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"HYDRAULIC AND HYDROLOGICAL IMPACT ON BRIDGE"

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Abstract - *This study discusses hydrologic and hydraulic bridge/culvert studies to estimate the 100-year water surface elevation at a given project site. Bridges (and sometimes very large culverts) are very expensive hydraulic structures that typically have a design life of 100 years. Most of the bridges are collapsing due to overflowing flood water. In Pakistan, this important study is usually neglected, resulting in bridges collapsing before the design deadline. In the present scenario, no one can deny the importance of this study, especially after the destruction of bridges due to the recent flood (July 2010) in Pakistan. This study focuses on various hydrologic and hydraulic procedures to calculate the 100-year flood discharge at the Long Branch culvert site located under Guinea Road in Virginia, USA. To do this, we used Anderson's method to estimate the discounts for different payback periods. The bridge engineer can then correct the road level for the culvert by taking into account the corresponding freeboard value. Such a structure will not block a flood with a periodicity of 100 years*

Key Words: Hyrological modeling, hydraulic bridge, bridge

1. INTRODUCTION

Bridges are very expensive structures. Millions of rupees are spent on bridges in Pakistan, but most of them will not last much longer because either hydrological and hydraulic studies are not done at all or even if the study is done, it is not done properly. Therefore, the free board provided is not sufficient to calculate the floods of different period. Therefore, the bridge overturns and the structural integrity of the bridge is compromised. A hydrological and hydraulic study should be done for the bridge/culvert and then apply all the findings from the study to a real world scenario. The project involves carrying out hydrological and hydrotechnical studies of bridges and culverts. Different hydrological and hydraulic procedures are used to determine the water surface elevation for floods of different recurrence periods at the site of a bridge or culvert. The study ensures that the structure will not collapse during its entire service life and will remain intact and secure during its use. Each bridge must be designed to ensure that a 100-year flood will pass without compromising the integrity of the structure. In most cases, bridges collapse due to overflowing flood water. Therefore, bridges must be designed to allow enough space for floodwaters to pass safely without overturning the bridge.

2. STUDY AREA

2.1 BRIDGE INFORMATION

"A structure that carrying a pathway or roadways or railways over a depression or obstacles (such as a river, valley, road or railway.) a bridge connecting the island to mainland."

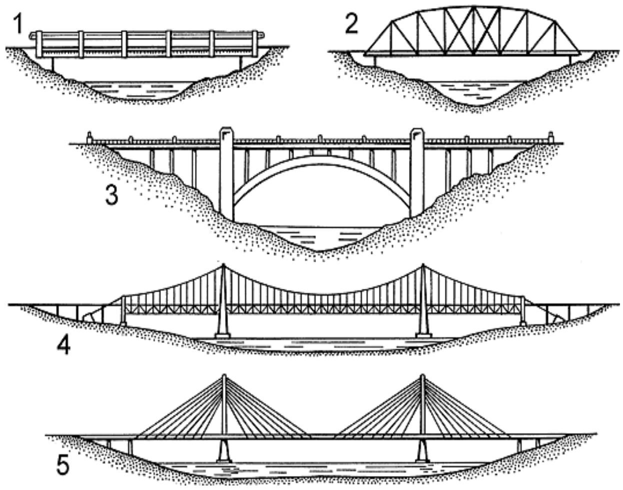


Fig 1 : Types of Bridges

Types of Bridge:

1) Truss Bridge
2) Beam Bridge
3) Suspension Bridge
4) Arch Bridge
5) Cantilever Bridge
6) Cable Stayed Bridge

2.2 Hydrological impact on Bridge

2.2.1 Action Mechanism of the Water Current Loads on the Bridge Piers

When a bridge abutment is affected by a flood, another research topic is the calculation of the dynamic response and pressure of the flow stream taking into account the fluid-structure interaction. Mikel and Buanani [19] proposed a practical formulation for studying the dynamic response of structures vibrating in contact with water on one or both sides, and developed simplified procedures for the practical evaluation of vibration periods, hydrodynamic loads, and structure-water seismic response. systems including higher mode effects. However, relatively few systematic studies considering the effect of impact, particularly fluid-structure interaction, have been conducted on piers with water flow pressure.

When a flood impacts a bridge abutment, the abutment impact process caused by the flow can be divided into two parts: the moment of flood impact on the bridge abutment and the movement of water flowing around the abutment after the moment of impact.

