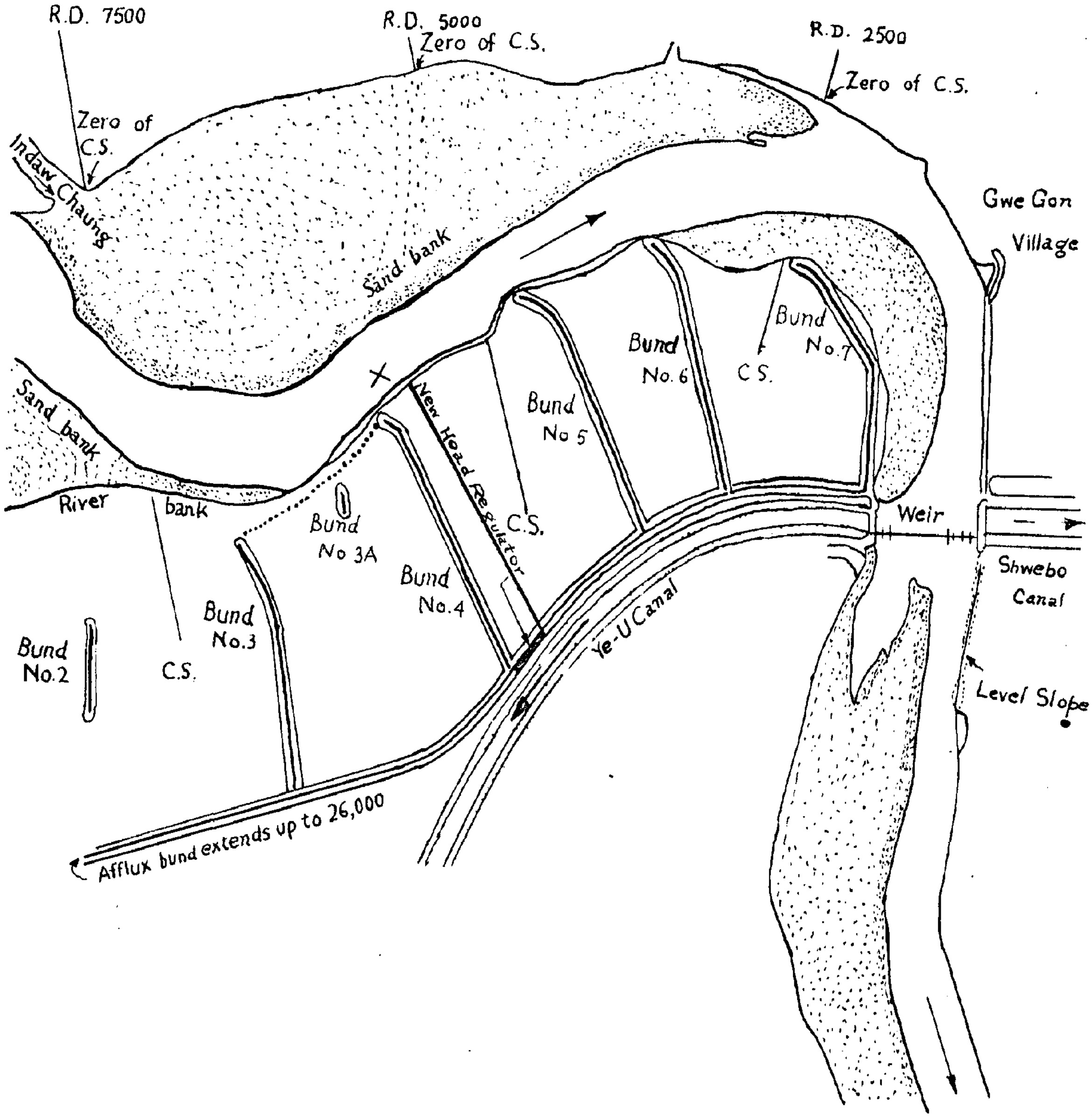


Fig.13 Plan of Mu river at Kabo (Burma) showing Kabo headworks training bunds. Ye-U and Shwebo canals and position of new head regulator.

in case of Ye - U Canal Burma as shown in Fig. 13.

e) APPROACH CHANNEL :-

In order to ensure efficient exclusion of sand, sometimes it becomes necessary, to give the suitable approach to the offtake by imposing an artificial curvature of flow by constructing an approach channel as was done in case of Sukkhur Barrage and the Mith rao Canal, as shown in Fig. 14 and Fig. 15.

Effect of Sill Level at the Entrance to the Offtake :-

Since long in India it was a practice to provide a high sill level at the enterance to the offtake in order to prevent the entry of coarse sand. In most of the cases it was found ineffective. Generally, the heightofcrest of the sill is of the order of 7 to 9 feet. In many diversion works, the sill level of the head regulator has been raised with a view to prevent the entry of coarse sediment into the canal. Experiences on many of the diversion works, where the sill level were raised to prevent the sand entry, have shown that the raising of sill does in noway, help in silt exclusion for a longer period. It is realized that in case of offtake which draws a considerable proportion of water from parent channel, the high sill level cannot neutralize the unfavourable curvature of flow in the main channel upstream of the junction.

Experiments at Poona in connection with the head regulator of Fulleli Canal (Q = 19,200 cusecs) indicated that even with a sill 2/3rd the water depth at full supply, the coarse

INDEX PLAN OF INDUS FROM BUKKUR ISLAND TO BARRAGE SHOWING POSITIONS OF C. SECTIONS.

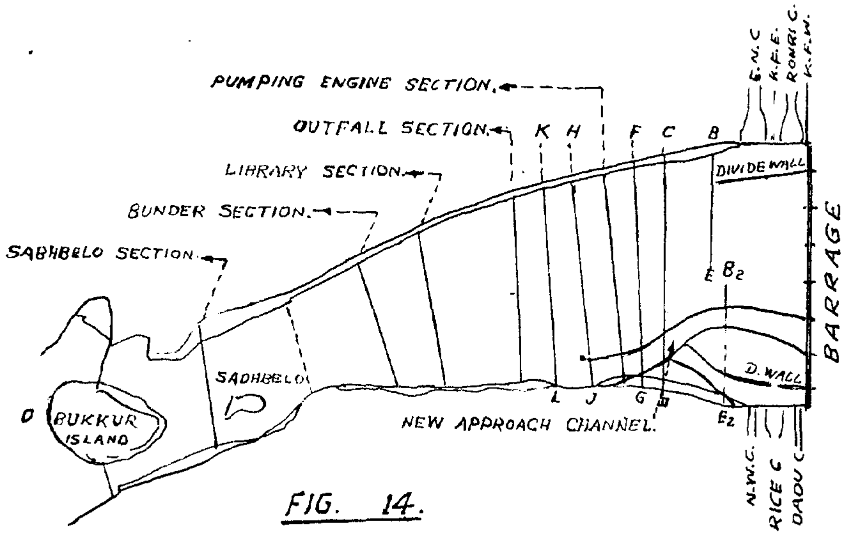
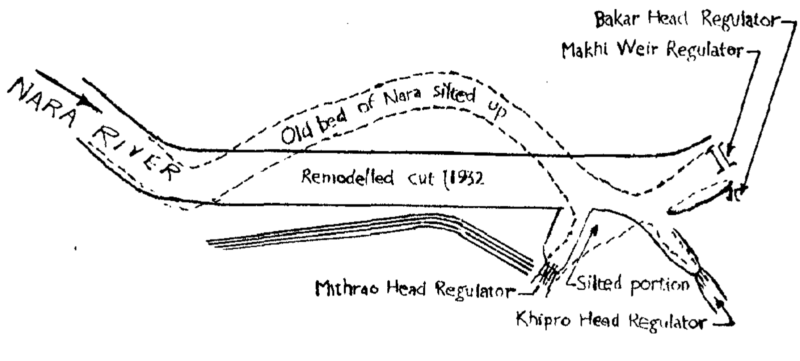


FIG. 14.



EASTERN NARA AT MAKHI AS IT EXISTED IN 1932

FIG: 15

material was able to enter the canal. Model experiments and field experiences have shown the limitation of the height of sill as a method to prevent the entry of silt into the canal. A raised sill is expected to allow only the surface water to enter the offtake which carry finer silt in suspension. Thus, the coarser load will be eliminated to some extent. But this will be possible under the following conditions :-

1. The ratio of discharge drawn in the offtake to the main channel discharge should be small.
2. The raised sill will not work effectively for longer period since the coarse bed load deposited in the pocket will get raised in due course. Hence the coarse particles will roll into offtake later on.

However, a raised sill can be successfully used to prevent the entry of extremely coarse bed material and boulders into the canal.

Mushtaq[10] conducted experiments on this aspect in order to prevent the entry of silt into offtake. He showed that an increase in the sill height of the offtake will decrease in the suction reach to some extent. But it was seen that the increase in the sill height does not show a corresponding decrease in suction reach. The result of these tests were plotted as shown in Fig.16. The results show that by increasing the sill height, the bed load entry into the offtake reduces, when still pond regulation is adopted.

For further study of the effect of the height of sill

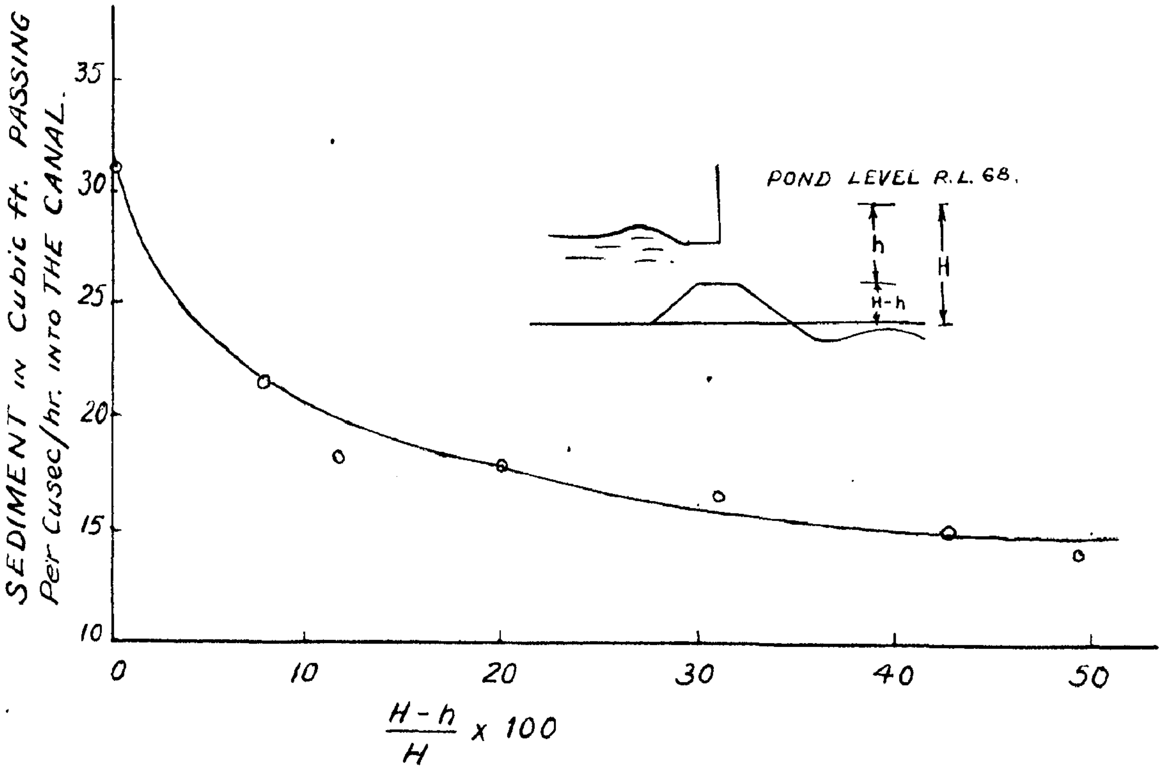

SEDIMENT IN Cubic ft. PASSING
Per Cusec/hr. INTO THE CANAL.
35
30
25
20
15
10
0
10
20
30
40
50
POND LEVEL R.L. 68.
h
H-h
H
$\frac{H-h}{H} \times 100$

FIG - 16

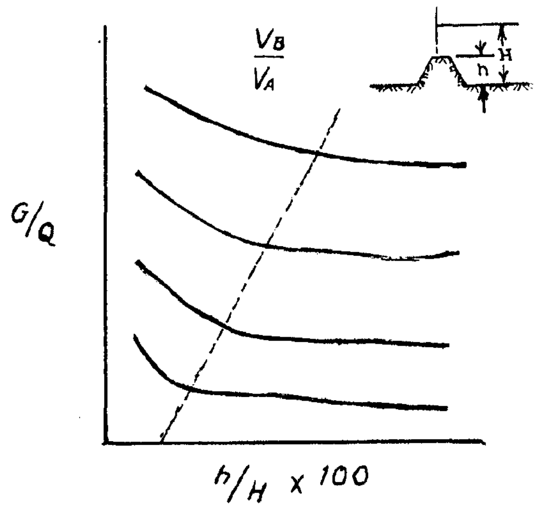

V_B / V_A
G/Q
H
h
h/H x 100

FIG - 17

the upstream floor of the under sluices.

For a given height of the crest of the regulator when water is drawn into the offtake from the pool, there is always a region above the regulator in which the higher velocities are created than the normal velocities, if any, in the pool. The velocity decreases as we recede from the regulator till they become equal to the normal velocity of the pool. This reach can be termed as suction reach of the regulator. From the sediment withdrawal point of view, the active suction reach will be that in which sediment to be excluded cannot deposite but is drawn into the offtake. With the still pond regulation, unless the coarser particles deposite out of the suction reach of the head regulator, they will find their way into the offtake.

With still pond system the velocity in the pocket designated by V_p has to be kept below the critical velocity that can move the sediment of 0.2 mm. dia., and above which is generally considered necessary to be excluded from the canal offtakes. In order that sediment should deposit in the pocket the velocities in it should be less than the velocity, V_B, in the river. The low velocity in the pocket will continue to deposit the sediment and raise the bed till the velocity in the pocket again increases to such an extent that the sediment starts entering the canal again. The canal is then have to be closed and the undersluices opened till the entire deposit is washed away. The scouring operation usually takes a day or two and for this period the supply to the canal is interrupted. The

the following functional relationship is now under consideration in the hydraulic laboratory, Punjab.

$$G/Q = \phi\left(\frac{V_B}{V_P}, \frac{V_0}{v_0}, \frac{h}{d} \times 100\right)^{G/Q}$$

The various terms in the above relationship are :-

G = sediment charge in cft/sec. in offtake.

Q = discharge in cusec in offtake ,

V_B = velocity on barrage side of divide wall,

V_P = Velocity in the pocket,

V_0 = Fall Vel. of sand particle,

v_0 = Vel. in the offtake,

h = sill height.

d = Full supply water depth u/s of the offtake in the main.

The results which were of the form shown in Fig. 17 might be compared with Fig. 16. It should be seen that the value of h/d. x 100 beyond which no further advantage in sediment exclusion was affected was itself a function of V_B/V_P .

REGULATION OF BARRAGE :-

The channels which carry high discharge also carry along with them a large quantity of sediment load. In certain high river stages when the stream carries heavy sediment, the canal has to be closed at the head to prevent the undesirable entry in it. It also becomes necessary to close the canal system when the bed level of pocket is sufficiently high, and the sediment picked from the pocket finds its way in the canal. The field experiences have revealed that the "Barrage Regulation" palys an important role in ensuring the efficient exclusion of sand. It is more effective when the canals are taken off from the one side of the river. In general, the methods adopted for regulation of barrage with a view to keep away the sediment from the offtake are as under :-

1. Still pond regulation.
2. Semi-open flow system of regulation.
3. Wedge type system of regulation.

Still Pond Regulation :-

The function of a divide wall projecting at right angles upstream of the barrage or weir is to isolate the canal head regulator from the main flow and to create a pocket for the undersluices, separating their from main weir.

In the still pond regulation the under sluice in the pocket are kept closed when the canal is running. The quantity of water entering the pocket depends on the intake of the canal. Only that much water enters in it, which is required by the canal, and the surplus amount of flow is being discharged from the other sections of the weir. With the result, the velocity of flow inside the pocket gets, therefore, reduced considerably as the smaller discharge enters through the same water way. The sediment load thus settles down and a relatively silt free water finds its way into the canal. This system is effective till the crest of the head regulator is sufficiently high than canal is then opened and the sluices closed till the scouring again becomes necessary.

This system has been tried in the Punjab and found quite effective for silt control(3). Its draw back is that it necessitates closing of the canal for a day or two each month resulting in wastage of discharge and loss of irrigation to that extent.

Semi-Open Flow System :-

The undersluices are kept open to the required extent to escape the surplus water, entering the pocket in front of the head regulator. The partial opening of the undersluices under normal working of canal, increases the discharge and consequently the velocities and water surface slopes in the pocket. With the result the velocities in the pocket will be greater than that in the case of still pond regulation. It is misunderstood that the partial opening of the undersluices increases the forward velocity and carries greater quantity of coarser sediment into the main river down stream, and a relatively silt free water passes into the canal. The increase in the velocity results a heavy withdrawal of coarse material within the suction reach of the canal. The ratio V_B/V_P also comparatively reduces and hence a greater amount of bed load enters the pocket. The velocity will also exceed to that extent which is required to deposite the sediment. Consequently the sediment will not deposite in the pocket. The sediment either will enter the cancal or will pass through the undersluices.

With the creation of high velocity of the flow at the mouth of the pocket, a greater amount of sediment enters the pocket. Due to the high velocities of the flow inside the pocket a large proportion of top water moves down straight through the under sluices into the river and a relatively sediment ladden layers of water find its way into the canal.

It was found during the extensive repairs of the Lower Chenab Canal that the many freshets were moved through the undersluices with canal running. The canal silted up to the extent of 4 to 8 ft., in first mile(3), whereas with still pond system it was found to be only 0.2 feet.

The semi-open flow system especially at low stages of river discharge does more harm than good. The advantage of this system is that there is continuous scouring of silt and canal does not have to be closed.

<u>Wedge System</u> :-

With a view to push away from head regulator a considerable amount of bed material, a greater quantity of flow will have to be diverted away from it. Based on this principle the division of bed load at the nose of divide wall and the increase in the V_B/V_P ratio, between the pocket and the river, can be controlled to some extent by the regulation of barrage gates. A number of alternatives gate openings of the dams were tried at Malakpur and Madhopur Research Station. It was found that the 'wedge' system of opening gave the minimum entry of silt into the canal.

In this system, the gates farthest from the head regulator should be opened more than those near to the head regulator. Hence the higher velocities are produced bn the river side and the sediment entry to the pocket is considerably reduced.

KING'S VANES :-

Curved or King's vanes, shown in Fig. 18 are constructed slightly upstream of the offtake on the bed of the main channel. The effect of such vanes is to impose an artificial curvature on the bed flow diverting it away from the offtake, and thus help to deflect bed material away from the bank into midstream. These are concave in shape and takeoff from the head regulator upstream into the parent channel. In 1940-41 three simple vanes, two large and one small, had been provided at the old head of the Upper Bari Doab Canal. Observation made on these vanes showed that they were very efficient in diverting all the gravel carried by the canal.

Vanes are economical, easy to construct, easy to maintain and being submerged offer less resistance to the normal flow of the channel. The number and spacing of the vanes should be determined by model study.

These are not efficient, in case, the discharge entering the offtake channel is more than 1/3rd of the main channel. There should be enough water passing over the vanes to fill the offtaking channel with plenty to spare, other-wise

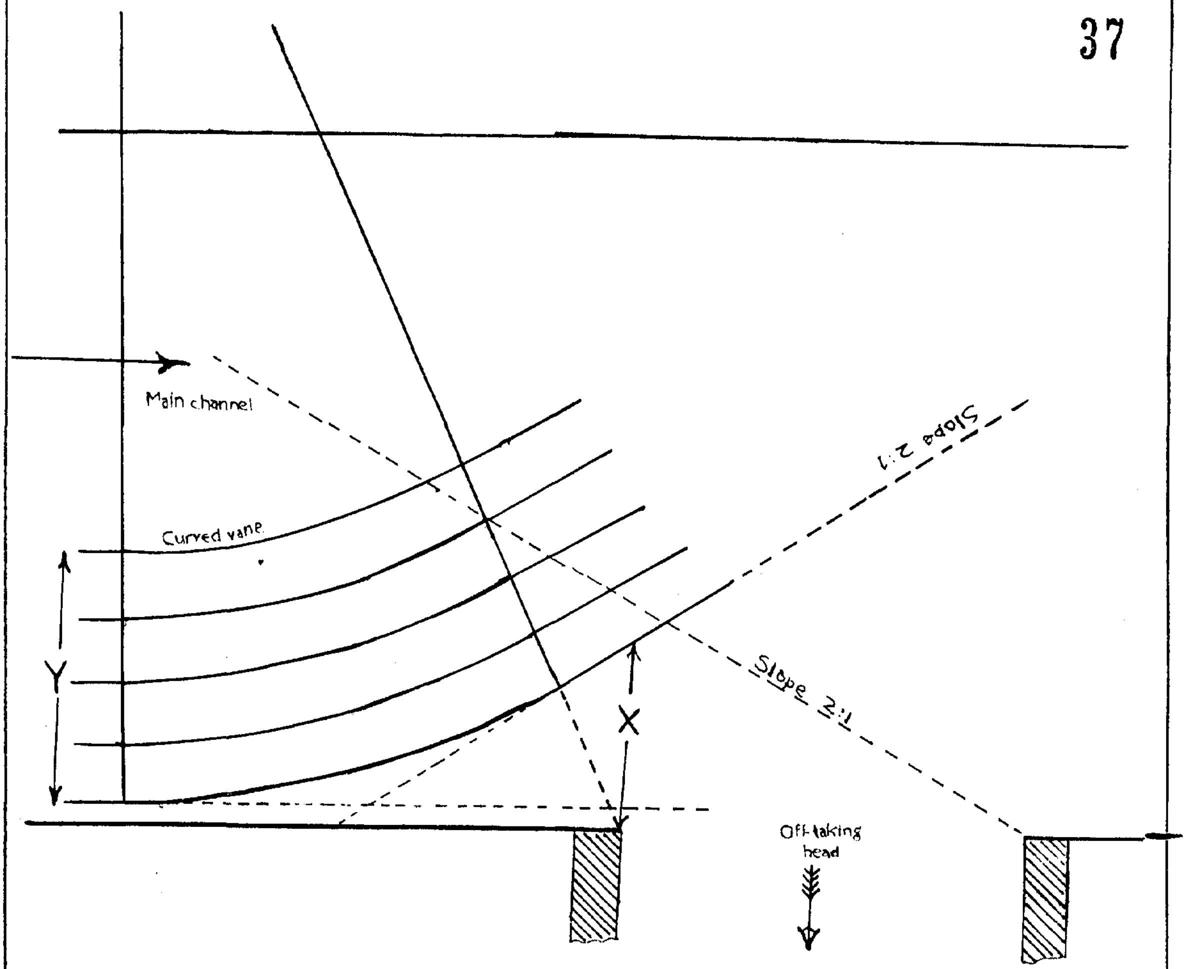

Main channel
Curved vane
Y
X
Slope 2:1
Slope 2:1
Off-taking head

Fig. 18.