2.2.2 Influence of Fluid –Structure on the Dynamic Water Pressure after the Moment Impact

To further investigate the effect of fluid-structure interaction on the water flow pressure applied to the bridge abutment when the flood acts on the abutment in a steady state, the maximum displacement at the top of the bridge abutment and the maximum stress at the bottom of the bridge abutment are considered as investigation volumes. variation of the fluid-structure interaction effect coefficient (F-Sc) as a function of flow velocity, where F-Sc is defined as the ratio of the numerical response of the bridge abutment under the pressure of flowing water to bridge abutment responses under water pressure excluding the effect of fluid-structure coupling.

3. DATA COLLECTION

Sr No		At Defined c/s (130 m u/s)	At Existing c/s
1	Catchment area		1.74 Curas mail
2	Hydralur Gradent	1.223.73	
3	H.F.L Talled at side	98.250	97.670
4	L.B.L @ Site	96.220	95.815
5	Proposed RTL	99.205	98.685
6	Bed width @ Site	10.00 m	12.00 m
7	Bank width @ Site	15.00 m	28.00 m
8	Foundation	Open	Open
9	% obstruction at H.F.L	28.65 %	-
10	% obstruction at 0.FL	16.35 %	-
11	Required water way at H.F.L	13.06 m	-
12	Waterway Provided	14.00 m	-
13	Angle of site	30*	-
14	Proposal		7.00 m che 2 gale

3.1 General Data

Name of Work :- Construction of Minor Bridge in Km 7/700 On Nandgaon
Kh. Mokhad Savner Mhasala Dadapur to Tahashil Boundry M.D.R 75
Necessity :- At Present there is a H.P culvert having 3 rows of 900 mm dia C.C Pipe at
This crossing This H.P Culvert is located in Ch. 7/721 having very
Insufficient wasterway causing damages to structure. Hence high level
Crossing bridge is necessary.
Selection of Site :- Actually the nalla meets to road crossing at Ch. 7/625. Then it flows
parallel to road upto Ch. 7/721 on U/S side causing heavy damages to
exising B.T road to overcome this problem new bridge site is proposed in
Ch. 7/625 where nalla crossing the road with skew angle 30 degree
Also a slab culvert having 2.0 m clear span is proposed at existing
Crossing to flow out water from road side gutter and water from village
Hydraulics :- Hydraulic details are separately attached. High level minor bridge clearing
the H.F.L with a provision of affiux and nominal clearance.
Proposal :- Span arrangement - **High level submersible Minor bridge** **2 Spans of 7.00 M. C/C**
Type Of Foundation - Open Foundation

3.2 HYDRAULIC DATA

S.N	Particulars	X section	
		Define at 130M U/S	Existing

1 Catchment Area 1.740 SQ Miles
2 Bed Width 10.00 M 12.00 M.
3 Bank Width 15.00 M 28.00 M
4 L. B. L 96.220 95.815 M
5 O.F.L (designed) 97.250 96.670 M
O.F.L (observed) 97.250 96.670 M
6 H.F.L (Designed & Tallied with English) 98.250 97.670 M
H.F.L (Observed) 98.250 97.670 M
7 Hydraulic gradient 1 in 223.73 0.00447

8 Nature of crossing skew – 30 u
9 Nature of bed medium gravels with murum
10 Nature of Bank Firm
11 Rugosity coeff.

Compartment No 1 0.035
No 2 0.030
No 3 0.035
12 Angle of Skew Skew 30
13 Type of Bridge High level submersible bridge with Open Foundation

14 Slit Factor 4.75 (assumed)
15 Linear Water at O.F.L 9.15 M.
16 Linear Water at H.F.L 13.06 M.
17 Inglish Discharge 92.533 Cumec
18 Manning Discharge 91.176 Cumec
19 Velocity Of H.F.L 3.402 M/sec
20 Velocity Of O.F.L 2.133 M/sec
21 Obstruction at HFL 28.65 %
22 Obstruction at OFL 16.35 %

PROPOSAL :- Type of Bridge - High level Submiersible Minor Bridge
Span Arrangement – 2 spans of 7.0 m c/c
Width Of Bridge - 7.50 M Wide.
Type of Foundation - Open Foundation
RTL proposed - 98.685
Height Of Bridge (RTL –LBL) 2.870 M
(98.685 – 95.815)

4.RESULT

(i) DISCHARGE BY ENGLISH FORMULA

$$Q = \frac{C \times A}{\sqrt{A+4}}$$

A= C.A in sq. miles 1.740

For C.A upto 20 sqmiles

Table – 1 Discharge by English Formula

S.N	Area in sqmiles	Value of C
1	0.25	4000
2	0.5	4000
3	0.75	4000
4	1	4200
5	2	4600
6	3	4800
7	4	5000
8	5	5200
9	6	5550
10	7	5700
11	8	5850
12	9	6000
13	10	6100
14	11	6200
15	12	6300
16	13	6400
17	14	6500
18	15	6600
19	16	6700
20	17	6775
21	18	6850
22	19	6950
23	20	7000

$$Q = \frac{CXA}{\sqrt{A+4}}$$

C = 4200+0.74(4600-4200) C = Constant 4496.00
Q = 3265.274 Cuses
92.533 Cumec
i.e 92.533 Cumec

4.1HYDRAULIC GRADIENT

Table -2 Hydraulic Gradient Calculation

S.N	U/S		D/S		Diff	Slope
	CH	R.L	CH	R.L		
1	2	3	4	5	6	7
1	300	97.310	0	95.815	1.495	
2	270	96.890	30	95.610	1.280	
3	240	96.685	60	95.480	1.205	
4	210	96.335	90	95.320	1.015	
5	180	96.260	120	95.230	1.030	
6	150	96.190	150	95.020	1.170	
7	120	96.080	180	94.800	1.280	
8	90	96.020	210	94.710	1.310	
9	60	95.900	240	94.540	1.360	
10	30	95.890	270	94.210	1.680	
11	0	95.815	300	93.890	1.925	

14.750
Average - 1.341
1 in 223.729 i.e 0.00447

DISCHARGE BY MANNING'S AT H.F.L
Define X-section at 130 m. On U/S
98.250 M

Table 3 Discharge By Manning's At H.F.L
Compatment No 1

CH	G.L	H.F.L R.L	Height	Mean Ht.	Length	Area	Ht.Diff.	Perimetre
10	98.250	98.250	0.000					
8	97.910	98.250	0.340	0.170	2.00	0.340	0.340	2.029
6	96.780	98.250	1.470	0.905	2.00	1.810	1.130	2.297
5	96.350	98.250	1.900	1.685	1.00	1.685	0.430	1.089
						3.835		5.415

Hyd gadlent 0.00447
Rug Coeff 0.035 V = 1/n x R 2/3 x S 1/2
R = A/ Wp 0.708 1.518
Velocity 1.518
Discharge (Q) = A x V
DISCHARGE 5.820 Cumec

Table -4 Discharge By Manning's At H.F.L
Compatment No 2

CH	G.L	H.F.L R.L	Height	Mean Ht.	Length	Area	Ht.Diff.	Perimetre
5	96.350	98.250						
4	96.320	98.250	1.930	0.965	1.00	0.965	0.030	1.000
2	96.260	98.250	1.990	1.960	2.00	3.920	0.060	2.001
0	96.220	98.250	2.030	2.010	2.00	4.020	0.040	2.000
2	96.230	98.250	2.020	2.025	2.00	4.050	0.010	2.000
4	96.290	98.250	1.960	1.990	2.00	3.980	0.060	2.001
5	96.340	98.250	1.910	1.935	1.00	1.935	0.050	1.001
						18.870		10.003

Hyd gadlent 0.00447
Rug Coeff 0.030 V = 1/n x R 2/3 x S 1/2
R = A/ Wp 1.886 3.402

Velocity 3.402
Discharge (Q) = A x V
DISCHARGE 64.202 Cumec

Table -5 Discharge By Manning's At H.F.L
Compatment No 3

CH	G.L	H.F.L R.L	Height	Mean Ht.	Length	Area	Ht.Diff.	Perimetre
5	96.340	98.250	1.910					
6	97.290	98.250	0.960	1.435	1.00	1.435	0.950	1.379
7	98.080	98.250	0.170	0.565	1.00	0.565	0.790	1.274
10	97.610	98.250	0.640	0.405	3.00	1.215	0.470	3.037
30	97.810	98.250	0.440	0.540	20.00	10.800	0.200	20.001
67	98.250	98.250	0.000	0.220	37.00	8.140	0.440	37.003
						22.155		62.694