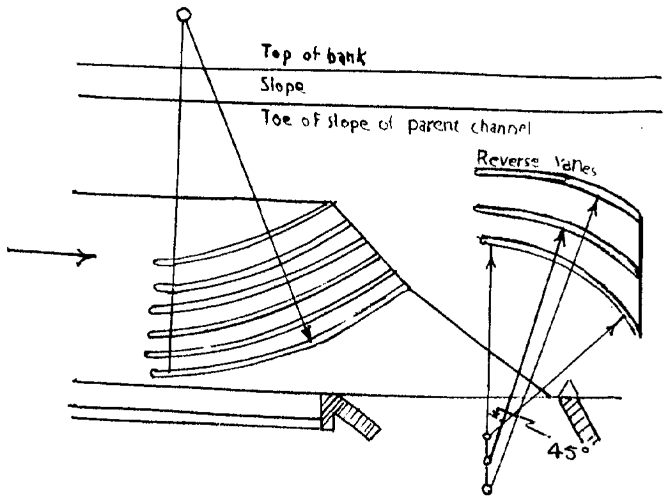

Top of bank
Slope
Toe of slope of parent channel
Reverse vanes
45°

Fig. 19

velocities of water passing across the vanes to the offtake may get increased to an extent to pick up the particles from between the vanes and hence carry them into offtake channel. The conclusion drawn by Poona Research Station( ) regarding the King's Vanes was that the vanes could exclude practically all the bed sediment where the discharge conditions were relatively steady.

Silt vanes if properly designed, built and correctly positioned give most efficient results, but on the contrary, if wrongly designed, or built or incorrectly positioned, give detrimental results.

The Fig. 18 shows the main dimensions which are generally adopted in practice. King[5] constructed a number of these vanes and drew certain generalisation giving the main feature of designs. The ~~compressive~~ account of the detailed features of designs can be obtained from his paper[5].

The King's vanes have been labelled with the following objections :-

1. Unless constructed sufficiently upstream, the bed sediment thrown up in suspension due to the turbulence ~~and~~ may enter the canal.
2. There is possibility of vanes going completely or partially out of action when the accretion of bed starts in the main channel.
3. The discharge capacity of the channel, for which the design of these vanes is fixed, is an uncertain factor. A

design effective for lower discharges, may or may not be suitable for higher discharges.

REVERSE VANES :-

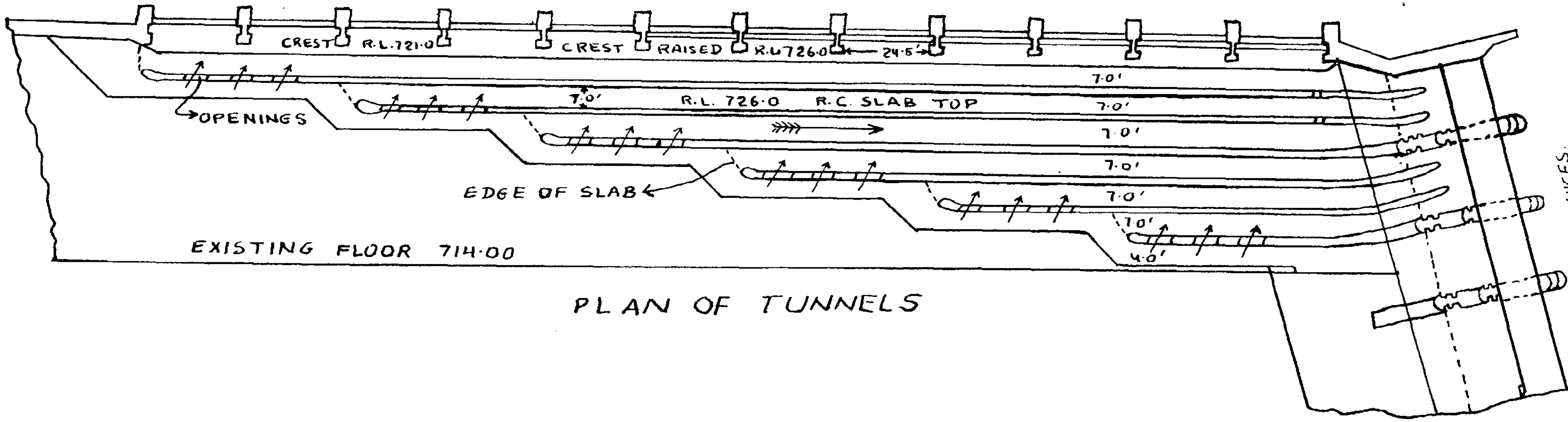
In many cases, sand is deposited downstream of vanes, due to the concentration of silt in a part of the channel. The remedy is to construct reverse vanes for re-adjusting the charge. Vanes are suitable, particularly, when discharge in the parent channel does not flustuate, considerably. Fig. 19 shows a sketch of these vanes.

TUNNEL EXCLUDER :-

In spite of the suitable location of a head regulator for sediment exclusion, a large quantity of coarse sediment may find its way into the channel. Elsden[12] in 1922, gave an idea of tunnel type excluder. The idea took a practical shape in 1934 when Nicholson constructed silt tunnel in the pocket of lower Chenab Canals at Khanki and now known as Khanki type excluder.

A tunnel excluder essentially consists of rectangular tunnels with the top level of the roof covering at the level of the crest of the canal head regulator. The water approaching towards the diversion work, contains heavy charge of sediment, is neatly separated into two parts by the roof slab of the excluder tunnels - the part on the top enters into the canal and that underneath carrying most of the sediment flows through the tunnels and is escaped from the undersluices.

KHANKI EXCLUDER



PLAN OF TUNNELS

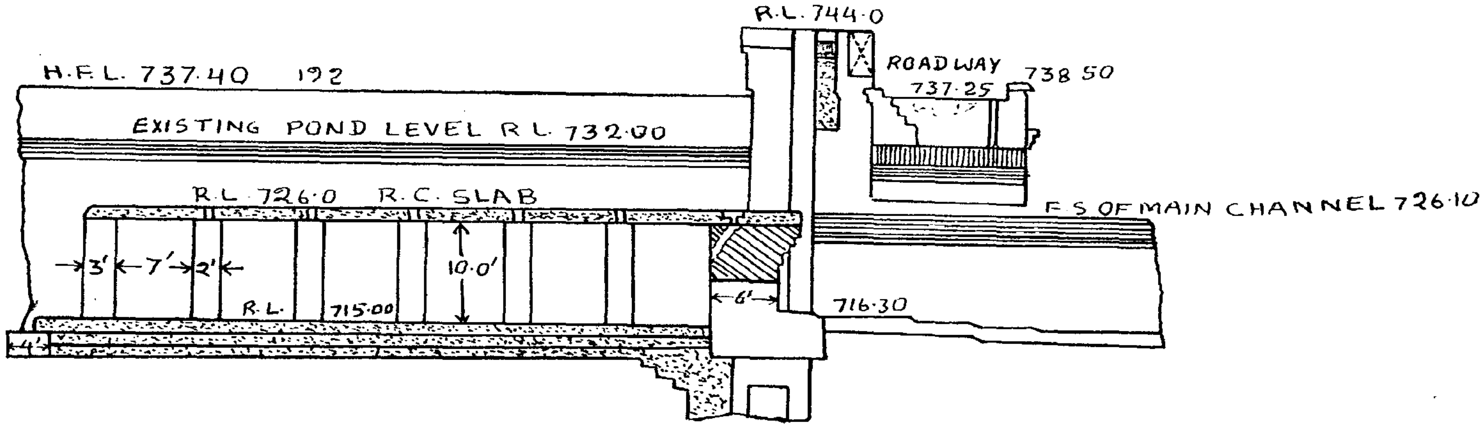


Fig. 20 CROSS SECTION OF TUNNELS

The designs have to be based on past experience and finalised by model experiments. The design of the tunnel excluder depends on the river conditions and the size of the regulator. The number and dimensions of the tunnels should be such that these should have a sufficiently high velocity in order to exclude the coarser sediment without being clogged.

The tunnels nearest to the crest of the regulator should have the same length as that of the regulator. Other tunnels may be made shorter in length but these details can only be decided by model experiments.

The roof of the slab must be able to support the maximum waterload from the top with no water in side. A plan of the excluder tunnels at Khanki weir in the Punjab is shown in Fig. 20.

CURATIVE METHODS :-

In spite of all devices to prevent the sand entry into a canal at head regulator, it may be that considerable quantities of coarse sediment may find its way into the canal. Under such conditions it becomes necessary to remove the entered sediment from the channel. This is best achieved by constructing suitable structures in the bed of the canal. A concise discription of the main features of such structures which are generally adopted for this purpose, may be as under :-

1. Ejector or Extractor :-

Material held in suspension due to the higher velocities of the incoming water is dropped on the bed of the canal, due to the reduction in the velocity. The ejector have successfully been employed to remove coarse sediment from the canals. In principle it is similar to tunnel type excluder.

A silt ejector essentially consists of a horizontal diaphragm slab a little above the canal bed which separates out the bottom layer ladden with sediment from the top layers. The diaphragm slab is provided throughout the width of the canal. The mouth of the ejector is divided into a number of tunnels to eject the silt ladden water into an escape channel. These tunnels converge towards one side and are taken out through the bank. In each main tunnel, there are partition walls, further sub-dividing it into number of tunnels. These walls, however, end in the straight portion towards the emergence of the tunnels. The tunnel entrances have to be so designed that there is no disturbance at entry and then the velocity should have increased quickly to such a value which is required inside the tunnel to prevent themselves from being choked. The canal bed is slighly depressed under the diaphragm and the height of the tunnel at m mouth is about 1/4 to 1/5 the depth of flow. The roof extends beyond the mouth for a length of about 1.5 ft. and is an cantilever. The increase of velocities is achieved, quickly and steadily by gradually reducing the cross-sectional area with streamlined vanes. As the lengths of the tunnels are different, the head loss in them would be different if all of them were to take the same discharge. As the head available is the same for all the tunnels, the smaller tunnel would tend to draw greater discharges than the longer one. This would mean a higher velocity at entry for shorter tunnel than in the others, and would lead to the disturbance at entry. To avoid this, either the shorter tunnel should serve for the major portion of the width of the canal than a larger one or the tunnel section should be altered, each serving with equal width.

The ejectors tunnels, when work full bore, give the maximum efficiency. Minimum head required for their operation is 2.5 ft. Higher heads, however, give more efficiency. The efficiency of silt ejector or excluder is defined as ;

$$E = \frac{qs_a - qs_e}{qs_a}$$

where,

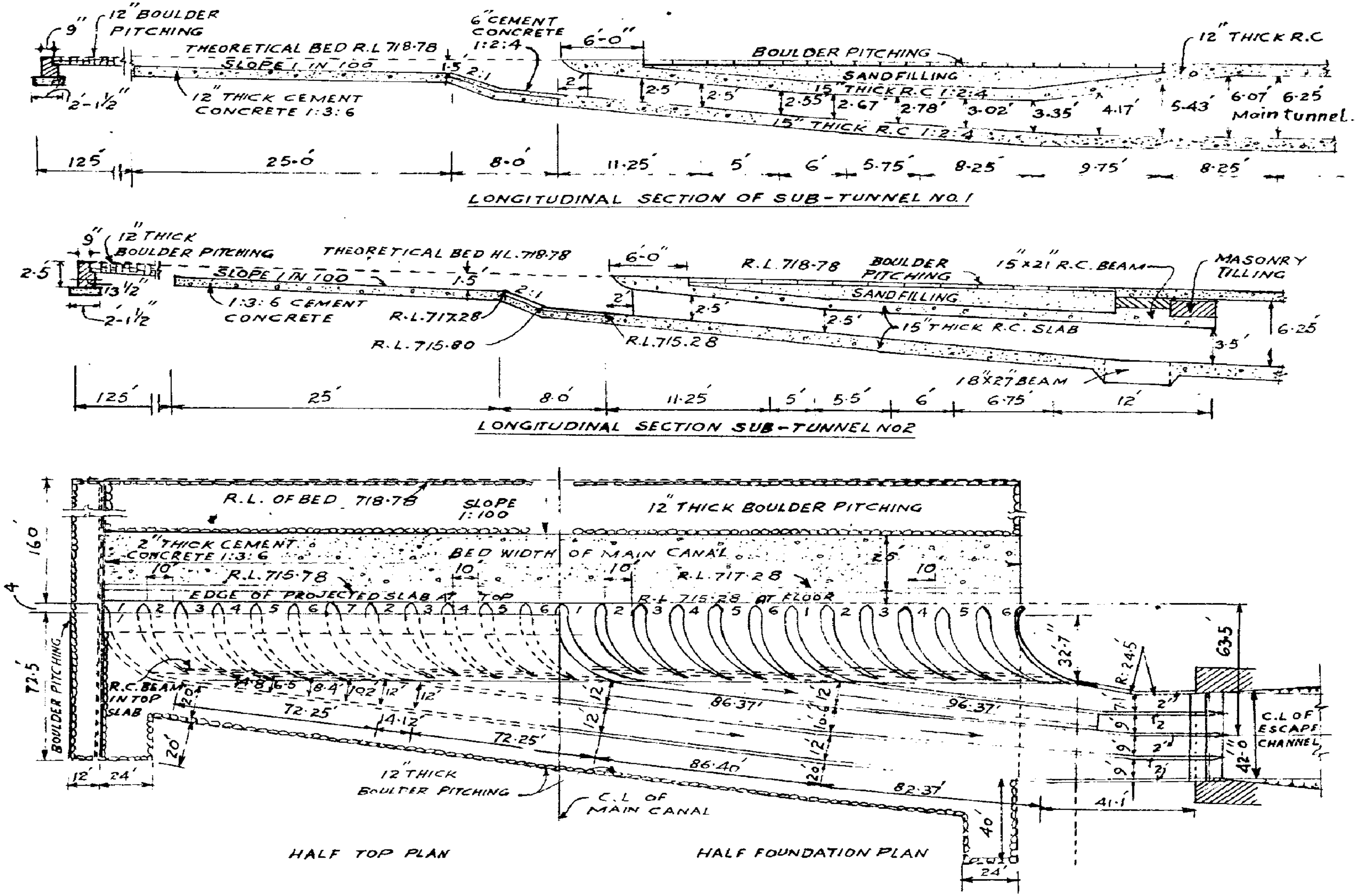
E is the efficiency of the work,

qs_a is the concentration of silt load in the approach channel.

qs_e the concentration of silt load in the canal downstream of the work.

This is most suitable definition of efficiency for a quantative assessment of a particular design. The velocity in the tunnels is generally kept at about 9 to 10 ft per sec. For efficient working of the extracter about 20 to 25 % of the canal discharge is required for escapage.

Fig. 21 shows the ejector of Sarda Main Canal[9] at Banbarra (Distt. Nainital, U.P.)



DESIGN OF THE SILT EJECTOR SHOWING DETAILS OF MAIN AND SUB-TUNNELS.

FIG 21, (I.C.J)

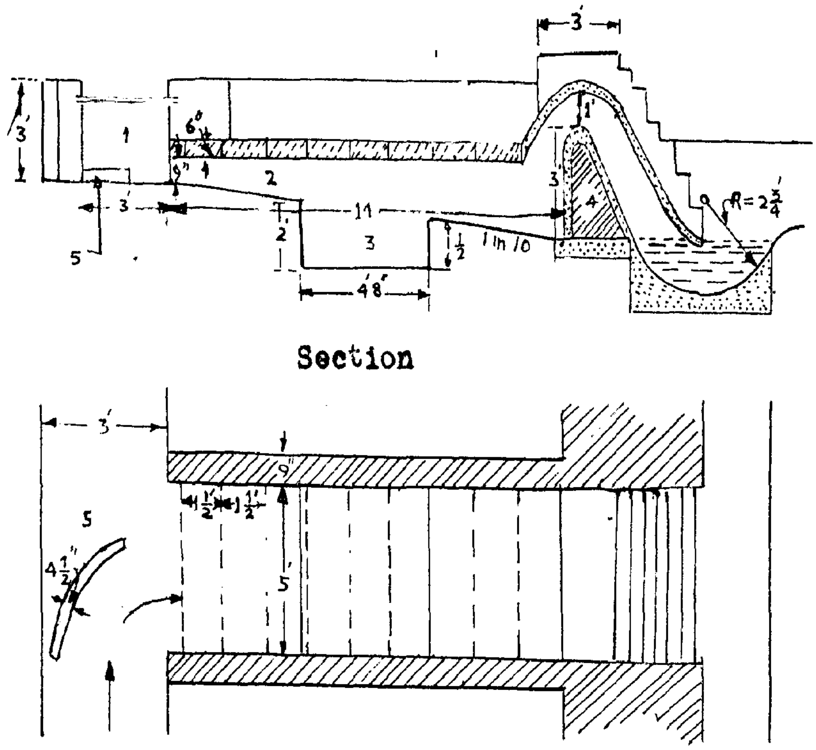
SIPHONIC EJECTOR :-

Siphonic ejector is based on the well known principle of siphonic action in an inverted bent tube. In these structures water has to rush up and passes through the annular space between the body and the hood. The siphonic ejector during its operation can suck the sediment that comes into its path, because of the presence of the vertical component of velocities. Based on this principle, experiments have been conducted(2) to evolve the possibility of this structure being used as an sediment ejector.

The main features of saddle siphon as sediment ejector(2) shown in Fig.22 are :-

1. A guide vane across the main channel to deviate the sediment transported in the main channel.
2. An approach tunnel to collect sediment and feed it at the inlet of the siphon.
3. A saddle siphon to dispose the surplus water with the sediment collected in tunnel.

The sediment which is diverted during the normal functioning of the channel has no possibility of being ejected until the monsoon season arrives. During the monsoon season, the full supply level of the channel is likely to exceed and the siphon would eject out the material collect alongwith surplus water. Hence a pit is necessary in the approach tunnel to collect the sediment. The structure can be placed near the junction of a cross drain with the channel or near the head regulator of the channel.



Index

1. Main channel
2. Closed tunnel
3. Silt trap
4. Saddle siphon
5. Silt vane

Fig. 22 Plane of a Siphonic Ejector.

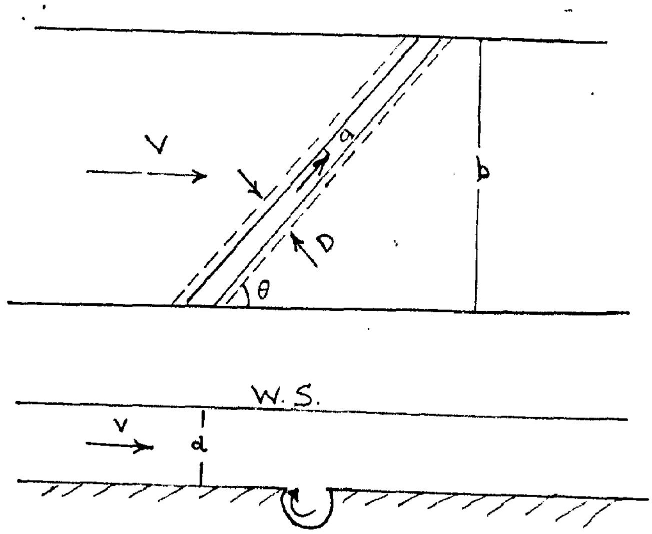


Fig.23. Schematic layout of a vortex tube.

The conclusion drawn on the basis of the laboratory experiments show that ;

1. The saddle siphon is more effective in the removal of sediment than a sluice under similar conditions.
2. Ejection of sediment is accelerated if the pit is covered.
3. There is a great possibility of a siphonic ejector being used along the canal system.

VORTEX TUBE :-

It consists of an open top tube placed across the bottom of a channel either normal to it or at an angle greater than 30°. To control the flow out of the tube, its downstream end is regulated by a valve. The upper portion of the tube is removed to trap the sediment. As the water passes over the tube, a shearing action across the open portion sets upon a vortex motion with in the tube, which has sufficient velocity to prevent deposition of sediment of considerable size. Such devices have been used in U.S.A. The design of this tube was first developed by Parshall. Uppal[12] xalso carried studies on these lines and has developed what are known silts in the bed of canal. Fig. 23 shows the layout of a vortex tube.

-:O:-

3

THEORETICAL APPROACH

THEORETICAL APPROACH.

The problem of sediment entry in offtakes can more easily be understood by dividing it into two categories :-

1. Offtake which takes off from a curved channel .,

and 2. The offtake which takes off from a straight channel.

The problem of silt entry is simpler in case of inmundation canals than in case of canals taking off upstream of a permanent head work. Further the weir or barrage obstruct the free passage of silt in the river and thus increases the tendency for silt to be diverted into the canal.

1. CURVED CHANNEL :-

A particle (14) moving along a curved path is acted upon by the forces, it weight acting vertically down wards and a centrifugal force acting horiantally as shown in Fig. 24. This centrifugal force is given by ;

$$\frac{d_W}{g} \; \frac{V^2}{x} , \qquad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

in which, V is the ~~mkm~~ velocity of the particle on the surface at a distance x.

d_W is the weight of the particle.

x = the distance of the particle under consideration from the reference axis.

g the acceleration due to gravity.