Hyd gadlent 0.00447
Rug Coeff 0.035 V = 1/n x R 2/3 x S 1/2
R = A/ Wp 0.353 0.955
Velocity 0.955
Discharge (Q) = A x V
DISCHARGE 21.153 Cumec
Total Discharge Comp No 1 + 2 + 3
91.176 Cumec
98.250 m at define cross section
Discharge is 92.533 Cumec Which is -1.47 % & i.e within (+,-) 2 %
DISCHARGE BY MANNING'S AT H.F.L
Define X-section at 130 m. On U/S
97.250 M

Compatment No 1

CH	G.L	H.F.L R.L	Height	Mean Ht.	Length	Area	Ht.Diff.	Perimetre
7	97.250	97.250	0.000					
6	96.780	97.250	0.470	0.235	1.00	0.235	0.470	1.105

5	96.350	97.250	0.900	0.685	1.00	0.685	0.430	1.089
						0.920		2.194

Hyd gadlent 0.00447
Rug Coeff 0.035 V = 1/n x R 2/3 x S 1/2
R = A/ Wp 0.419 1.070
Velocity 1.070
Discharge (Q) = A x V
DISCHARGE 0.985 Cumec

Compatment No. 2

CH	G.L	H.F.L R.L	Height	Mean Ht.	Length	Area	Ht.Diff.	Perimetre
5	96.350	97.250						
4	96.320	97.250	0.930	0.465	1.00	0.465	0.030	1.000
2	96.260	97.250	0.990	0.960	2.00	1.920	0.060	2.001
0	96.220	97.250	1.030	1.010	2.00	2.020	0.040	2.000
2	96.230	97.250	1.020	1.025	2.00	2.050	0.010	2.000
4	96.290	97.250	0.960	0.990	2.00	1.980	0.060	2.001
5	96.340	97.250	0.910	0.935	1.00	0.935	0.050	1.001
						9.370		10.003

Hyd gadlent 0.00447
Rug Coeff 0.0300 V = 1/n x R 2/3 x S 1/2
R = A/ Wp 0.937 2.133

Velocity 2.133
Discharge (Q) = A x V
DISCHARGE 19.991 Cumec

Compatment No. 3

CH	G.L	H.F.L R.L	Height	Mean Ht.	Length	Area	Ht.Diff.	Perimetre
5	96.340	97.250	0.910					
5.80	97.250	97.250	0.000	0.455	0.80	0.364	0.910	1.212
						0.364		1.212

Hyd gadlent 0.00447
Rug Coeff 0.035 V = 1/n x R 2/3 x S 1/2
R = A/ Wp 0.300 0.857
Velocity 0.857
Discharge (Q) = A x V
DISCHARGE 0.312 Cumec
Total Discharge Comp No 1 + 2 + 3
21.287 Cumec
This discharge is 23.35 % Of HFL discharge
Hence it is O.K

Linear Water Way @ HFL / OFL

CALCULATION OF WATERWAY @ H F L R.L 98.250 M

H F L 98.250 m

Wetted area = A2 + A1 x Q1/Q2 + A3 x Q3/Q2

A1	3.835	Q1	5.820
A2	18.870	Q2	64.202
A3	22.155	Q3	21.153
	44.860		91.176
	Sqm		cumec

= 26.517

d = Maximum flood depth

H F L – L B L

98.250 96.220

2.030

Linear

Water Way = Wetted area @ HFL / Max. depth

= 26.517

2.030

13.063 m

Considering and to accommnodate Bed and bank width at existing C/S

2 spans of 7.00 m C/C is provided.

CALCULATION OF WATERWAY @ O F L R.L 97.250 M

O F L 97.250 m

Wetted area = A2 + A1 x Q1/Q2 + A3 x Q3/Q2

A1	0.920	Q1	0.985
A2	9.370	Q2	19.991

A3 0.364 Q3 0.312

10.654 21.287

= 9.421

d = Maximum flood depth

O F L – L B L

97.250 96.220

1.030

Linear

Water Way = Wetted area @ OFL / Max. depth

= 9.421

1.030

9.15 m

DESIGN OF AFFLUX

Data W/A = Wetted area @ HFL = 26.52 Sqm.

Q = 91.176 Cumec

Q1 = unobs Discharge = Total discharge – Obs. Discharge

91.176 - 26.117

65.058 Cumec

V= mean velocity in m/sec. 1.958 m/sec

$$\text{Afflux} = \left\{ \left[\frac{v^2}{17.86} + 0.0153 \right] \times \left[\left(\frac{Q}{Q1} \right)^2 - 1 \right] \right\}$$

$$\left\{ \left[\frac{3.835}{17.86} + 0.0153 \right] \times \left[\left(\frac{91.176}{65.058} \right)^2 - 1 \right] \right\}$$

0.22 < 0.60 hence Safe

Provide, 0.30 M.