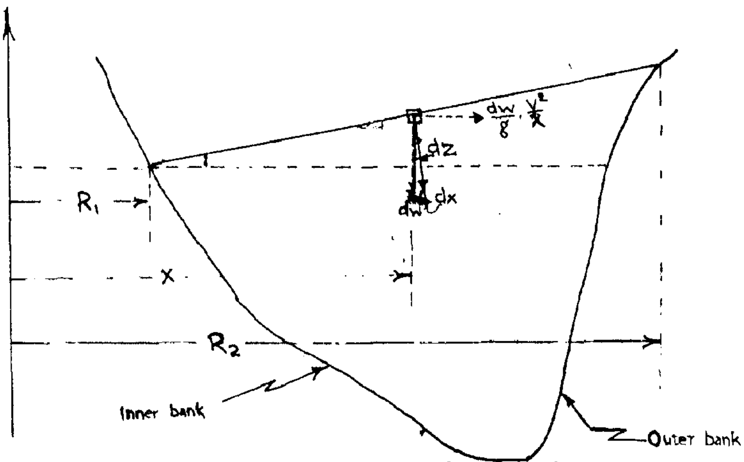


Fig.24 Water surface at the bend

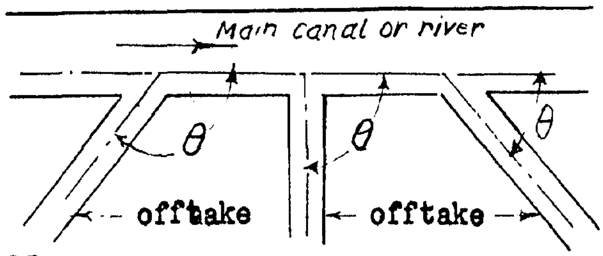


Fig. 25.

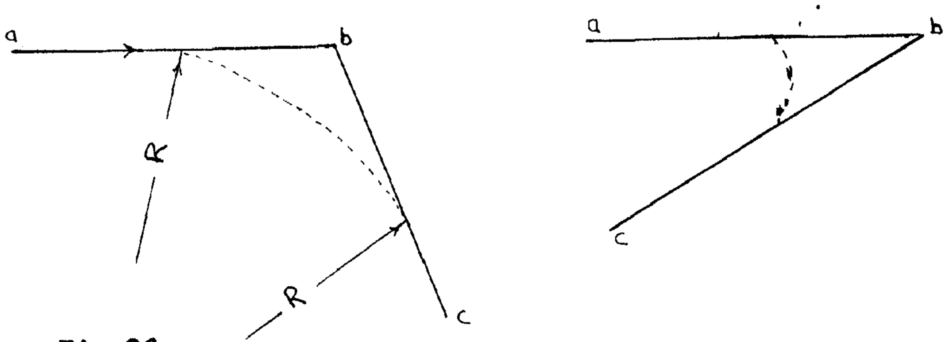


Fig.26

Direction of flow

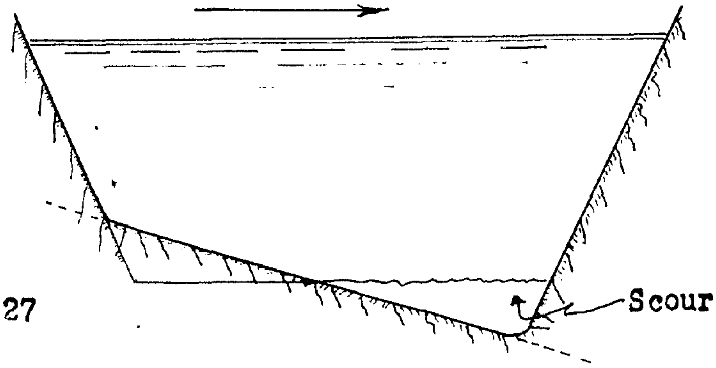


Fig.27

The water surface assumes a position perpendicular to the resultant of these forces as shown in Fig. 24 and accordingly the transverse slope of water surface is ;

$$\frac{dz}{dx} = \frac{\frac{dW}{g} \cdot \frac{V^2}{x}}{dW} \qquad \ldots\ldots\ldots\ldots\ldots (2)$$

which on integration gives ;

$$gz = V^2 \log_e x + C \qquad \ldots\ldots\ldots\ldots\ldots (3)$$

where z is the difference in elevation between the water surface at x and that at the inner bank.

At $x = R_1$, the rise of water surface is zero and therefore,

$$0 = \frac{V^2}{g} \log_e R_1 + C \qquad \ldots\ldots\ldots\ldots (4)$$

if it is assumed that the velocity is the same everywhere, in the cross section, the equation for water surfaee becomes ;

$$z = \frac{V^2}{g} \log_e x / R_1 \qquad \ldots\ldots\ldots\ldots (5)$$

The difference of elevation between the water surface at the outer and inner bank is ;

$$h = \frac{V^2}{g} \log_e \frac{R_2}{R_1} \qquad \ldots\ldots\ldots\ldots (6)$$

Thus at any level, according to eqn. (6), there is a greater pressure near the outer bank than the inner bank or in other words it can be stated that the free water level for any particle near the outer bank is higher than the free water level near the inner bank in the same cross section. Therefore, the

the water at higher free elevation has a prevailing tendency to flow to the places of lower elevations. However, this tendency is prevented along the surface by the centrifugal force.

Further, at the bottom, the velocity is considerably less than that at the top due to the fluid viscosity and the bed resistance. With the result the magnitude of the centrifugal force developed at the bottom according to eq. 1, will be smaller as compared to that at the top. This difference of centrifugal force in a vertical results in a helicoidal motion in the flow as shown in Fig. 11.

The top water, therefore, dives in from the outer bank and moves along the bottom, carrying sediment to the inner bank, where it is deposited.

This type of rotary motion as in Fig. 11 has also been observed by Azins (8) near the entrance of water to the offtake. He found that this spiral motion reduces the efficiency of the defensive devices which are commonly used to reduce the entry of bed load into the diversion works. He considers that the angle between the parent channel and the diversion, which he calls 'angle of twist', is the main parameter of this asymmetry of the flow. Thus, according to him, the angle of twist off-take angle) determines the intensity of centrifugal force engendered by the curvature of the flow filaments at the entrance to the diversion.

Later on, Leliavsky [6] conducted a series of experiments in order to verify the observations of Azim.

From these experiments, a correlation between the angle of offtake and the radius of curvature of flow filaments was presented by him in a graphical form as shown in Fig.10. From this graph the value of R is presented in terms of the bed width of the offtake channel, b, and is as under :-

$$R = b/2 \tan \frac{\pi - \theta}{2} \qquad \text{..........(7)}$$

In establishing this form of inter-relation between θ and R, model test work were carried out. These tests confirmed that the channel form at the entrance to the offtake was basically unsymmetrical. It was found similar to that occuring in a bend of an alluvial river. At the point where the water changes its direction and strikes the downstream bank of the canal, a deep scour (occurs in errodible bed only) was developed while the sediment accummulated in front of it at the apposite bank of the offtake as shown in Fig. 27.

It is obvious that the change in the direction of a moving filaments of water, which is deflected from its original path ab to bc, cannot take place abruptly at the apex b of the angle but occurs gradually as shown by dotted curves in Fig. 26. It is evident from the figure that 'R' in right hand diagram, ($\theta > 90^o$) can never be made equal to R in the left hand diagram ($\theta < 90$).

Thus, from equation (1) and equation (7), it appears that the magnitude of the centrigual force produced at the entrance to the offtake mainly depends upon the value of θ . It is believed that division of bed load between the main and offtake channel is a function of this angle. Leliavsky has has plotted a curve showing a relation between angle of offtake and centrifugal force produced at the entrance to the offtake. He stated that this graph relating F and θ is derived from the average radius of curvature of the flow filaments and angle of offtake relationship. According to him this was verified by theory as well as by experimentation.

Tults[16] while discussing on the Leliavsky's paper pointed out that the design of head works for diversion of water from a main channel as described by Leliavsky in his article 'Sloping Sill Sand Screen' does not take care of all the hydraulic conditions involved in this problem.

According to Tults, the angle of offtake, expressing the intensity of centrifugal force is a hand emperical formula and not the only factor which is responsible for the excess entry of sediment into the offtake.

In his opinion, theoretically there is another possible method of improving the performance of a diversion structure by balancing the centrifugal force locally in a bend of the intake. This reduces the otherwise unproportionate volume of sediment ladden bottom layers entering the intake works.

The basic formula for the change in centrifugal pressure in curved flows is ;

$$\frac{dp}{dR} = \frac{\rho V_t^2}{R} - \rho V_t \frac{dV_R}{Rd\theta} \qquad \ldots\ldots\ldots(8)$$

where,

p is the centrifugal pressure

R the radius of flow filaments,

ρ the density of fluid,

V_t the tangential velocity.

V_R the radial velocity.

θ the angle of deflection.

The flow along the bend follows approximately the potential flow pattern with a velocity ;

$$V_t = C/R \qquad \ldots\ldots\ldots\ldots\ldots \qquad (9)$$

in which,

C is constant, replacing V_t in equation (8) by C/R, and neglecting second order terms. The radial pressure in a bend becomes ;

$$\frac{dp}{dR} = \frac{C}{R^3} \qquad \ldots\ldots\ldots\ldots \qquad (10)$$

and the total radial pressure difference between the side walls is

$$p = \rho C \int_{R_2}^{R_1} \frac{1}{R^3} \, dR \qquad \ldots\ldots(11)$$

It is abvious that the value of p may be kept constant in a cross-section by decreasing the radius, R, of the flow near the bottom to offset the reduction of C due to friction. In this way it seems to elliminate the unbalance centrifugal force in the bend to the intake which produces secondary current which is deterimental there.

Thomas(7) has also given a good explanation about the flow in a curved channel, which briefly may be a stated as follows:

When water flows in a curved reach of a stream a force is needed to produce a change in momentum of flow due to change in direction of flow. The water rises towards the outer bank in a curved canal and the transverse gradient, as given by Eqn. (2), of the surface represents the increase of pressure necessary to produce this change of momentum. This increase of pressure is uniform on any vertical, that is, at any point in plan the pressure increase is the same in water near the surface as in the water vertically beneath. The velocity of flow is greater at the surface, than near the surface as the water vertically beneath. The velocity of flow is greater at the surface than near the bed and hence, with the same force acting on each surface due to the same pressure gradient, the coarse sediment moving along the bed is deflected more easily than the surface water. It can clearly be understood from Fig.28 showing the change of momentum of small imaginary prism of water at the surface and at the bed.

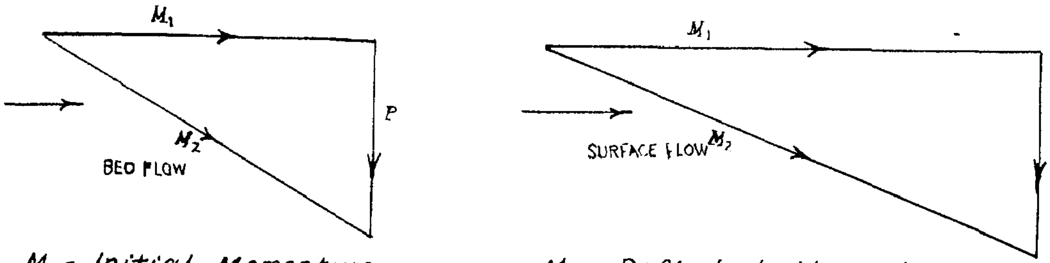
The difference between the angles in the above vector diagrams is reduced by the interchange in momentum due to turbulence and by bed friction. But the general result is that the mean curvature of surface currents in plan is less than the mean curvature of the stream, where as the mean curvature of bed currents is greater , as shown in Fig.29 resulting in a cross-flow at bends and surface water diving at the concave bank.

2. OFFTAKE FROM A STRAIGHT CHANNEL :-

Similar action also occurs at an offtake from a straight reach of the main channel. If the main channel is straight and offtake is at an angle to it, the flow entering the offtake is curved and the slow moving bed load will be deflected more sharply towards the offtake than the surface water. Consequently the offtake draws more sediment ladden water than surface water. If the drawing force of an offtake is expressed in terms of velocity and if for the sake of simplicity two dimensional resolution of velocities alone is considered the vectorial diagrams of bottom and top waters for the offtakes [4] will be as shown in Figs. 30,31, 32.

i) Right angled offtake:- The vectorial diagram of top and bottom waters for right angled offtake will be as in Fig.30. The resultant velocity of a slow moving bottom water will be found to be more inclined towards the canal head than of the top water moving at greater velocity.

ii) Fig.31 shows the conditions considerably improved. The difference in the inclination of resultant velocity of the bottom and top waters is very much reduced. An inclined offtake as shown in Fig. 31 is thus enabled to attract



M_1 = Initial Momentum, M_2 = Deflected Momentum

P = Lateral Force due to transverse Pressure gradient equal in each case.

FIG - 28.

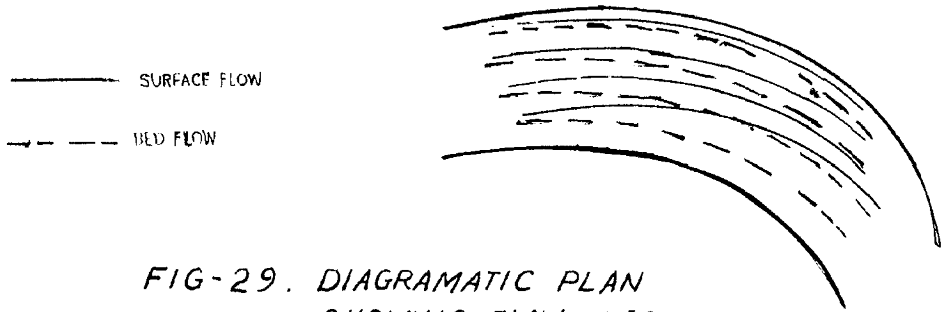
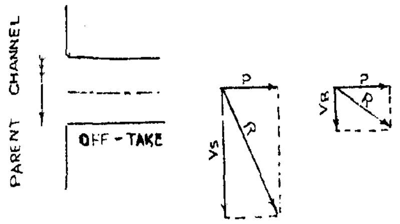
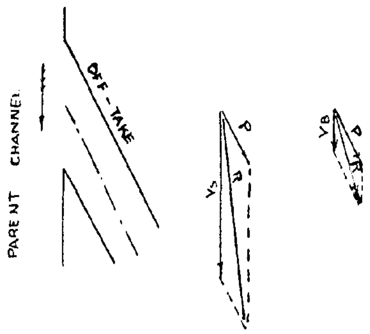


FIG-29. DIAGRAMATIC PLAN SHOWING FLOW LINES.



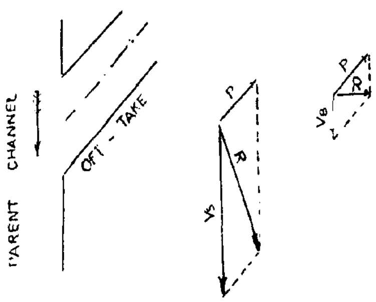
Velocity Vector for Right Angle Offtake.

FIG - 30.



Velocity Vector for Downstream Offtake.

FIG - 31.



Velocity Vector for Upstream Offtake

FIG - 32.

more of top water. As the top water does not carry appreciable amount of sediment, a large quantity of its diversion into the offtake ultimately reduces the sediment carriage towards the offtake.

iii) On the same anology more light could be thrown on the off-takes reversely inclined. In Fig.32 are drawn vectors separately for water moving at bottom and top layers from the stream into the reversely inclined offtake. From these it can be seen that instead of results improving they get worse. The resultant vector for bottom water is much more inclined in comparison to the top water than even incase of right angled offtake.

A comparative study of the vectoral diagrams consequently reveals that from the sediment distribution point of view, the offtkes at acute angle to the stream are better than any other angles of 90^{o} deg. or greater. As the acuteness of the offtake increases, the quantity of the sediment entering the offtake also correspondingly reduces.

-:O:-

4

EXPERIMENTAL SETUP & PROCEDURE

EXPERIMENTAL SET UP & PROCEDURE:

The experiments reported herein were carried out in the Hydraulics Laboratory of the University of Roorkee, Roorkee, in a 3 ft. wide and 20 ft. long concrete flume as shown in Fig. 33. A 15 in. wide offtake channel was taken off from the right hand side wall at a distance of 7.78 ft. from the upstream end of the main flume. The offtake angles adopted for various orientations of this channel were 30°, 60° 90°, 120° and 150°.

A 4.5 ft. long and 3 ft. wide head box fitted with double row of brick baffle walls, was used as a stilling device. The suitable gate arrangements were also provided at the down-stream ends of both the channels. The top of the side walls were marked at an interval of one foot in order to allow an accurate determination of the position of water and bed surface. The bed of the flume was also marked along and across the section at 0.5 ft. intervals from 6 to 12 ft. It was, therefore, made possible to obtain the velocity traverses and depths of flow at these sections.

Proper arrangements were also provided for feeding and collecting the bed load as shown in Fig. 33.

Water was supplied to the flume from an over head tank through a 4 in. diameter supply line fitted with a 4" x 2" calibrated orifice-meter. The taps on both the sides of the

SCHEMATIC DIAGRAM OF THE EQUIPMENT

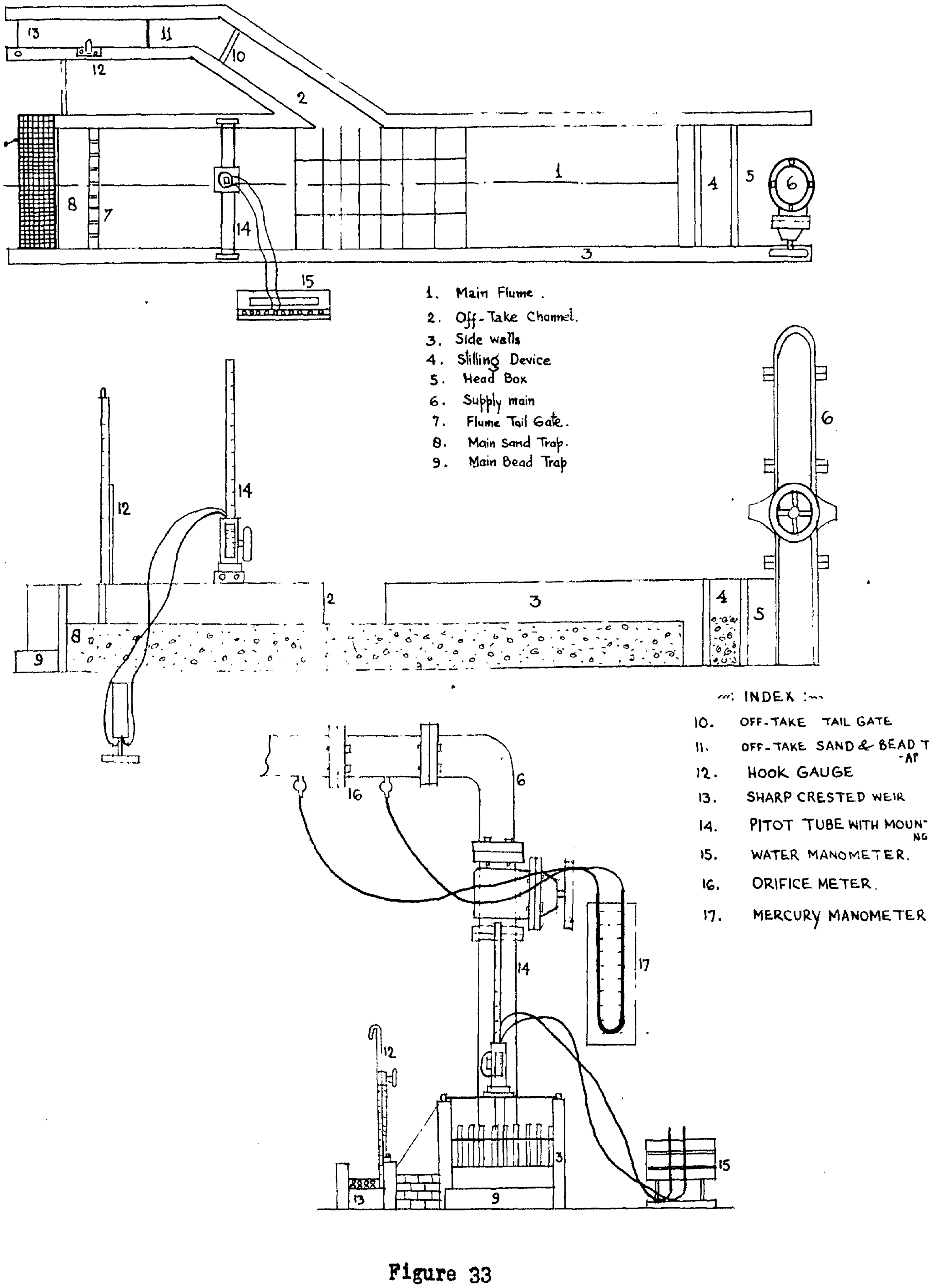


Figure 33

orificemeter for measuring the differential head were connected through 3/8 in. rubber tubing to the mercury manometer which was fixed at a height of 3.5 ft. above the bed of the flume.

The discharge was controlled by means of a regulating valve situated in between the headbox and the orifice meter. The water was then allowed to pass through the baffle screens and the spaces of dumped boulders in the gap of the baffle walls, and then to the flume. The stilling device helped to destroy the excess energy of flow and to distribute the flow uniformly across the width of the flume. The water which entered the flume was thus considerably stilled. It then flowed over a distance of 7.78 ft., and from there the water was shared by the offtake channel in accordance with the gate adjustment at the downstream end of the main flume. The remaining water after flowing through the main flume beyond the downstream ~~through~~ end was discharged to the sump through the overflow channel.

The water after passing through the offtake was directed into a tail box and then was allowed to pass over a 1.45 ft. long sharp crested weir. A hook gauge, 2 ft., upstream of the weir, was also provided to measure the discharge passing over the weir. It was graduated in inches having a least count of 0.01 in., which was considered satisfactory to measure the head over the weir. Thus, the discharge shared by the offtake was measured with the help of this hook gauge.

Thereafter, the discharge passing over the weir was led to sump from the sump the water was pumped back to the over head tank.

POINT GAUGE :-

A point gauge mounted on the wooden frame was used for measuring water and bed surface profiles. It was possible to measure a difference of 0.001 ft., in the elevation with the help of this point gauge.

PITOT TUBE :-

The pitot tube clamped to similar point gauge mounting and connected by 1/4 in., rubber tubing to water manometer was used to obtain the velocity traverses. The scale attached to the manometer was having a least count of 0.1 inch which could be further read upto 0.025"by visual inspection.

EXPERIMENTAL SAND AND RED BEADS :-

The sand used for the experimental purpose was off dark in colour with few greyish and shining white grains and were fairly rectangular. The sand used was of size passing through the U.S. Seive No.20, having the openings of 0.84 mm., and below that. The seive analysis of the sand was carried out and the size distribution curve, as plotted for the sand sample, is as shown in Fig.34 and d_{50} = 0.69 mm., was taken as the representative of size of the sand.

Red beads used as bed load locally called 'Rattis' . The Rollers were having the characteristics property of moving at small velocities and were blood red in colour with black spot.

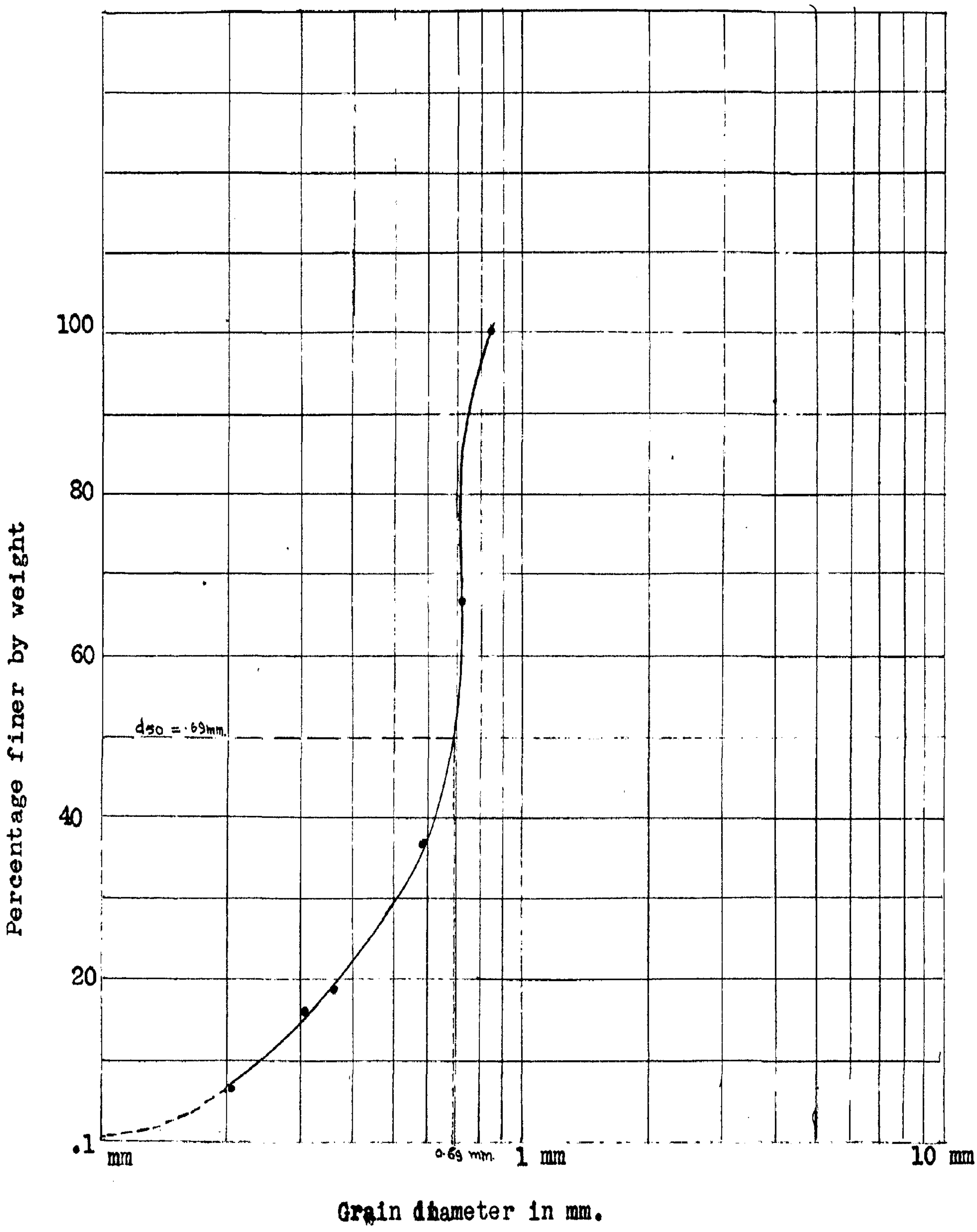


Fig. 34. Grain size distribution of the sediment.

These were spherical in shape and their diameters varying from 1 mm to 2 mm.

NUMBER OF RUNS :-

The runs were taken for a set of predetermined variables. These variables include five angles of offtake , three discharge values in the parent channel with their three proportion 10%, 20%, 30% in the offtake channel, and two types of bed loads. A combination of these gave in all, a total of 5 x 3 x 3 x 2 = 90 runs. But the red beads runs for the 120^{o} offtake angle, however, were not taken.

PROCEDURE

The supply was limited to a maximum of 0.96 cusec. It was therefore, considered worthwhile to carry out the experiment at three discharges within 0.96 cusec and the adopted discharges were, full supply, three-fourth supply and one-half supply (i.e. 0.96 cusec, 0.7 cusec, and 0.46 cusec).

Next, one of the adopted discharges was then allowed to enter the flume by operating the regulating valve. The discharge entering the flume was controlled with the help of mercury manometer. The flow was allowed to attain steady conditions and the tail gates were then operated to divert the requisite quantity of water in both the channels.

Three proportions 10%, 20% and 30% of the parent channel flow were in turn, diverted to the offtake channel.

The water and bed surface levels along the centre line of the flume were taken at intervals of 2 ft., under the steady flow conditions.

Measurements of the depth of flow across the flume were carried out at 6 ft., 7 ft., 8 ft., 8½ ft., 9 ft., 10 ft., and 11 ft., from the upstream and of the flume. Depths were also measured in the offtaking channel at the entrace and also at 1 ft. and 2 ft., downstream the entrance.

VELOCITY DISTRIBUTION :-

Velocity traverses were obtained with the aid of a pitot tube at five places in a cross-section of the flume, as shown in the fig.(33), at intervals of 1 ft. The velocities were also obtained at three points in the vertical (i.e. at the bed mid-depth, and surface level). Such a velocity distribution was obtained at 6 ft., 7 ft. 8 ft. 8½ ft. 9 ft.10 ft., and 11 ft. along the bed of the main flume.

Velocity traverses were also obtained on the bed of the offtake at the entrance, 1 ft. and 2 ft., downstream the entrance.

SAND FEEDING :-

Next, the weighed quantity of the experimental sand was fed regularly by hand spreading over the entire width of the flume at a place 6 ft. upstream the point of diversion. The runs for sand feeding were continued for 2.5 hrs to 3 hrs.

at higher discharges and for about 4 hrs. to 5 hours at low discharges.

When the feeding of sand was stopped, the material lying on bed, upstream the point of diversion was allowed to move down. The run was closed, as soon as the steady conditions were achieved indicating that no sand was being drawn by the offtake channel from the sand deposited before the mouth of the offtake.

FEEDING OF RED BEADS :-

Red beads numbering 600 to 700 were fed across the width at intervals of 1 in. with the help of a scale fitted on a large wooden plank kept across the flume. These rollers were fed two to three times to ensure the surety of results obtained.

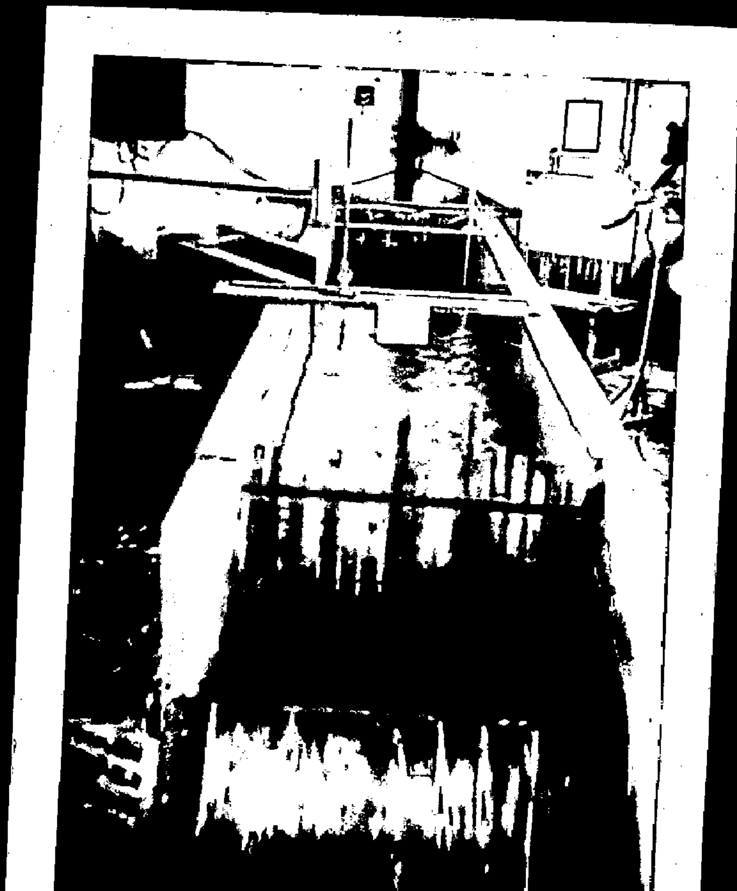
A mean of these sets of feeding was taken.

COLLECTION OF BED LOAD :-

The sediment as shared by both the channels arms was collected from the two trap boxes, situated at the end of the respective channels. The sand deposited on the bed of the respective channels below the point of diversion was also counted towards that collected from the traps.

The sand was then dried and weighed on a balance.

The percentage of sand shared by both the channels was then calculated.



GENERAL VIEW OF THE EXPERIMENTAL SET UP.

The beads shared by both the channel arms were trapped in the especially provided wire mesh traps at the downstream end of the respective channels. These were then collected from the traps at the end of the run. The percentage of beads diverted to the offtake was then found out.

A similar procedure was adopted for each run.

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5

ANALYSIS

ANALYSIS

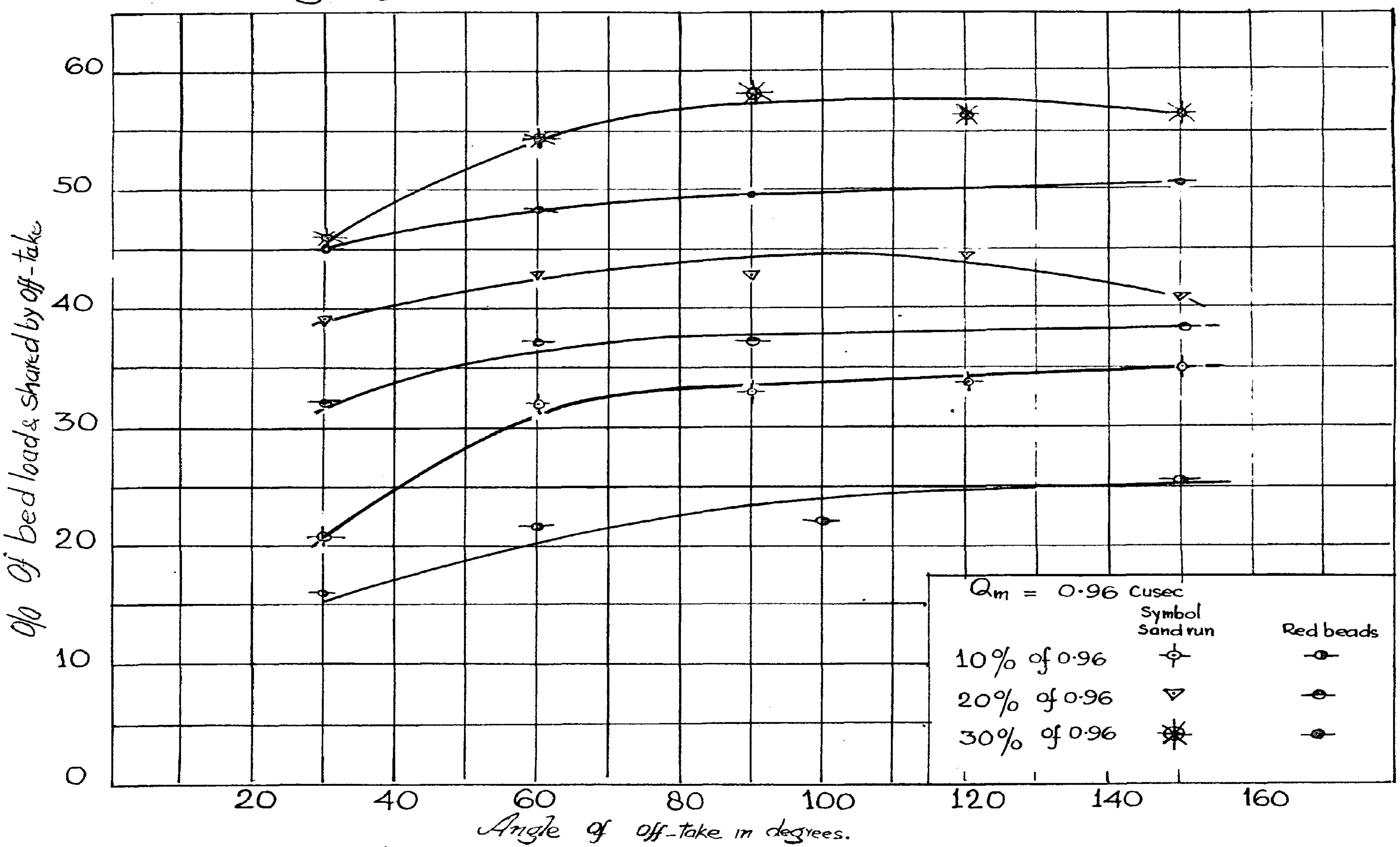
In order to study the effect of the angle of offtake on sediment distribution in canal offtakes, experiments were conducted on five different angles. Three discharge values were allowed in the parent channel for each angle and afixed quantity of sediment was introduced at the head of the parent channel at a distance of about six feet from the point of offtake. Sediment proportion were studied in offtakes for 10%, 20% and 30% of the flow in the parent channel. Thus for each angle of offtake there were nine observations of sediment distribution.

It was observed that the movement of sand was not significant at lower discharges and hence red beads locally known as 'rattis' were introduced in the flow which moved for all values of discharge. Red beads were used for four angles and 36 observations were taken using them.

Bed Load - Angle of offtake relationship.

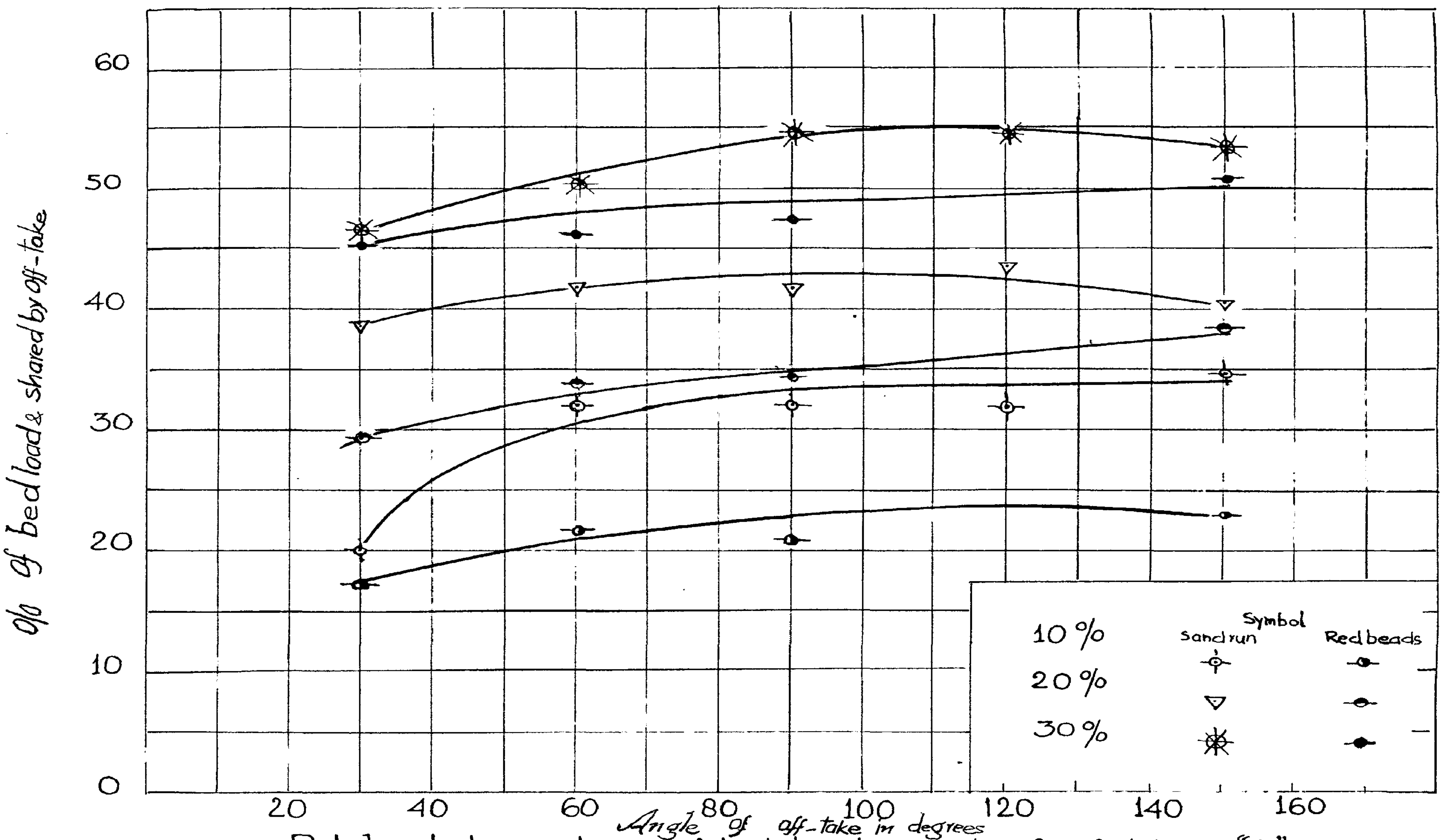
Fig. 35 shows a plot between the percentage of bed load shared by the off-take as ordinate and the angle of branch as abscissa. The different lines indicate the different discharge values allowed in the offtake which were 10% , 20% and 30% of 0.96 cusecs discharge in the parent channel. It can be seen that the curves continue to rise from the angle of 30° upto about the angle of 90° , and then they tend to become horizontal. The nature of these curves indicate that the

Fig: 35



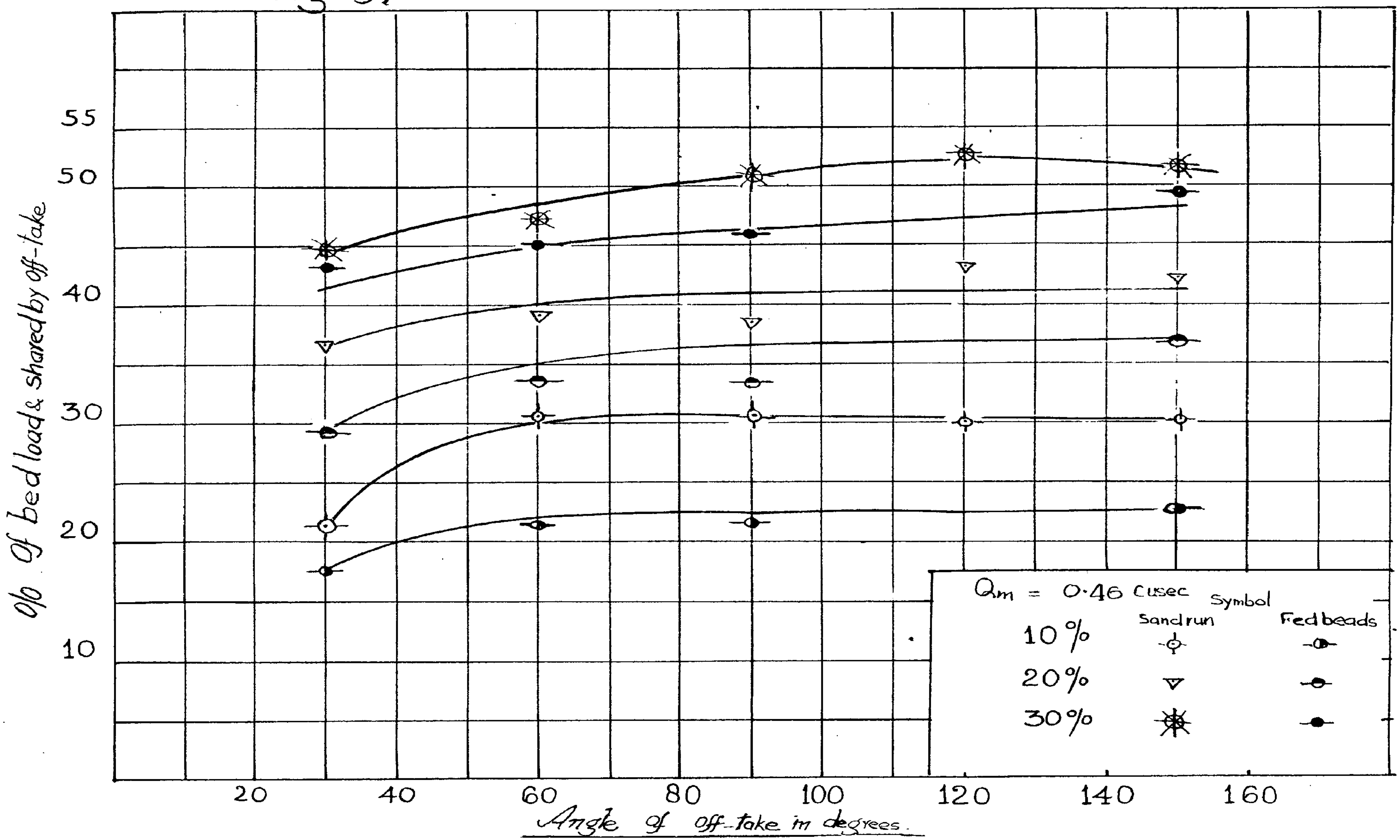
Relation between division of bed load & angle of off-take at "Q_m" = 0·96

Fig: 36



Relation between division of bed load & angle of off-take at "Q_m" = 0·7

Fig: 37



Relation between bed load & angle of off-take at "Q_m" = 0·46 cusecs.