SCOUR DEPTH CALCULATIONS

FOR OPEN FOUNDATION

Q = 91.176

F = 4.75

L = 13.06

H.F.L 98.250

At Existing H.F.L 97.670

Normal scour depth Q = 91.176

f = 4.75

d = 0.473 x (Q) 1/3

(f) 1/3

0.473 (91.176)1/3

(4.75) 1/3

= 1.266

Max Socur depth D = 2 x d

2.533 m.

Socur level - H.F.L – D 98.250m - 2.533

= 95.717

Bottom R.L of Foundation = Lower of the Following

1 H.F.L – 1.33 x D

94.301

2 H.F.L - Max Socur depth – 1.5 m.

93.637 m.

3 As per Trial pit 1.50 m keying

from hard strata – (95.815 – 1 .0) = 94.815 - 1.50 936.315 M.

Soft rock

Adopted - 93.315

being a lower

R.T.L Calculations

For High level Submersible Bridge

RTL is fixed now H.F.L 98.250

+ Affiux 0.300 * Slab Depth of 8.0 m

+ Slab depth 0.640 span is considered

+ Wearing course 0.075 o.64 m being a skew

+ Vert. Clearance bridge

99.265

R.T.L at defined C/ section = 99.265 M.

Defined c/ section is = 130 m on U/S side

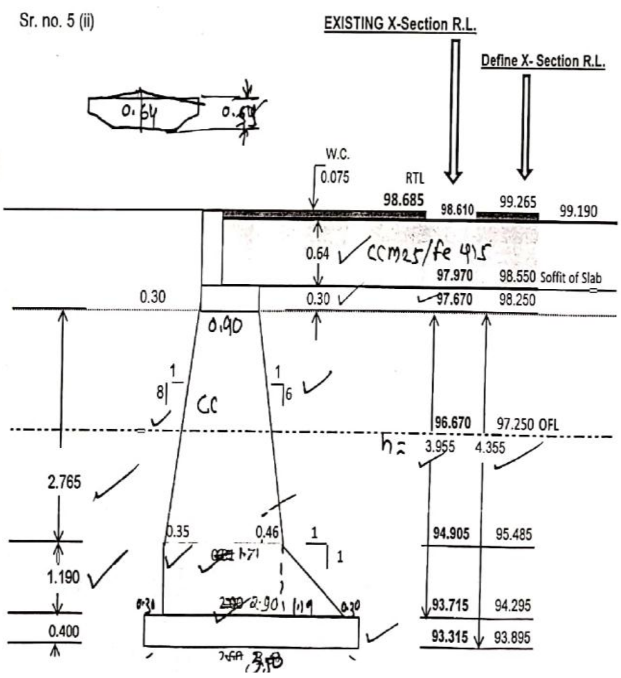
Bed slope is = 0.00447

Therefore R.T.L existing site = 98.684 M.

say 98.685 M.

DESIGN SECTION OF ABUTMENT

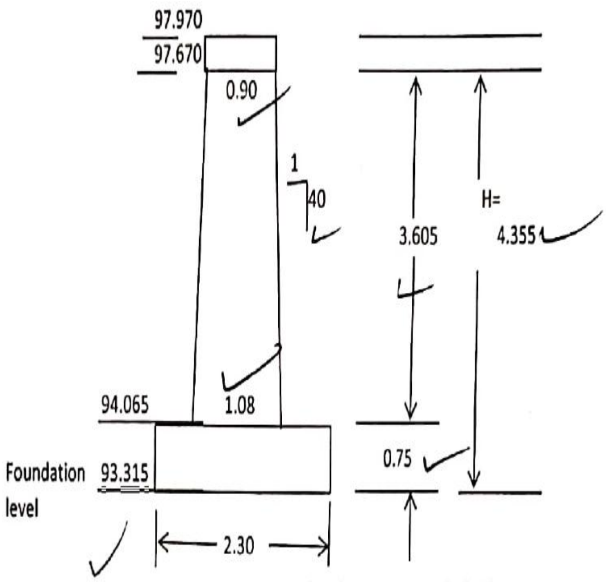
(As per Design circle Drg No. BR –NGP /2002-054)