RELATION BETWEEN THE DIVISION OF LOAD & DISCHARGE IN THE OFF-TAKE CHANNEL FOR AN ANGLE OF OFF-TAKE 30°

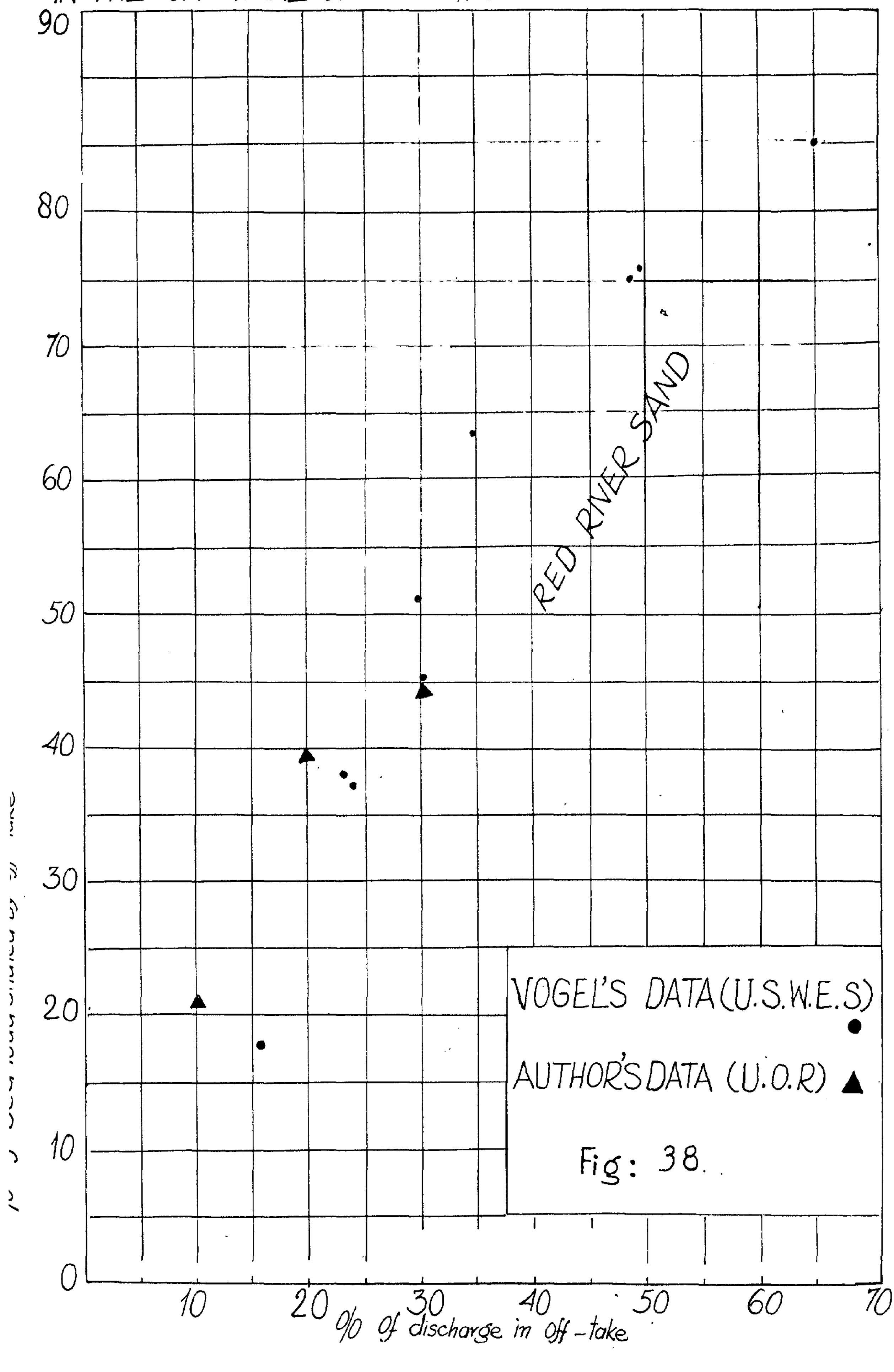


Fig: 38.

increase in the percentage of bed load moving in the branch channel, for a particular percent of discharge diverted in the branch channel, continue to increase with the angle of offtake upto 90° and then there is no variation in the percentage of bed load, for increase in the offtake angle.

In Fig. 35 the curves are obtained for three percentages of discharge entering the branch, and for particular total flow, Q_m ,. With the increase in the percentage of discharge entering in the branch, the curves lie above the preceeding one.

It can be seen that smooth curves obtained from the experimental results, show a general trend, for each of the case plotted, but a slight departure in the shape of the curves, for quite a few cases, can be noted. The curve for 20% of 0.96 cusec discharge, is flatter, as compared to those of 10% and 30%.

It is indicative in fig. 35 that there is little scatter in the plot , the points which departs from the smooth curves lies in the close proximity of the curves. Similar plots for Q_m = 0.7, and Q_m = .46, are obtained in Fig.36 and Fig.37 respectively. In Fig.36, the curve for 10% discharge has a very sharp increase of the percentage of bed load, G_b , from the angle of offtake equal to 30° to 90°, whereas in case of other two, it is not so. The curves, for 20% and 30% discharge have more or less the same shape, which is evident from the Fig.36 itself. In case of curves, for 10%, of discharge, there is a scatter in the results plotted, but in case of other two, the data appears consistent with the curves.

A similar explanation also holds good for Fig.37 for Q = .46 cusec.

Fig.38 shows results of the experiments conducted by Vogel. The data of the present investigation for full supply discharge (i.e. 0.96) and for an angle of 30° has been supperimposed on his plot. It can be seen from Fig.38 that author's data conforms to Vogel's data to a great extent. The slight deviation in the two may be due to the difference in the composition of bed material.

The data of the present investigation as plotted in Fig.35 for the percentage of sand diverted into the offtake, differ from the observation of Bulle. It is interesting to note that in the present investigation the amount of bed load shared by offtake at an angle of 30° was found to be minimum as shown in Figs. 35,36 & 37, whereas in case of Bulle's studies it was maximum, which is evident from Fig.1. It should be noted that the offtake channels in his studies, had the same areas as the parent channel and the discharge in offtake and the parent channel were also same. In the present study, the width of the parent channel, and also the discharge ratio in the parent and the offtake channels were different. Hence variation in experiments may be the case of the inconformity.

Amongst the several possible factors, which cause the excess entry of bed load into the branch channel, is the curvature of flow. The presence of the curvature of flow is due to the fact that the approaching water at the point of diversion, deviates from its usual path, and changes its direction in order to enter the offtake channel. The flowing water has momentum in direction of flow, and the magnitude of which depends on the amount of velocity of flow.When the flowing water changes its direction, a force is needed to account for this change in momentum.

The water moving with a velocity V on the curved path is acted upon by its weight vertically downwards and a centrifugal of sediment entering the offtake.

The velocities at the bottom layers are considerably less than those at the top. Consequently, smaller centrifugal force is available at the bottom than that at the top. This difference in centrifugal force in a vertical produces a spiral flow pattern as shown in Fig.36.

The existence and significance of centrifugal force has been discussed in the earlier pages alongwith the theoretical aspects of the problem. It can be seen from Eq. 1 and Eq. 7 that the intensity of the centrifugal force produced near the entrance to the offtake mainly depends on the value of θ. It is stated that division of the bed load between the parent and offtake channel is a function of this angle. It is evident from the equation 7 that smaller the value of angle θ, greater is the value of R. Thus, it appears from Eq. 1 that the value of centrifugal force reduces with the increase in R or the decrease in θ.

The foregoing discussion evidently shows that smaller the angle of offtake, the smaller will be the percentage of bed load approximately in proportion of water diverted. The test results obtained, as plotted in Figs. 35, 36 & 37 also confirm the above facts.

EFFECT OF MECHANICAL COMPOSITION OF MATERIAL IN THE DIVISION OF BED LOAD AT OFFTAKES :-

In figures 35, 36 & 37, the relation between the percentage of red beads diverted in the branch channel and the angle of offtake has also been plotted along with the sediment data. The smooth curves obtained from the plots are fairly consistent and showing a general trend similar to that of sediment distribution.

When the curves of sediment data are comparedwith those of red beads, it will be seen that in each case, the curves of red bead lie below the curves of sediment data. The curves as obtained in Figs. 35, 36 & 37 indicate that the percentage of Red beads entering the offtake is lesser than that of sand percentage. It may be noted that the mechanical properties of the bed material is an important factor in the division of bed load at offtakes.

It is worthwhile here to mention that the red beads were perceptible to follow the path of flow even if the velocities were very low. The beads normally were transported as a bed load by rolling, sliding and slatation with small verticle amplitude.

It is seen that at the bed of the channel, the component of velocity in the direction of main channel are relatively low than the components in the direction of off-take channel is relatively high. Therefore, the velocity at offtake mouth were in-sufficient to transport the large quantity of heavier particles of sand beyond the offtake. With the result the sand particles were dropped by the flow in the form of an island, at the mouth of the offtake which moved in the offtake lateron. It was not the case with bead, since they were light enough to move at very low velocities. Hence the bead material was having a tendency to move down stream of the main channel instead of getting deposited at the mouth of offtake.

It should be noted that lighter particles which moved on the bed tend to deviate nearly in the proportion of water.

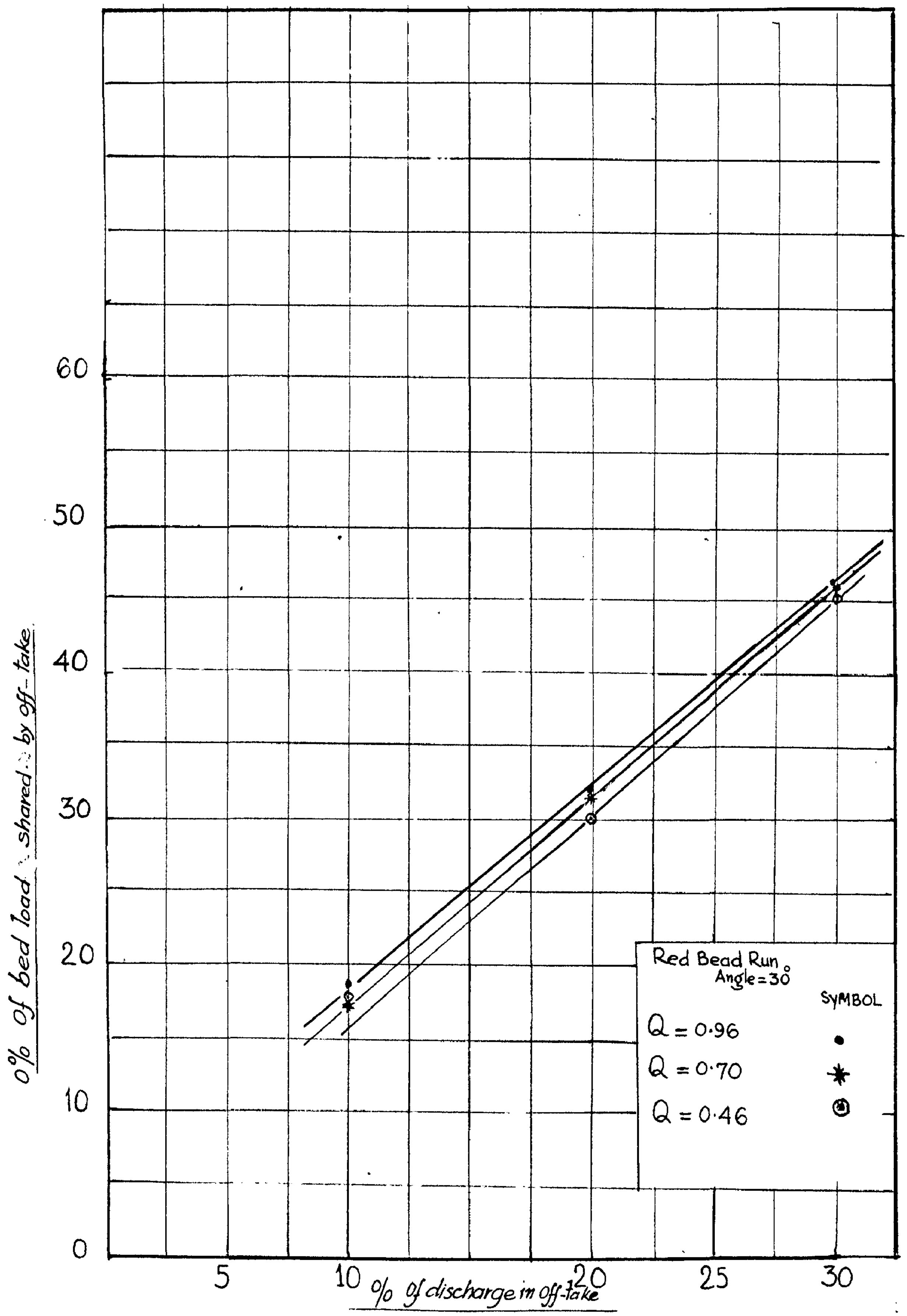
Hence the discussion supports that the difference in the percentage of diversion of the two material as shown in Figs. 35, 36 & 37 can be expected.

BED LOAD - DISCHARGE RELATION.

Fig. 40 shows a relation between the percentage of bed load and the percentage of discharge entering the offtake The total amount of flow introduced in parent channel is shown as a third parameter. Similar relations have been plotted in Fig. for each angle of offtake for sand as movable material and figures 39, 41, 43 & 45, for red beads as the moving material.

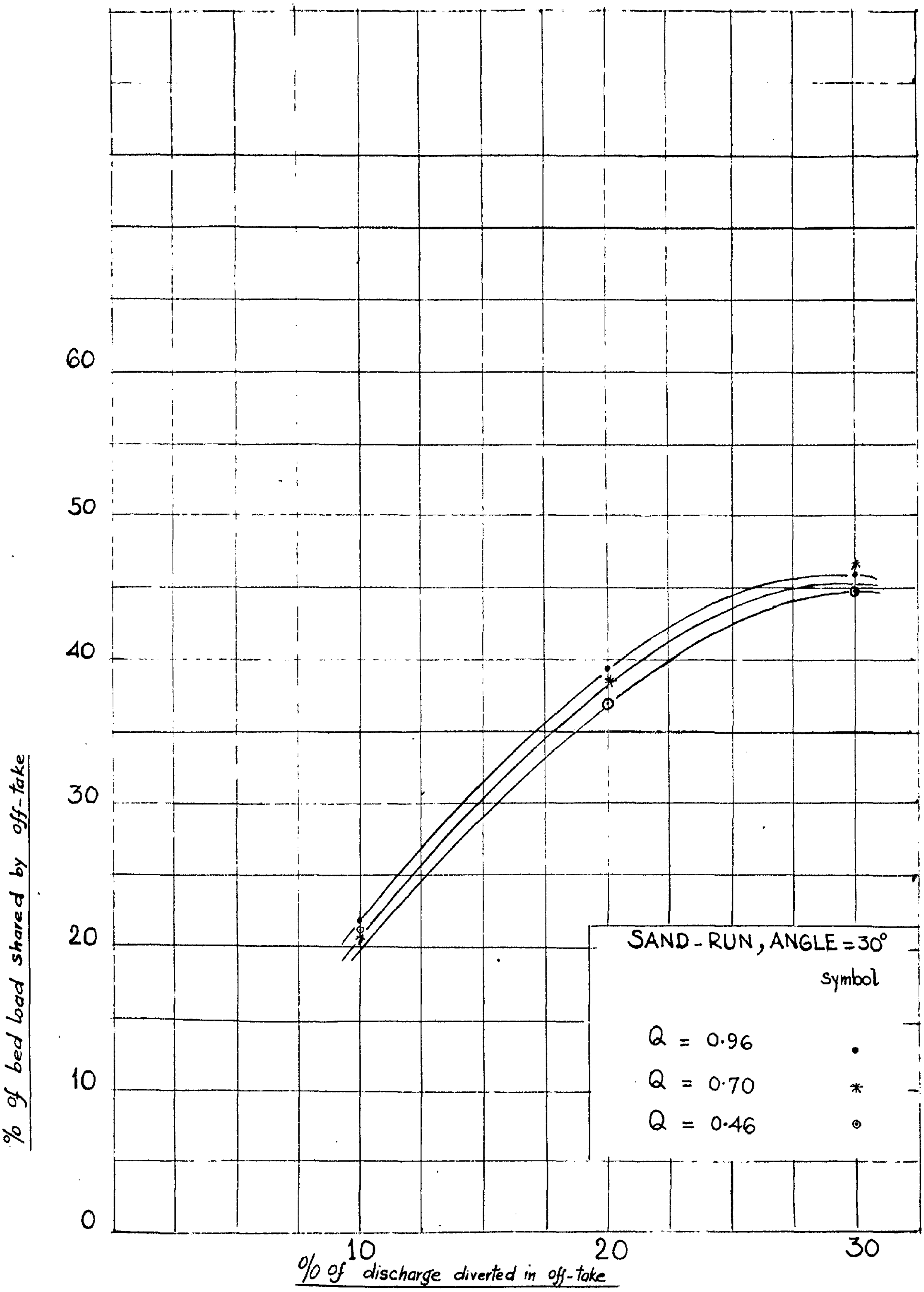
Fig. 40 reveals that as the percentage of discharge

Fig: 39



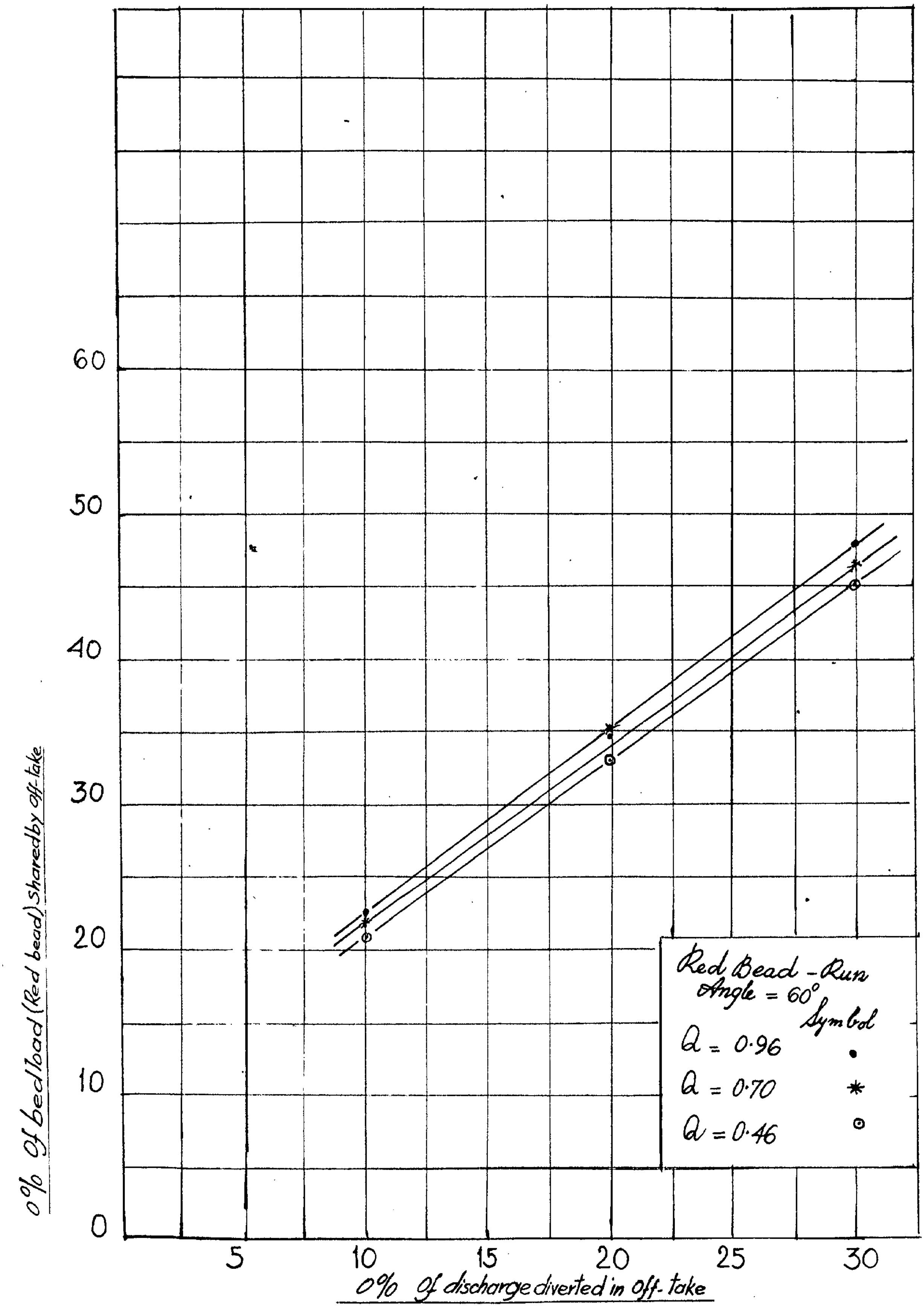
RELATION BETWEEN BED LOAD AND DISCHARGE IN OFF-TAKE, FOR 30°

Fig: 40



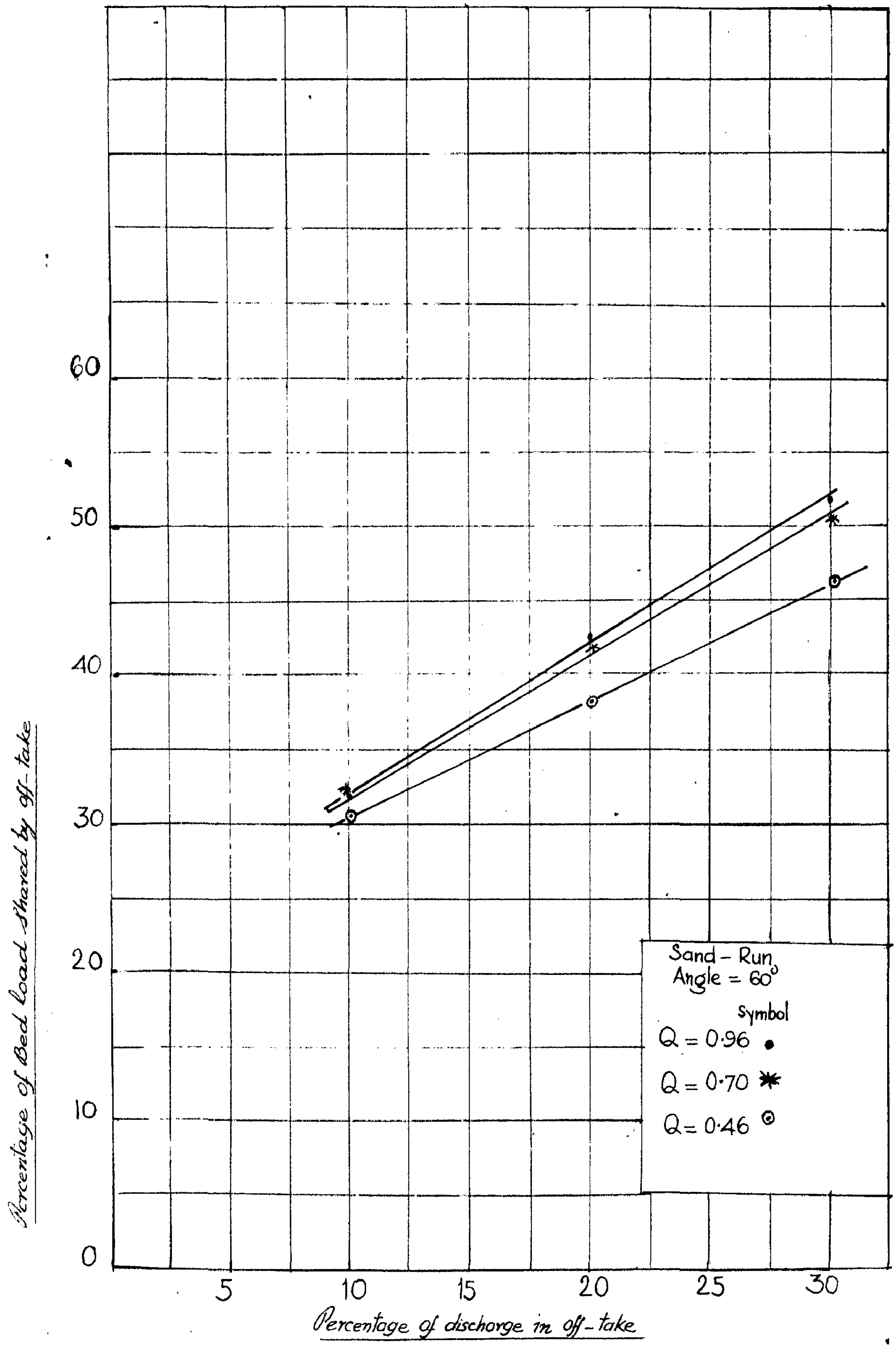
Relation between bed load & discharge in off take, for 30°

Fig 41



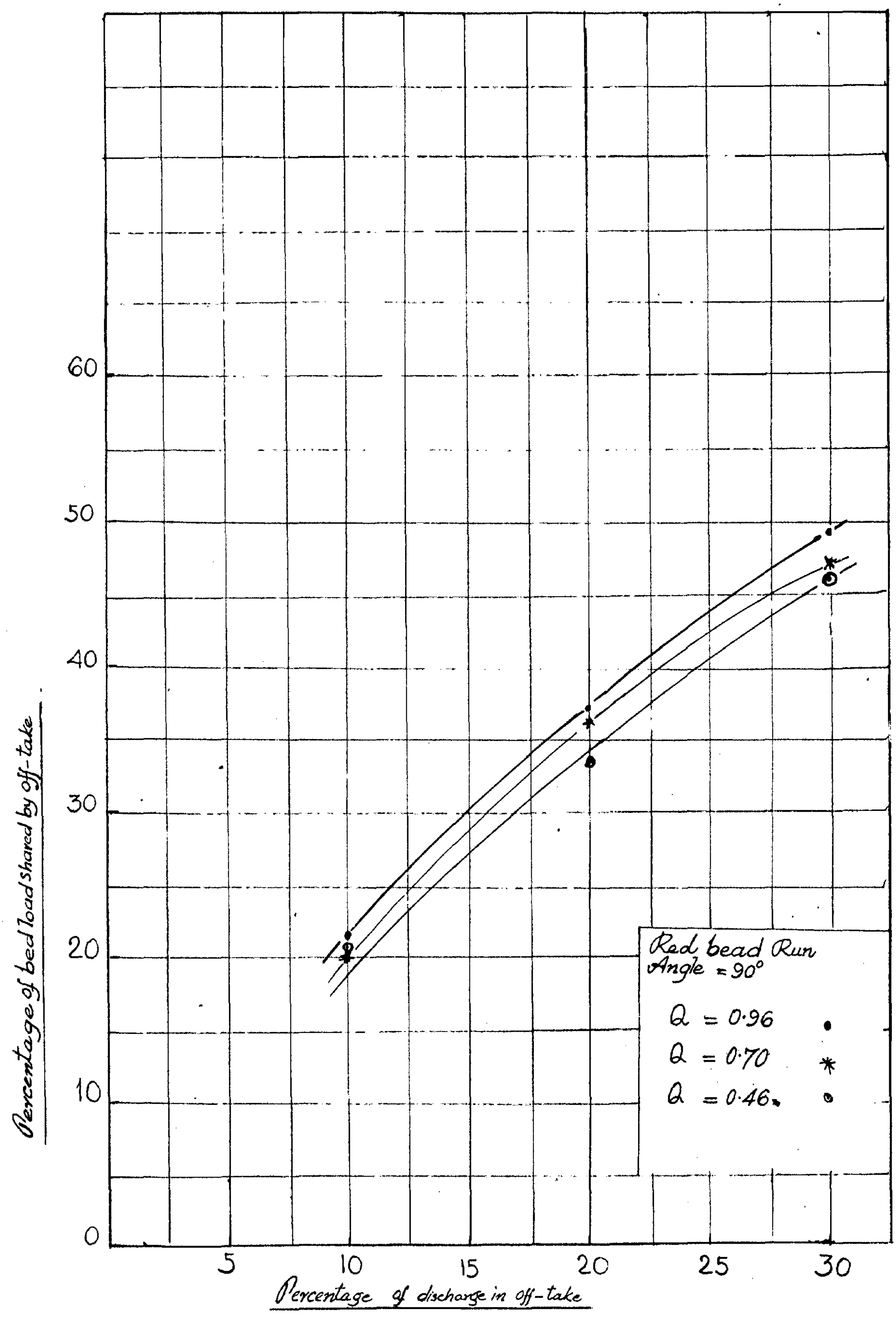
Relation between bed load and discharge in off-take.

Fig 42



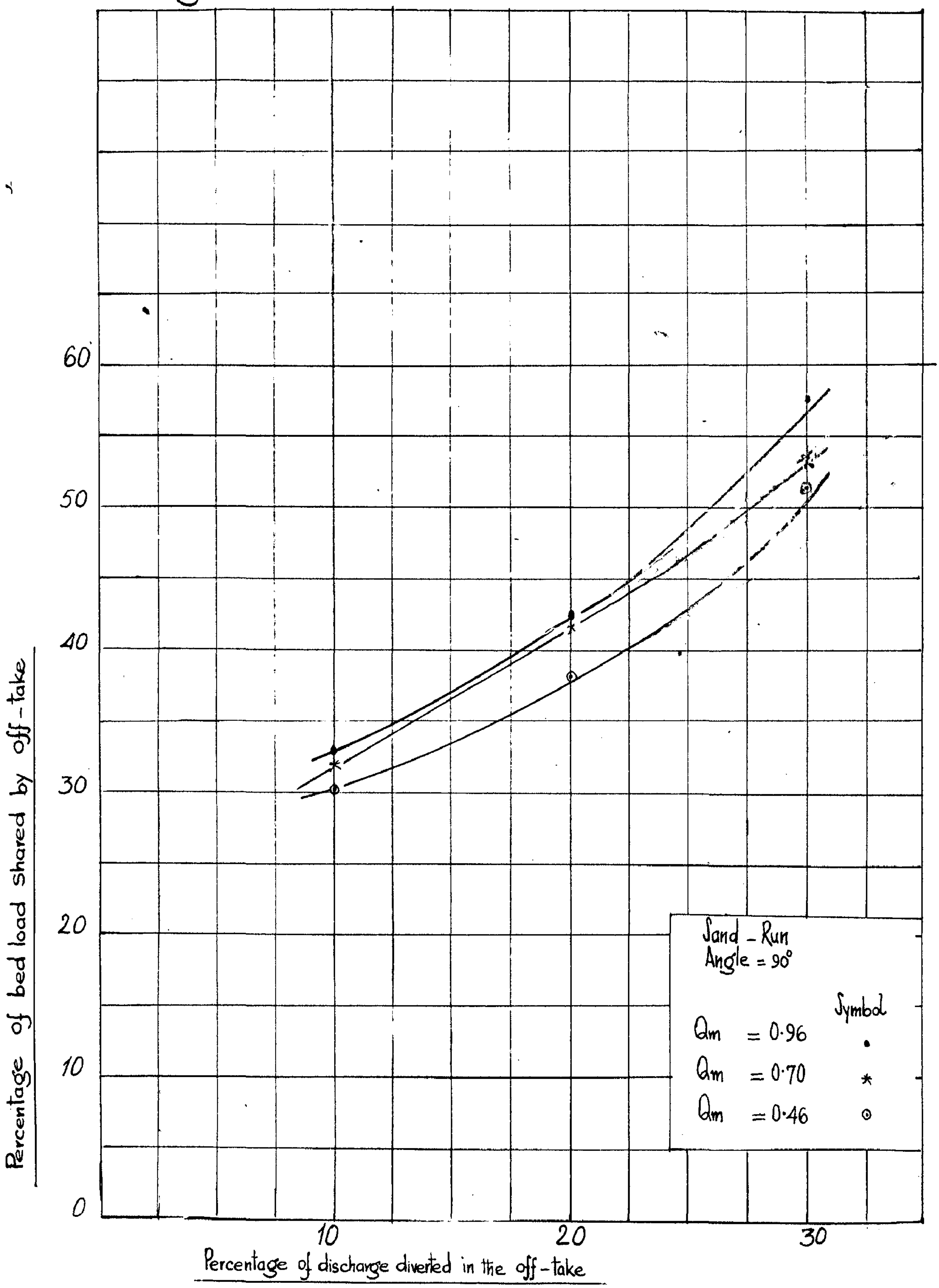
RELATION SHIP BETWEEN BED LOAD AND DISCHARGE IN OFF-TAKE

Fig 43



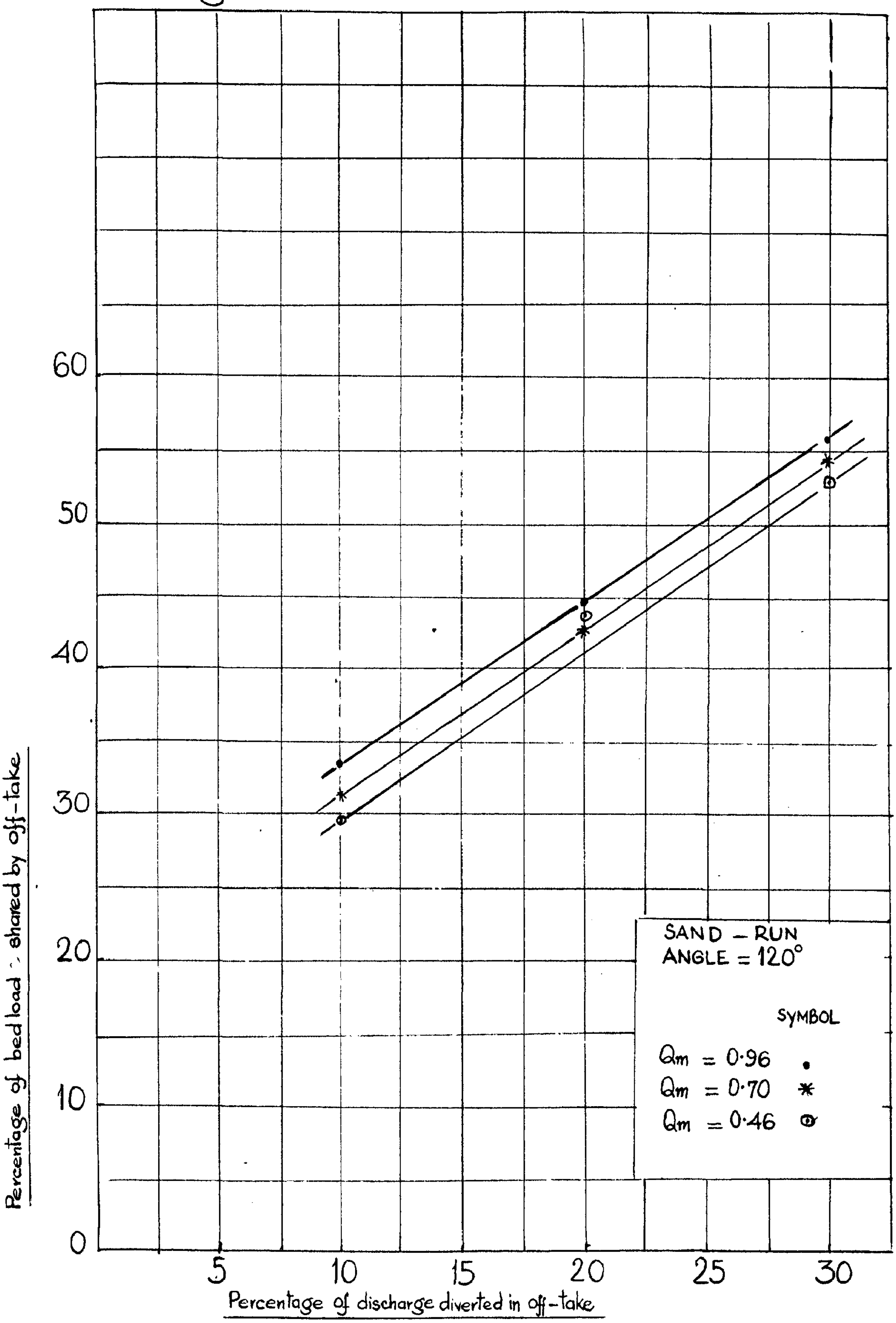
RELATION BETWEEN BED LOAD & DISCHARGE IN OFF-TAKE FOR 90°

Fig 44



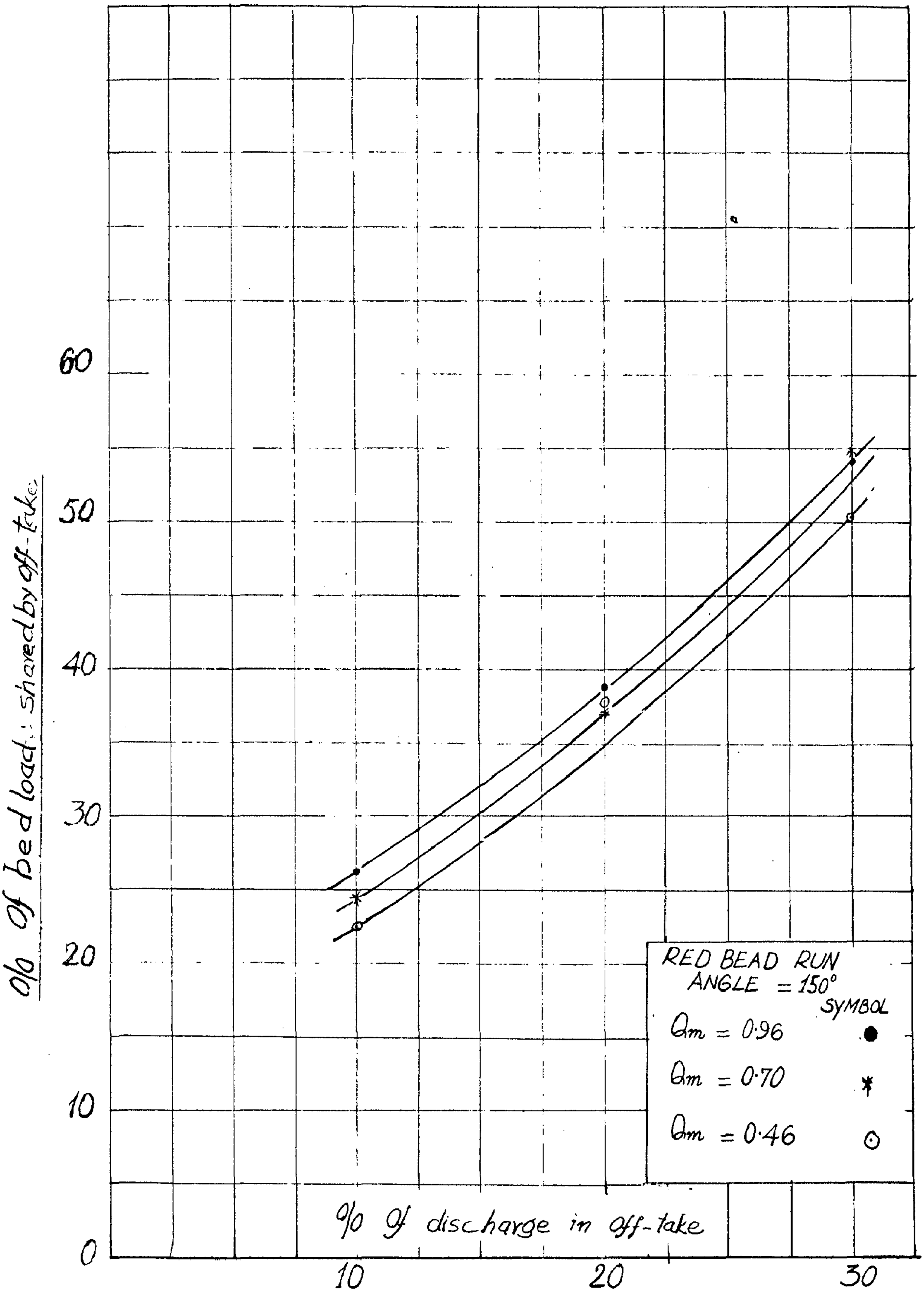
Relation between bed Load & discharge in off-take, for 90°

Fig 45



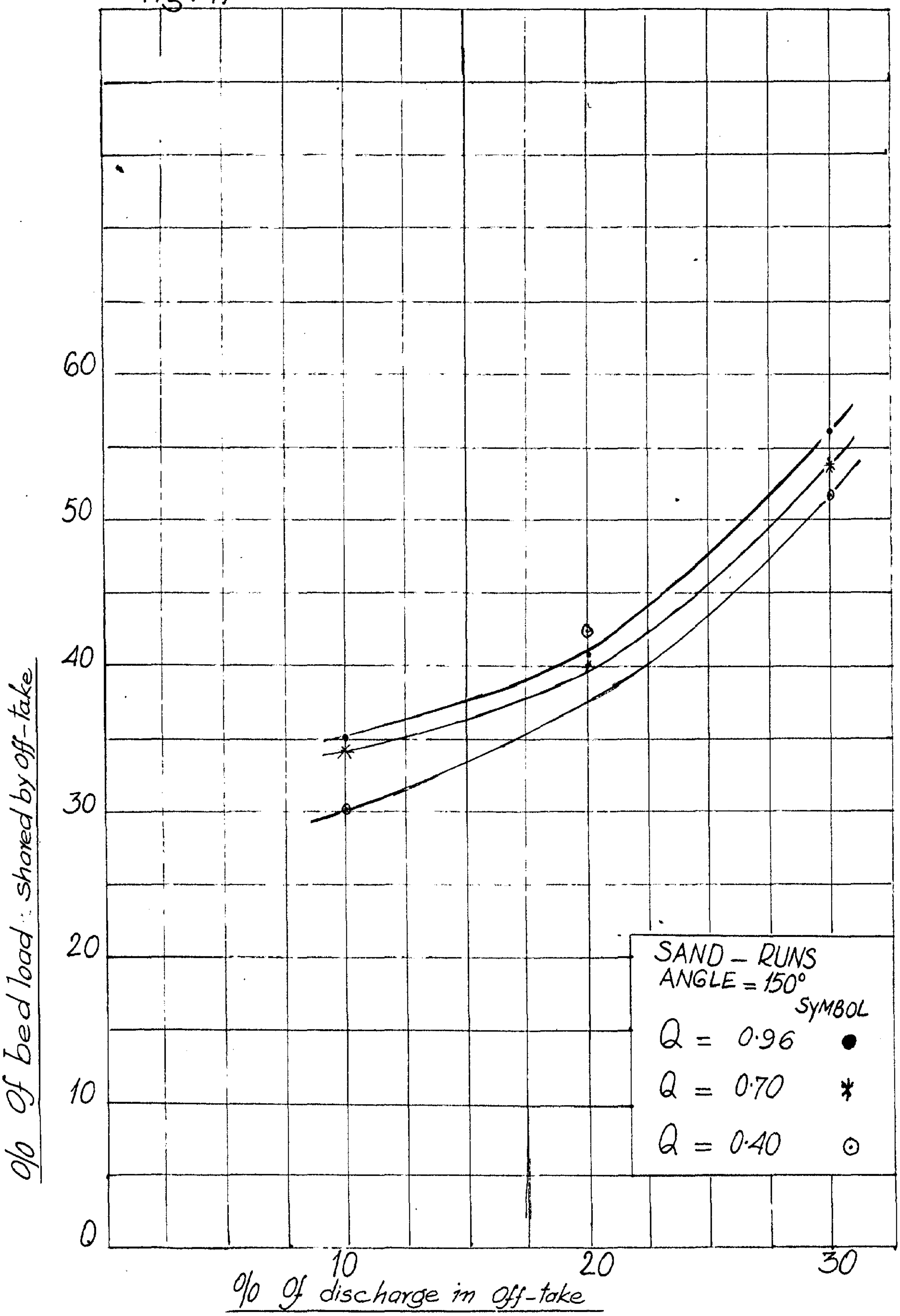
RELATION BETWEEN BED LOAD AND DISCHARGE IN OFF-TAKE

Fig 46



RELATION BETWEEN BED LOAD & DISCHARGE IN OFF TAKE

Fig: 47



RELATION BETWEEN BED LOAD & DISCHARGE IN OFF-TAKE into the offtake is increased, the quantity of the bed load entering the offtake also increases, but the increase is not corresponding to the proportion of water diverted. It can be seen from Figs. 40, 42, 44, 46 & 47, that the maximum percentage of bed load entered the offtake was found to be 58.07%, for the 30% of full supply discharge (.96 cusec) at an angle of 90°, whereas a minimum of 20% was observed, at an angle of 30° for a discharge value of 0.7 cusec in the parent channel. The other percentage of sediment load shared, for each discharge value in the parent channel and for each percentage of discharge in the offtake channel at various angles tested, lie in between 20% and 58.07 %.