DESIGN SECTION OF PIER

(As per Design cicle Drg. No BR-NGP/2002-043)

Sr no 4



Levels Transfer at Existing

Defined X section On 130 m. on U/S Slope = 0.00447

Table 6- Level Transfer at Existing Details

SN		R.L at Defined	R.L at Existing
1	H.F.L	99.265	98.685
2	O.F.L	97.250	96.670
3	R.T.L	99.265	98.685
4	Foundation Level	93.895	93.315

SPAN / HEIGHT RATIO

1 Foundation of Pier = 93.315 M

2 Pier top level = 97.670 M

3 Height of Bridge = 4.335 M

4 Clear span of Bridge (7.090) = 6.10 M

5 S / H Ratio = 6.10 / 4.355

= 1.29 O.K

CALCULATIONS FOR PERCENTAGE OBSTRUCTION AT O.F.L R.L 97.250 M.

For 2 Spans of 7.00 m c/c

Compartment -1

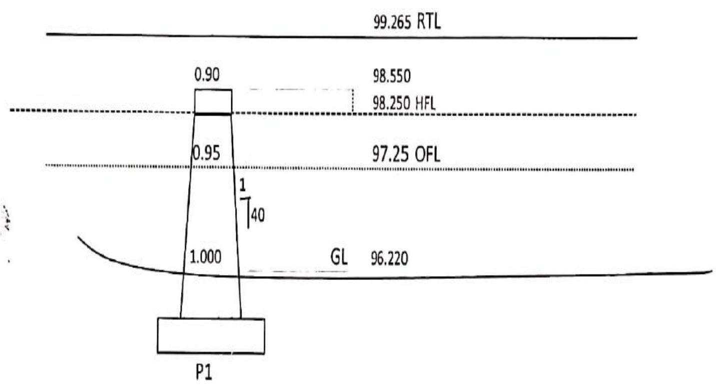
Obs Area (as per O.F.L manning) 0.920

Net Obs area = 0.920

Area x Velocity

0.920 x 1.070 0.985 - 1 cum

Compartment -2



Obs Area due to P1 with = (0.95 +1.0) /2x (97.25 -96.220)

1.024

Total Obs Area = 1.024

Obs Discharge 1.024 x 2.133 2.184 - 2 Cumec

Compartment -3

Obs Area (as per O.F.L manning) 0.36

Obs area = 0.364

Area x Velocity

Obs Discharge 0.364 x 0.857 0.312 - 3 cum

Total Obs Discharge = 1 + 2 + 3 3.481 Cumec

Total Discharge at O.F.L = 21.287 Cumec

% Obstruction at O.F.L = (Obstructed discharge/ Total discharge) x 100

(3.468/21.287)/100

16.35 % < 30%

Hence safe & O.K

5. CONCLUSIONS

Based on the results of this study, the following conclusions were drawn:

1. From this study, it can be assumed that if waterways become narrower, more expected bank erosion and erosion may occur. To avoid such a drastic situation, river preparation works from 1 km upstream to 1 km downstream may be recommended and continuous monitoring should be carried out during and after the construction of this type of structure in the stated situation.

2. The result of the study was only a change in the level of the bottom and erosion of the shore. There were differences in the water level, as well as in the speed of the current. The result of the study is based on the existing condition of the Nala River. The approach may be the same for all rivers, but there is the possibility of deviations in case of other baseline conditions and other rivers. The result also varied depending on the condition of the soil, the speed of the current, the effect of waves, tides, surface runoff and so on.

3. This project found that many river bridges that are more than 40 years old are subject to collapse during floods and sudden increases in contraction and local erosion.

4. The results showed that the bridge abutment narrowed the flow cross-section and caused an increase in support in the upper sections. This increase in underflow caused a decrease in the longitudinal velocity in the upper reaches. Also, the results showed that the position of the maximum layer shear stress moved from the separation zone to the edge of the bridge support.

5. In addition, the results showed that for the cross-section of the downstream bridge abutment, the secondary flow pattern is completely different from the normal secondary flow in the case of an open channel incident without a bridge abutment.

6.1) Recommendations:

1. Hydrological and hydraulic surveys of all existing bridges in India should be properly carried out.

2. The bridge engineer should carry out these studies before providing sufficient free board at the new bridge location.

3. The level of the bridge deck should be at least 150 mm above the maximum height of the water surface.

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