All the plots in Figs. 40, 42, 44, 46 & 47, show more or less a straight line variation.

At lower percentage of flow in the offtake when the quantity of flow is increased in the parent channel, there does not appear to be a corresponding increase in bed load diverted into the offtake. On the contrary, at a higher discharge the sediment percentage in the offtake is appreciable.

It was observed that the average velocity upstream of the point of diversion is greater than the velocity below that point. At the mouth of offtake, the upper layers of waters are in movement and the lower layers are relatively stationary. With the result that upper layers which donot carry sediment load move straight down the channel beyond the offtake and the bed load gets deposited in the form of an island at the mouth of the offtake. The shape and the quantity of sediment load in the island depends on the discharge and the angle of offtake.

At the time of experiments it was seen that there was a slight depression in the water surface profiles at the mouth of offtake which latter gets back to its origion level down-stream of the offtake. It is, therefore, evident from Fig. 51,52, that velocity distribution changes and reduced in front of the mouth of the offtake, to a great extent.

Thus, with the change and reduction in velocity, the tractive force which is a measure of silt carriage, is abruptly reduced in parent channel before the head of the channel.

It was found that the reduction in tractive force of flow, drpps its bed load and gets deposited in the form of island before the offtke, and thus afforded on opportunity to the branch channel to draw more bed load.

It is known that the tractive force, $\tau = \gamma R S$, is responsible for the movement of bed load in the streams. Magnitude of the bed load transportation depends on the prevailing tractive force and increases with the discharge or water depth. The rate of bed load transportation is different for different water stages. The maximum activity of bed movement is at high water stages.

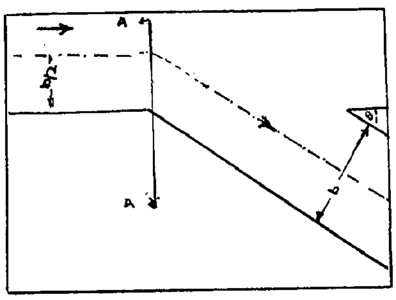
When greater quantity of flow enters the offtake at high discharge values, comparatively enough tractive force directed towards the offtake is available for the movement of bed load into it. Consequently a large quantity of bed material finds its way into the branch channel.

The foregoing discussion furnish an explanation to justify the trend of the curves, as in Figs. 40, 42, 44, 46 & 47 obtained from the experimental results.

A similar discussion will also be true to justify the behaviour of the curves obtained for red beads runs, in Figs. 39, 41, 43, & 45.

RELATION BETWEEN CENTRIFUGAL FORCE AND ANGLE OF OFFTAKE.

It was observed that water entering the offtake channel experiences a certain centrifugal force due to the curvature in flow filaments which produces a spiral motion in the flow. As a result of which the bed material rises towards the surface. The bed material coming near the water surface at the mouth of the offtake enters the offtaking channel alongwith the water entering the offtake. The centrifugal force is due to the velocity at a section A-A as shown in Fig. given below,



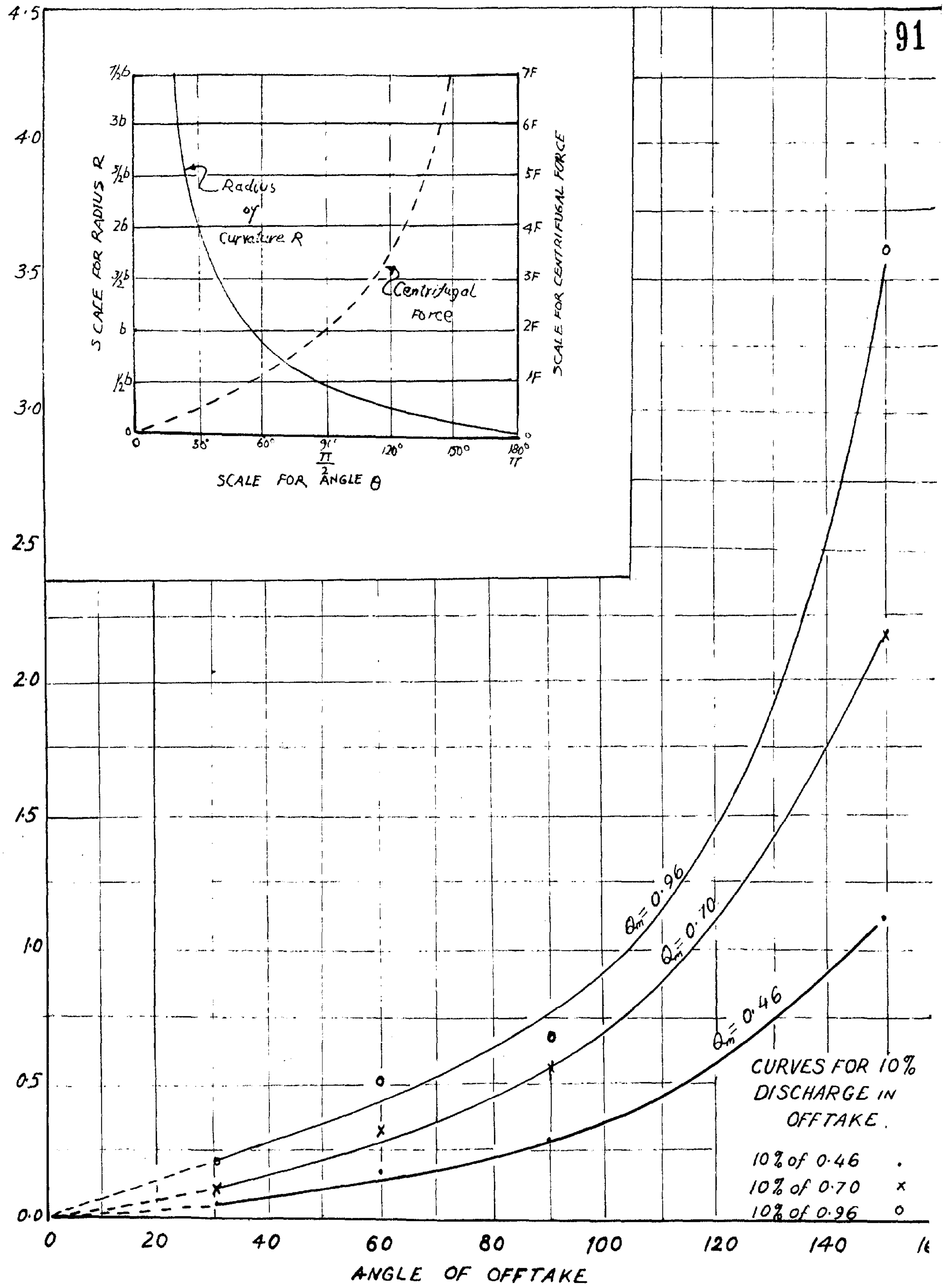


FIG-48 RELATION BETWEEN CENTRIFUGAL FORCE AND ANGLE OF OFFTAKE.

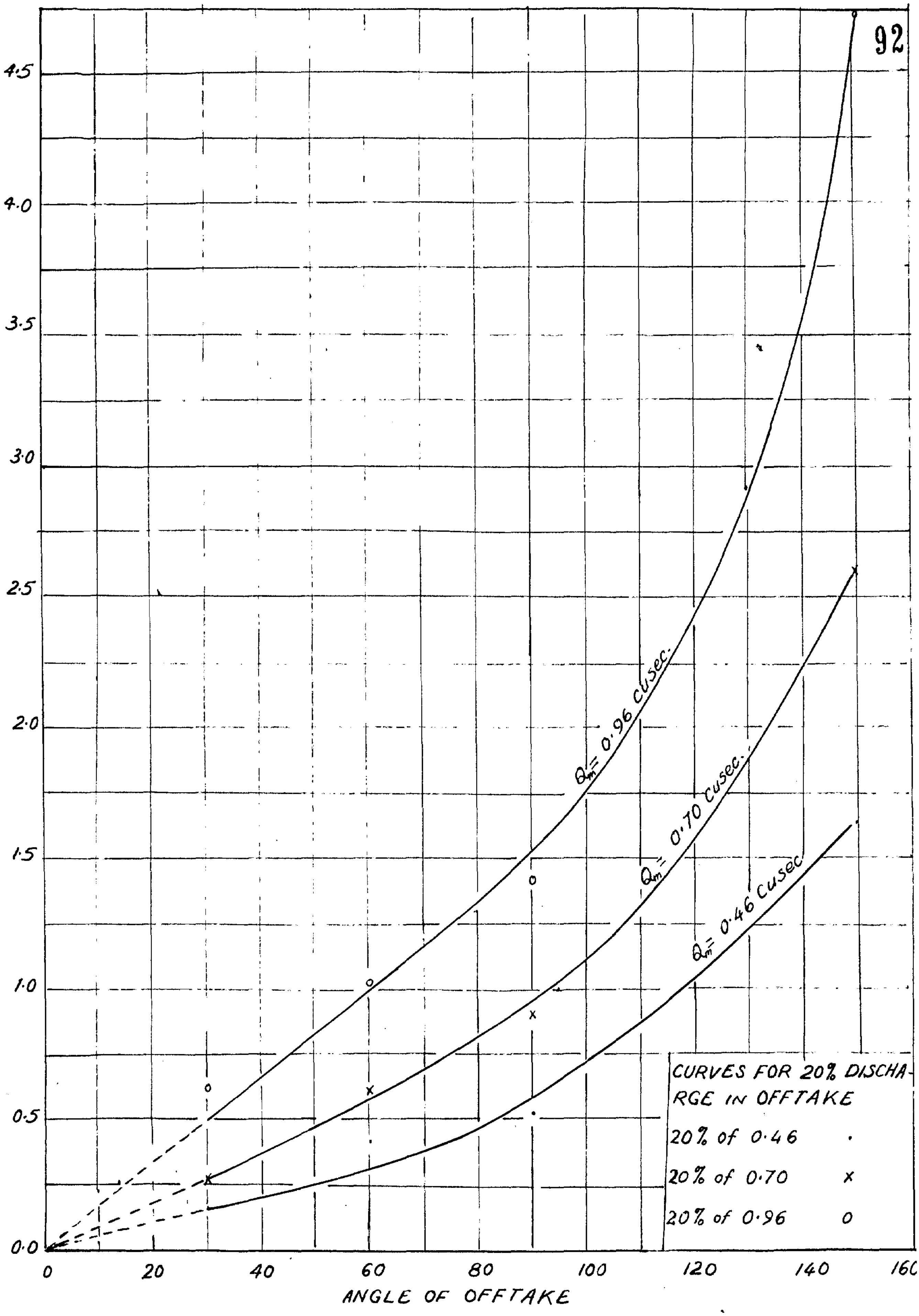


FIG-49 RELATION BETWEEN CENTRIFUGAL FORCE AND ANGLE OF OFFTAKE

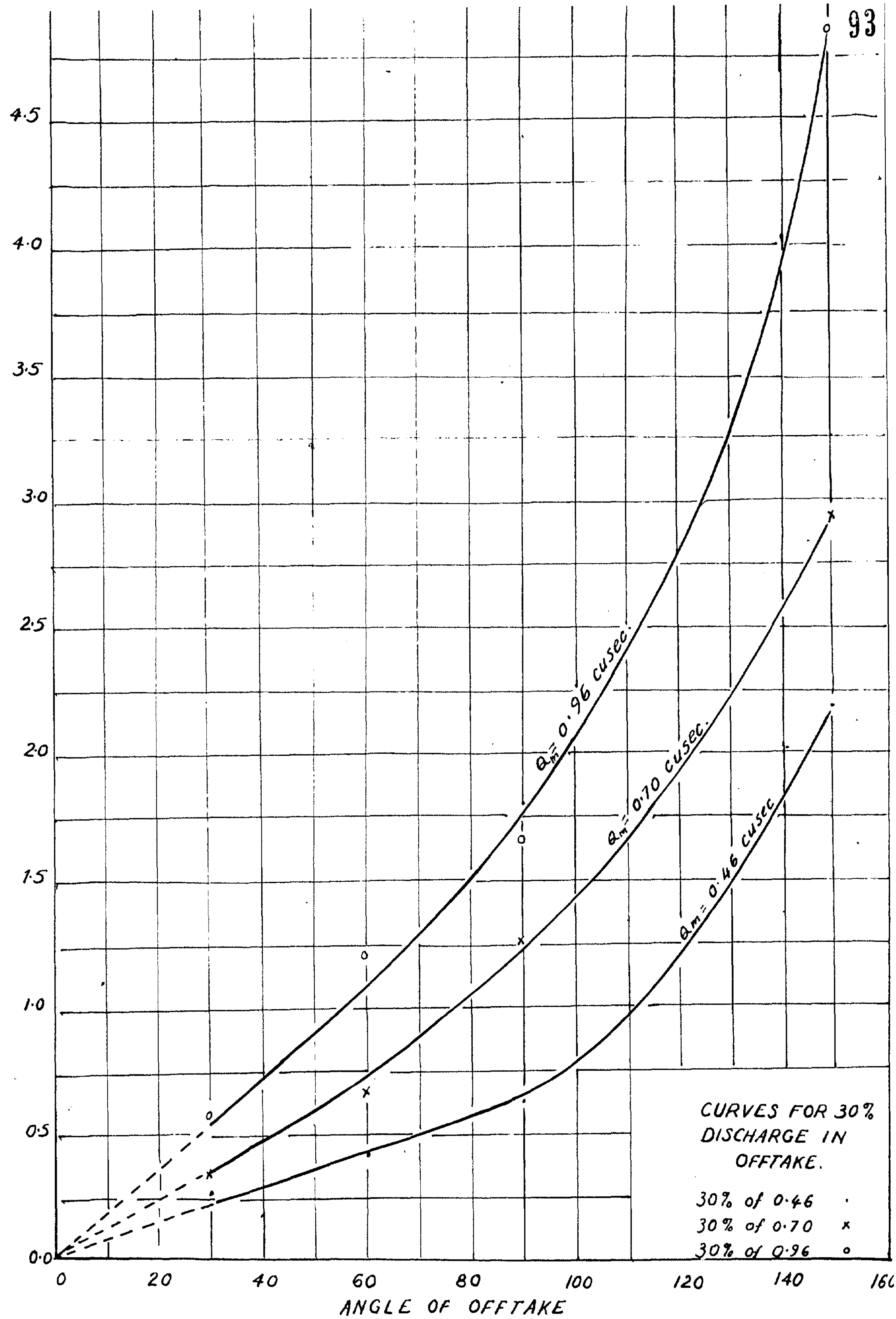


FIG-50 RELATION BETWEEN CENTRIFUGAL FORCE AND ANGLE OF OFFTAKE.

from where, the flow filaments start deviating, the radius of curvature of the flow filaments at the point of diversion, and the quantity of water entering offtake.

The computation of centrifugal force from Eqn. 1 and Equ. 7 have been done from the experimental data and the final results are presented in Table - 5.2 in the appendix I.

The curves in figures 48, 49 and 50 are the presentation of the results obtained in the above table. Fig.48 shows the relation between the centrifugal force and the angle of offtake in which the curves for 10% of the discharge with parent channel, have been obtained. Fig. 49 and 50 have also been prepared in a similar manner for 20% and 30% of diversion water. It can be seen that the curves obtained are consistent with data. The gradient of the curves is flatter at lower values of centrifugal force and gradually increases and is found to be maximum at higher values. The shape of the curves obtained from present investigation are similar to the theoretical curve presented by Leliavsky, which has been inset in Fig. 48.

The Figs. 48,49 & 50 show that centrifugal force increases with increase of angle of offtake. It can also be seen that with increase in the quantity of water in the offtake, the centrifugal force increases, since the value of w, increses with the increase in diversion of water.

Equations 1 and 7 show that change in any of the quantities in these equations results in a change in the magnitude of centrifugal force. The centrifugal force mainly depends on the values of velocities and radius of curvature.

The correlation of F and θ from Eq. 1 and Equ. 7 reveals conclusively that the centrifugal force engenered in the region where the flow filaments deviate from their normal coarse into offtake is a function of this angle.

The centrifugal force, therefore, constitutes the main factor in governing the behaviour of the sediment withdrawal at offtakes.

The experimental data obtained from experiments, and as plotted in Fig. 48, 49 & 50 are in full agreement and confirm the above statements.

FLOW CHARACTERISTICS.

When the water, without introducing sand was allowed to flow in both the channels, it was observed that there was a pronounced roller effect on the right side of the entrance to the side channel. The roller was having a clockwise motion on its vertical axis. In other words, it can be said that it was a case of whirling motion and it showed that its internal velocity were appreciably less to record. It was extending upto the centre of the offtaking channel.

On the left hand side of the offtake channel downstream the point of entrance of water, there was eddy motion which can be seen from the photograph.

This roller and eddies were huing the effect of reducing the cross sectional area of the offtake channel. With the result it was observed that the greatest velocity was noticed between the roller and eddies. When the sand was introduced in the channel, the roller and eddies in the branch channel get suppressed to same extent, and a bar of sand was build up in place of roller. The presence of roller and eddies was not significant in case of the angle of 30 deg.

A mild heading up of water was also observed in the parent channel just near the mouth of offtake which can be seen from the Fig. 54. The figure 53 plotted for water surface profile of the flow also shows its presence. This heading up of water surface near the mouth of offtake again gets back to its normal position beyond the offtake.

When the large quantity of flow was diverted into the offtake, negative or adverse slope occurs in the water surface of main channel downstream the offtake. On the contrary when the higher quantity of water was allowed to go down in the main channel, the slope of water surface were uniform and steep as occur in ordinary open channel. The Figures 53 are the indication of the above.

The transverse slope in the main as well as in side channel were also observed. The deepest water can be seen just

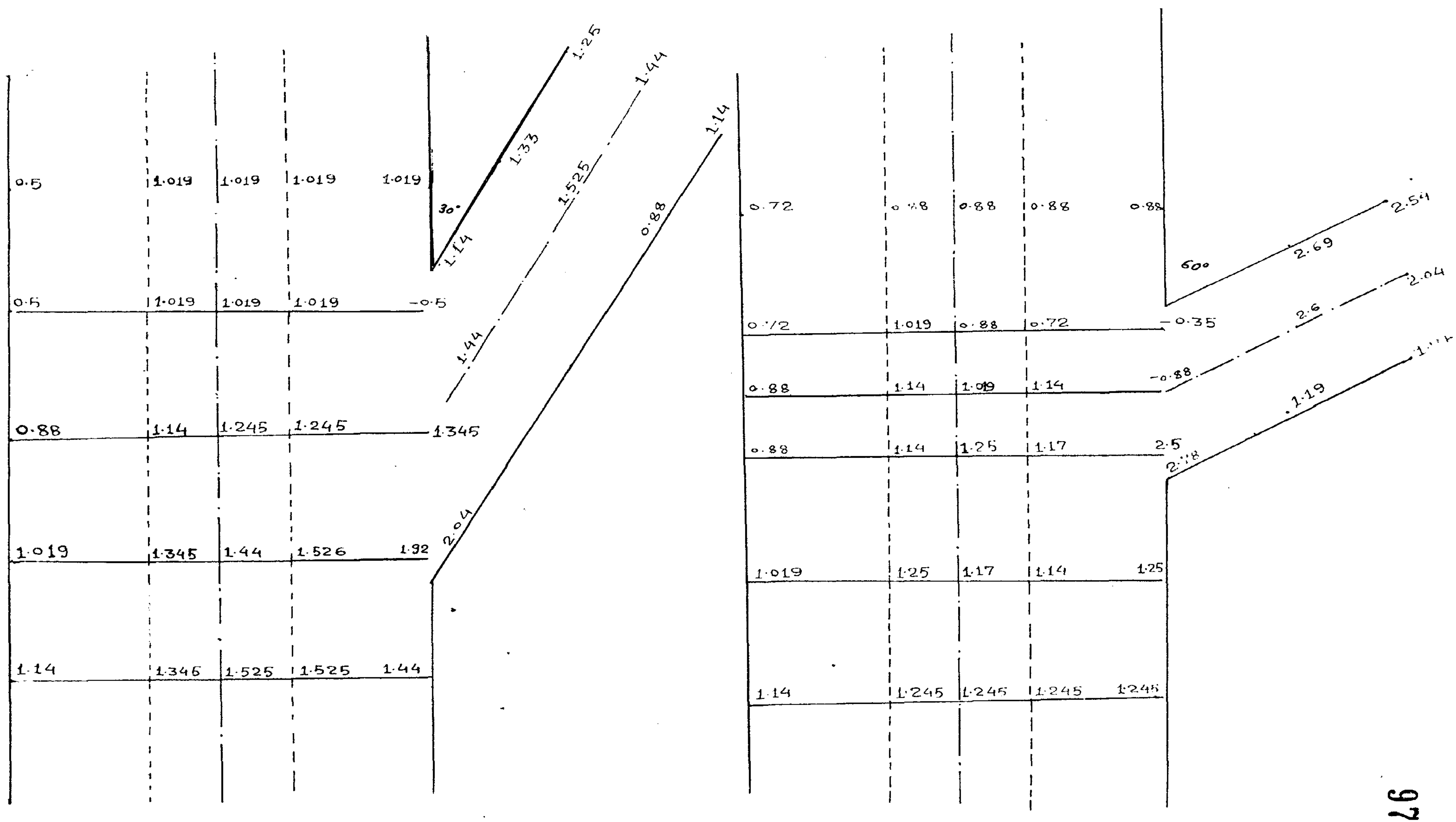


FIG-51 TYPICAL BED VELOCITY TRAVERSES.

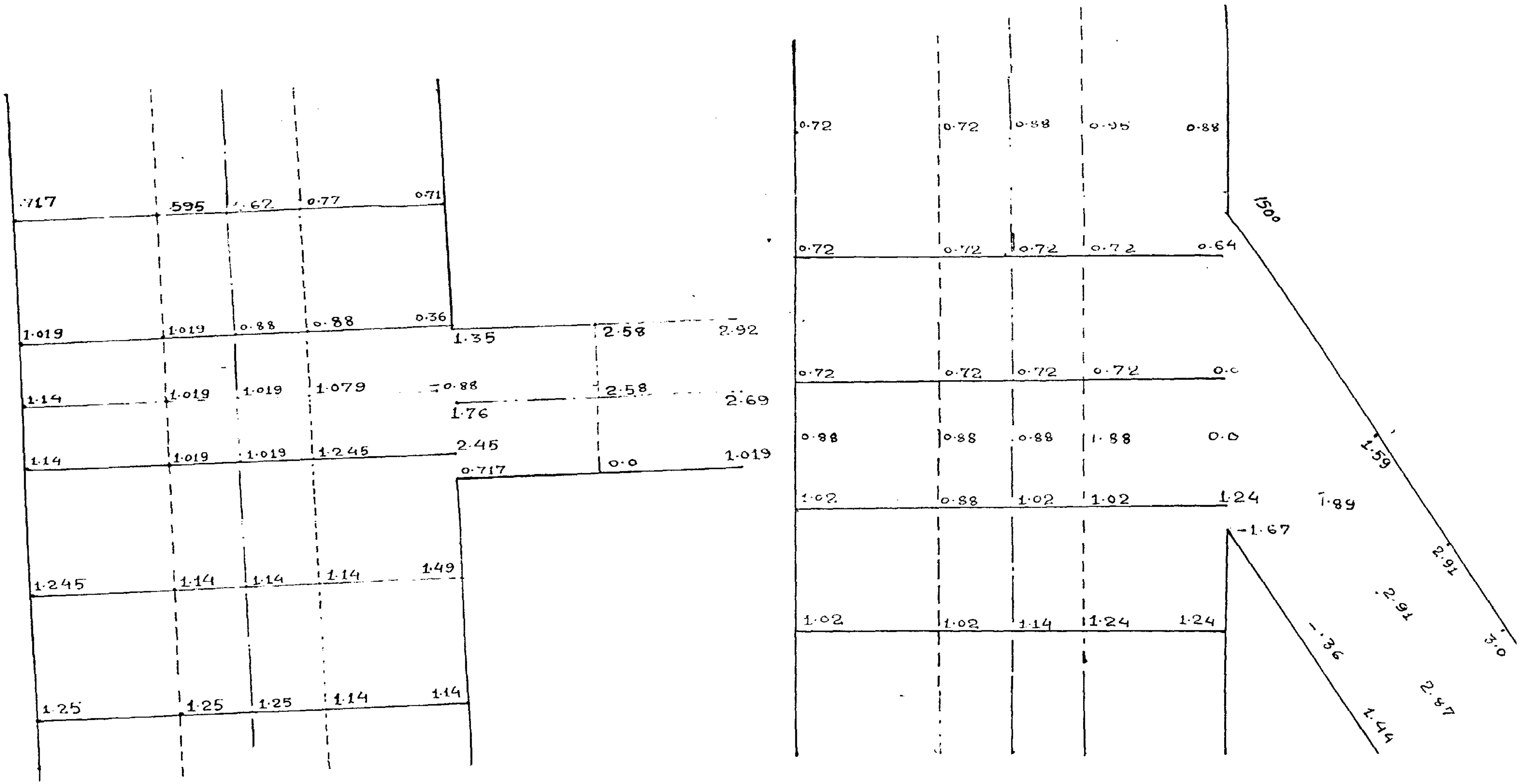
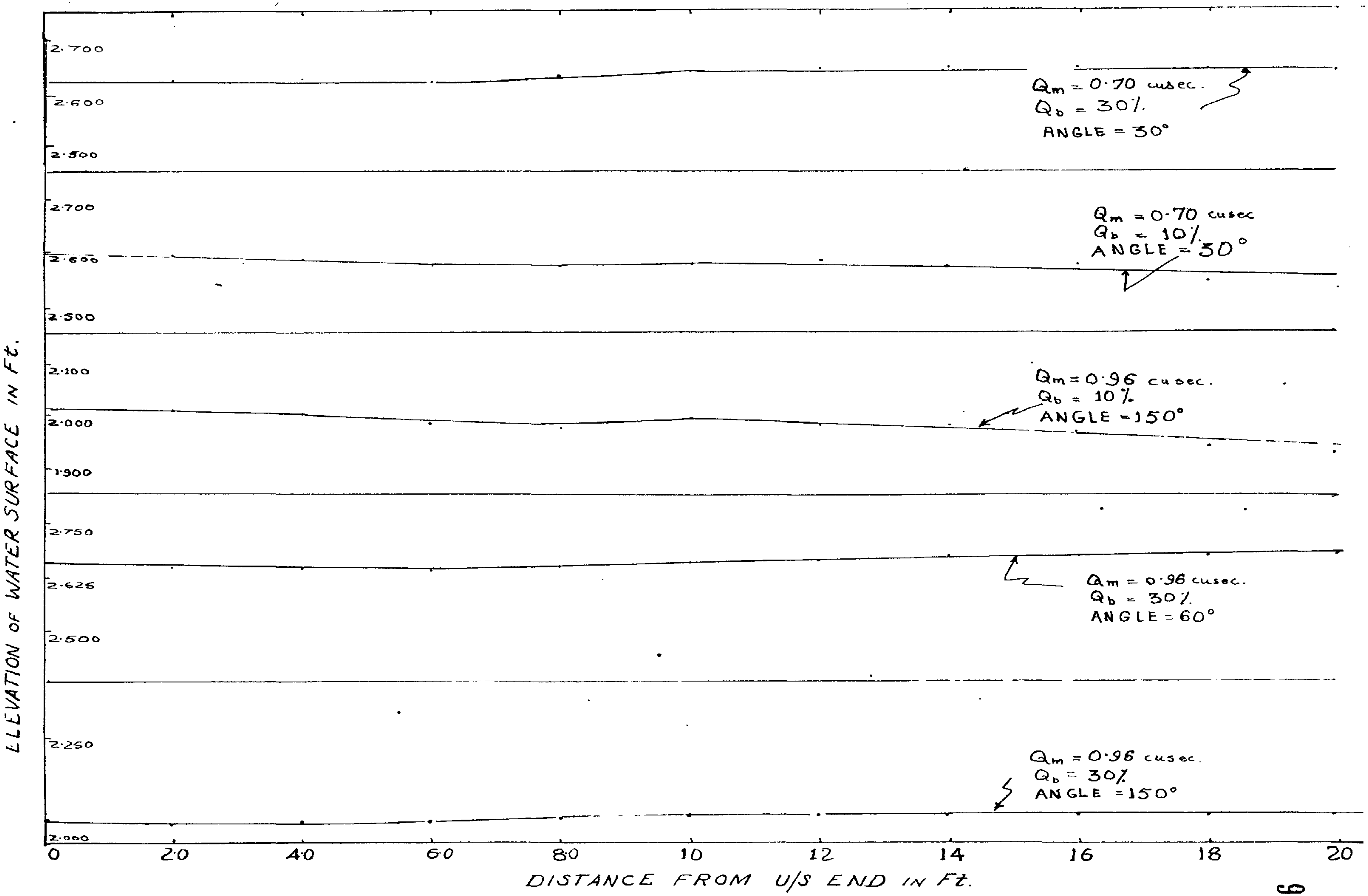


FIG - 52 TYPICAL BED VELOCITY TRAVERSES

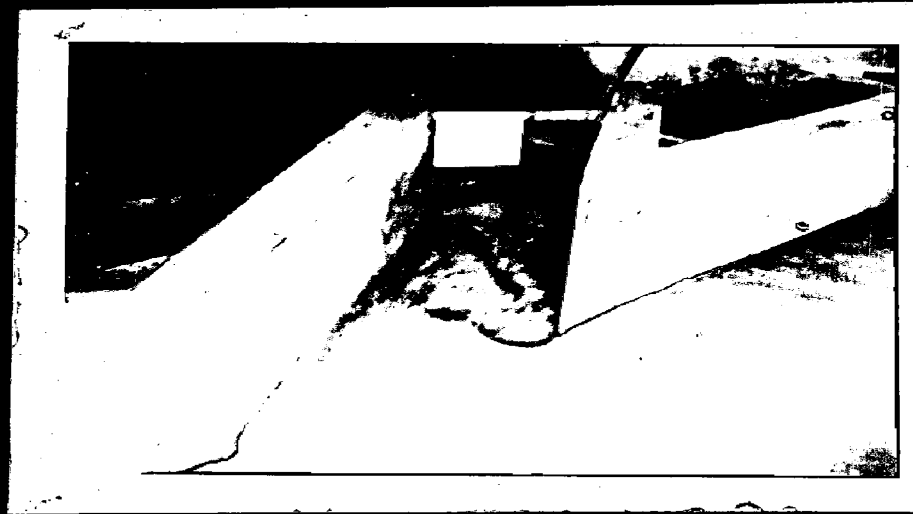

2·700
2·600
2·500
2·700
2·600
2·500
2·100
2·000
1·900
2·750
2·625
2·500
2·250
2·000
Qm = 0·70 cusec.
Qb = 30%
ANGLE = 30°
Qm = 0·70 cusec
Qb = 10%
ANGLE = 30°
Qm = 0·96 cusec.
Qb = 10%
ANGLE = 150°
Qm = 0·96 cusec.
Qb = 30%
ANGLE = 60°
Qm = 0·96 cusec.
Qb = 30%
ANGLE = 150°
0
2·0
4·0
6·0
8·0
10
12
14
16
18
20
DISTANCE FROM U/S END IN Ft.
ELEVATION OF WATER SURFACE IN Ft.

at the left side on the entrance to the side channel. It was found that a deep water grea before the mouth of the offtake was also persist in parent channel. When the slopes of the water surface were compared with in the side channel and parent channel, it will be seen that the steeper slope were existing in the side channel. It is evident from the Figs. 51 & 52 that the velocities down stream of the point of diversion were smaller than those at upstream of that point. This reduction in velocity, as discussed earlier, drops its bed load in the form of island across the mouth of the offtaking channel. The shape and size of the bar was depending on the quantity of flow in the main channel and its percentage of diversion in the offtake and also on the orientation of the offtake channel.

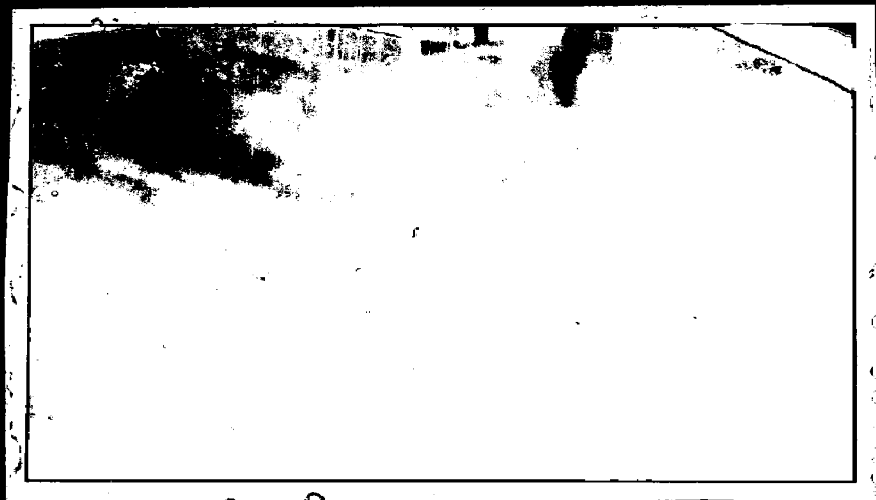
The building up of the sand bar in side the offtaking channel for the angle of 30° was quite different as compared with other four angles. In case of the other four angles, the sand bar was found to be building up on the right side inside the offtake channel at every discharge condition in it, whereas in case of an angle of 30°, the bar was moving from left to right side with the corresponding increase in the discharge condition in the offtake.

The flow in case of 30° angle of offtake was quite different than those at other angles. The smoothness offered to the flow by this orientation of the offtake tended to decrease the concentration of the roller on the right hand side

1. Flow characteristic for 60° offtake.



2. Flow Characteristic for 130° offtake.



3. Typical deposition of sediment in parent and offtake channels.

entrance of the offtake, and at the same time a decrease in the transverse slopes near the point of diversion in the parent channel as well as inside the offtake channel were observed.

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CONCLUSIONS & RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS:

The effect of the angle of offtake on the sediment distribution in channels was studied for five different offtake angles in a laboratory flume 3 ft. wide and 20 ft. long. The offtake was 15 in. wide. Three discharge values were allowed in the parent channel.

Sand of 0.69 mm (median dia.) was fed at the head of the parent channel and the proportion of sediment shared by the offtake for different discharge values was measured. In all 81 observational runs were conducted and analysed. From the analysis it can be concluded that :-

1. The 30° Offtake angle was found to be the most efficient among all the five angles studied. It has shown that with this orientation, the percentage of sediment entering the offtake channel was always less than that entered in other orientation angles.

2. Least amount of bed load entering the 30° offtaking channel was 20% at 10% of parent channel discharge into the offtake.

3. In each case, the percentage of bed load material carried into the offtake channel was greater than the percentage of water going down that channel.

4. The distribution of bed load is a function of the

mechanical composition of the material. Lighter the material, the greater is its tendency to divide approximately in proportion of water diverted.

5. The curves of Figs. 48, 49 and 50 as obtained from the present investigation show a fair agreement with Leliavsky's curve.

6. When pure water was flowing in both the channels, a roller was formed just inside the entrance to the offtake. This roller was having the effect of reducing the cross-sectional area of the offtake channel with a corresponding increase in mean velocity.

7. With the introduction of the sediment this roller action was suppressed to a great extent, but the higher velocity continued to exist.

RECOMMENDATIONS FOR FUTURE STUDY :

It is recommended that the following phases of the problem be further investigated :-

1. The effect of various entrance conditions for the side channel.
2. The effect of different cross-sectional relationships between the parent and offtake channels.
3. The effect of varying the slopes in the respective channels.
4. More definite relationship between the action of the bed load and its mechanical composition.

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APPENDIX

Table - 5.1

SUMMARIZED DATA.

Run No.	Angle θ in deg.	Q_m in cusec.	Q_b in cusec	Bed load	G_b	G_m
1	30	.46	10%	Sand	21.10	78.90
3	30	.46	20%	"	36.90	63.10
5	30	.46	30%	"	44.6	55.40
7	30	.70	10%	"	20.00	80.00
9	30	.70	20%	"	38.60	61.40
11	30	.70	30%	"	46.40	53.60
13	30	.96	10%	"	21.4	78.60
15	30	.96	20%	"	39.35	60.65
17	30	.96	30%	"	45.8	54.20
19	60	.46	10%	"	30.6	69.40
21	60	.46	20%	"	38.0	62.00
23	60	.46	30%	"	46.2	53.80
25	60	.70	10%	"	32.2	67.80
27	60	.70	20%	"	42.1	57.90
29	60	.70	30%	"	50.5	49.5
31	60	.96	10%	"	31.8	68.20
33	60	.96	20%	"	42.8	57.20
35	60	.96	30%	"	53.5	46.50
37	90	.46	10%	"	30.30	69.70
39	90	.46	20%	"	38.50	61.50
41	80	.46	30%	"	51.10	48.90
43	90	.70	10%	"	32.00	68.00
45	90	.70	20%	"	41.60	58.40

TABLE 5.1 (contd).

Run No.	Angle θ in deg.	Q_m in cusec.	Qb in cusec.	Bed load	G_b	G_m
47	90	.90	30%	Sand	54.80	45.20
49	90	.96	10%	"	32.80	67.20
51	90	.96	20%	"	42.50	57.50
53	90	.96	30%	"	58.07	41.93
55	120	.46	10%	"	29.60	70.40
57	120	.46	20%	"	44.10	55.90
59	120	.46	30%	"	52.90	47.10
61	120	.70	10%	"	31.3	68.70
63	120	.70	20%	"	43.6	56.40
65	120	.70	30%	"	54.2	45.80
67	120	.96	10%	"	33.6	66.40
69	120	.96	20%	"	44.5	55.50
71	120	.96	30%	"	55.8	44.20
73	150	.46	10%	"	30.10	69.90
75	150	.46	20%	"	42.7	57.30
77	150	.46	30%	"	51.7	48.30
79	150	.70	10%	"	34.4	65.60
81	150	.70	20%	"	40.1	59.90
83	150	.70	30%	"	53.7	46.30
85	150	.96	10%	"	34.9	65.10
87	150	.96	20%	"	40.9	53.10
89	150	.96	30%	"	56.0	44.0
2	30	.46	10%	Redbeads	17.1	82.90
4	30	.46	20%	"	29.7	70.30

TABLE -5.1 (Contd.)

Run No.	Angle θ in deg.	Q_m in cusec	Q_b in cusec	Bead load	G_b	G_m
6	30	.46	30%	Red bead	41.5	58.50
8	30	.70	10%	"	17.25	82.75
10	30	.70	20%	"	31.05	68.95
12	30	.70	30%	"	46.4	53.60
14	30	.96	10%	"	18.1	81.90
16	30	.96	20%	"	31.8	68.20
18	30	.96	30%	"	46.1	53.90
20	60	.46	10%	"	21.4	78.60
22	60	.46	20%	"	33.4	66.60
24	60	.46	30%	"	45.00	55.00
26	60	.70	10%	"	22.4	77.60
28	60	.70	20%	"	37.8	62.20
30	60	.70	30%	"	46.4	53.60
32	60	.96	10%	"	21.9	78.10
34	60	.96	20%	"	37.0	63.00
36	60	.96	30%	"	47.7	52.30
38	90	.46	10%	"	20.65	79.35
40	90	.46	20%	"	33.2	66.80
42	90	.46	30%	"	46.1	53.90
44	90	.70	10%	"	20.0	80.50
46	90	.70	20%	"	36.5	63.50
48	90	.70	30%	"	47.1	52.90
50	90	.96	10%	"	21.5	78.50
52	90	.96	20%	"	37.2	62.80

TABLE - 5.1

Run No.	Angle θ in deg.	Q_m in cusec	Q_b in cusec	Bead load	G_b	G_m
54	90	.96	30%	Red beads	49.1	50.9
74	150	.46	10%	"	22.6	77.4
76	150	.46	20%	"	37.8	61.2
78	150	.46	30%	"	50.4	49.6
80	150	.70	10%	"	24.2	75.80
82	150	.70	20%	"	37.2	62.80
84	150	.70	30%	"	54.8	45.20
86	150	.96	10%	"	25.6	74.4
88	150	.96	20%	"	38.6	61.4
90	150	.96	30%	"	54.2	45.8

Table - 5.2 (Continued)

Run No	Q_m	Q_b	Angle	R	H	V	V^2	V^2/R	W/g	$F=W/g.V^2/R$	G_b
81	.70	20%	150	.167	2.63	1.28	1.64	9.82	.272	2.615	40.1
11	"	30"	30	2.321	3.37	1.45	2.10	.905	.408	.37	46.6
29	"	"	60	1.082	2.87	1.34	1.785	1.651	"	.676	50.5
47	"	"	90	.625	3.14	1.4	1.45	3.12	"	1.278	54.8
83	"	"	150	.167	1.92	1.092	1.192	7.13	"	2.92	53.7
13	.096	10%	30	2.231	4.41	1.658	2.74	1.18	.1861	.22	21.4
31	"	"	60	1.082	4.98	1.76	3.10	2.865	"	.532	31.8
49	"	"	90	.625	3.70	1.52	2.30	3.68	"	.686	32.8
85	"	"	150	.167	5.24	1.803	3.26	19.5	"	3.64	34.9
15	"	20%	30	2.231	5.06	1.77	3.15	1.355	.373	.56	39.35
33	"	"	60	1.082	5.1	1.78	3.16	2.67	"	.996	42.80
51	"	"	90	.625	3.75	1.527	2.33	3.73	"	1.389	42.5
87	"	"	150	.167	3.47	1.47	2.16	12.92	"	4.79	40.9
17	"	30%	30	2.231	3.946	1.568	2.45	1.056	.56	.592	45.8
35	"	"	60	1.082	3.672	1.51	2.285	2.12	"	1.19	52.0
53	"	"	90	.625	2.96	1.36	1.842	2.95	"	1.652	56.0
89	"	"	150	-	-	-	-	-	-	-	-

Table - 5.2

Run No.	Q_m	Q_b	Angle	R	H	V	V^2	V^2/R	W/g	$F=W/g.V^2/R$	G_b
1	.46	10%	30	2.321	2.462	1.241	1.534	.661	.0893	0.0590	21.1
19	"	"	60	1.082	3.01	1.308	1.87	1.729	"	.1524	30.6
37	"	"	90	.625	3.39	1.45	2.10	3.36	.0893	.300	30.3
73	"	"	150	.1670	3.43	1.46	2.13	12.75	"	1.14	30.1
3	"	20%	30	2.321	3.459	1.468	2.15	.926	.1756	1.656	36.9
21	"	"	60	1.082	3.67	1.51	2.27	2.095	"	0.374	38.0
39	"	"	90	.625	2.23	1.182	1.385	2.22	"	.397	38.5
75	"	"	150	.167	2.34	1.262	1.405	8.67	"	1.55	42.7
5	"	30%	30	2.321	3.452	1.465	2.14	.925	.258	.385	44.6
23	"	"	60	1.082	2.88	1.34	1.79	1.652	"	.426	46.2
41	"	"	90	.625	1.42	1.092	1.192	1.910	"	.494	51.1
77	"	"	150	.167	1.725	1.035	1.07	6.40	"	1.65	51.7
7	.70	10%	30	2.321	3.41	1.456	2.13	.917	.136	.125	20.0
25	"	"	60	1.082	4.51	1.675	2.80	2.585	"	.352	32.2
43	"	"	90	0.625	4.104	1.602	2.57	4.12	"	.561	32.0
79	"	"	150	.167	4.35	1.641	2.70	16.15	"	2.2	34.4
9	"	20%	30	2.321	3.91	1.56	2.43	1.048	.272	.285	38.6
27	"	"	60	1.082	3.89	1.655	2.42	2.24	"	.61	42.1
45	"	"	90	0.625	3.24	1.42	2.02	3.235	"	.881	41.6