IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Bridge Planning and Design using Excel Program

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ABSTRACT

Hydraulics of bridge is first step of bridge planning and involves lengthy calculations to assess maximum flood discharge, highest flood level and maximum velocity by using data obtained from field such as topography of bridge site, bed material, strata available for foundation, annual rainfall in catchment area, highest observed and ordinary flood levels, bed slope, etc. All these parameters are required to assess forces acting on bridge structure to make it sustainable in severe conditions.

After hydraulic calculations, we move to planning of bridge structure, i.e., deciding span arrangement, slab thickness, type of foundation, pier and abutment sizes, bearings, return walls, railing, wearing course, etc according to standard type plans prepared by the Indian Road Congress for National Highways and Bridge Design Organisation of Govt. of Maharashtra for bridges on State Highways, District and village roads in Maharashtra.

An Excel program has been specially prepared for hydraulic calculations and further extended to design of piers, abutments, slabs, bearings and to work out cost of bridge along with its approaches. Thus, this program can be an excellent tool to work out techno-economic feasibility of proposed bridge.

For the purpose of this study, a case of construction bridge on river Kavathala in Chimur Town, Maharashtra has been considered and accordingly, a Microsoft Excel program is created for hydraulic calculations and further extended to design of various components of bridge. This program is universal and can be used for any similar bridge proposal after erasing old data and feeding new data in Excel sheet named as 'New Case'. Data taken from this sheet is linked to hydraulic calculation sheets and further linked to bridge components' design sheets. Thus, any change in basic data reflects in every sheet. Any mismatch of data or value beyond specified range is displayed as "????" in sheet named as 'Check', thus error in data feeding or output which is out of range is eliminated.

KEYWORDS: *hydraulic calculations, bridge design, planning, excel*

1. INTRODUCTION

Bridge Planning starts with survey data such as topography of bridge site, i.e., height of banks, bed width and bed slope of stream (i.e. river), bore data, rainfall, observed highest & ordinary flood levels (HFL & OFL), etc. Using survey data, the correctness of observed HFL and OFL can be cross-checked by adopting different methods of discharge calculation. This part of bridge planning is called hydraulics of bridge. Here, apart from HFL and OFL, we obtain velocity of water during maximum flood situation, scour depth, afflux, that is rise in water level due to obstruction caused by proposed bridge structure, etc. These parameters are necessary to assess forces acting on bridge structure to make it sustainable in severe conditions.

Survey data of bridge also includes measurement of catchment area of river that covers all contributing small streams as shown in topographic sheets published by Geographical Survey of India. Planimeter and scaling is used to measure area precisely. The discharge of stream is calculated using run-off formula applicable to the region such as Inglis, Dicken's formula, etc. Then, defined cross-section of river is selected where river bed width is minimum and its banks are high. Defined cross-section can be few hundred metres on upstream or downstream side of the proposed bridge location because many times traffic already plies at proposed location of bridge in dry season, hence banks are disturbed and thus such cross section is not suitable for hydraulic calculations. Hydraulic gradient which is equal to bed slope of stream is calculated from lowest bed levels (LBL) of stream for about 500 m to 1000 m on both upstream and downstream side of defined cross section. For the purpose of this study, we have considered a case of bridge on river Kavathala in Chimur Town, Maharashtra and created Microsoft Excel program for hydraulic calculations and further extended to design of components of bridge.

2. BACKGROUND OF SUBJECT

An important part of bridge hydraulics is to find such HFL that is matching to observed HFL and also pass discharge through selected defined cross section that is equal to earlier calculated discharge by run off formula i.e., by Inglis or Dicken's formula. To calculate discharge by alternate method, we use Manning's discharge formula where volume of flow is calculated considering bed slope and friction of bed material. Several trials have to be made before arriving matching discharge and HFL simultaneously. Manual calculations lead to error, hence Excel computer program can be a useful tool for ease of calculations.

Hydraulic calculations help us for ascertainment of field data. Sometime it may happen that observed HFL does not match with calculated HFL even after several trials. To find out discrepancy, we have to make several field trips for further investigation to verify other factors. For example, if there is effect of backwater from river on downstream side, which was not considered earlier. Thus, error is eliminated by quick trials of hydraulic calculations which is possible by using computer program specifically designed for the purpose. Once these HFL and discharge is finalised they are called as Designed Discharge and Designed HFL, and then we move to planning of bridge structure, i.e., deciding span arrangement based on economical span criteria, slab thickness based on span-wise standard type-plans prepared by the Indian Road Congress or Bridge Design Organisation of Govt. of Maharashtra (if bridge is to be constructed on State Highway and lower category road such as MDR, ODR or VR), type of foundation, pier and abutment sizes, slopes of their faces, bearings, return walls, railing, wearing course, etc.

The present Excel program has been extended to design of piers, abutments, slabs, bearings, estimated cost of bridge and its approaches. Thus, this program can be an excellent tool to work out techno-economic considerations which are essential before according Administrative Approval and allocation of funds by the Government.

3. AUTHOR'S WORK

Bridge planning entails deciding suitable location of bridge, span arrangement, bridge height, type and sizes of deck slab, foundation, returns, etc. Hydraulic calculation is first part of bridge planning to ascertain HFL and OFL which were initially obtained randomly from field as informed by the local people and the calculation of velocity of flood at surface level which is essentially required to decide the forces acting on bridge after structure is erected. While comparing flood discharge estimations by Inglis' formula, etc. with that of Manning's discharge formula which is based on velocity of flood, one has to go through several trials of flood levels. With manual calculation these trials are tedious and time consuming, and susceptible to error, hence, Microsoft Excel program is specifically prepared to find flood level that passes the design discharge through defined cross section. The MS Excel Hydraulic calculation program is further extended to find obstruction to flow due to proposed bridge for economic span arrangements and simultaneously calculate afflux. Previously, there was one software for hydraulic calculations in "C" program but that has limited options to compartmentalise cross-section of river and could be used to find HFL only. Obstruction or Afflux calculations were not possible. The current Excel program named as 'ALLEN Bridge

174' designed by the author provides option of any number of compartments to assess velocity of water in respective compartments thus providing more realistic discharge calculations.

The 'ALLEN Bridge 174' program is further extended to assess stresses in slab, pier and abutment for selected sizes, type of foundation, return walls and bearings, likely obstruction due to proposed bridge, calculation of afflux, scouring depth, cost of bridge along with approaches etc.

4. USE OF COMPUTER

As is well-known, Information Technology has penetrated in all sectors of knowledge, then why bridge planning and its design should be alienated. This study is focussed on creating a software program for detailed calculations with respect to hydraulic and planning of bridge for ease and verifying on best possible scenarios with respect to techno-economic considerations during design of bridge. This program is designed using MS Excel program considering a case study of construction of Bridge on Umred Chimur (NH-353E) on river Kavathala at ch. 45 + 490 Tal. Chimur Distt. Chandrapur.

5. OBJECTIVE

The objectives outlined in this study are listed as under:

a. Using MS Excel for creating a program to find maximum flood discharge, maximum velocity, Highest Flood Level. Ordinary Flood Level, scour depth Economical Span arrangement, decide sizes of other components of bridge, find out obstruction to flow, afflux calculations as part of bridge planning.
b. Using MS Excel for creating a program to calculate cost of construction of the bridge and its approaches.
c. Using MS Excel for creating a program to find stresses in bridge components for their suitability of sizes.

6. REVIEW OF LITTERATURE AND METHODOLOGY USED

The reviewed literature provides various methods for estimating discharge of stream on the basis of catchment area in different regions. Further this discharge is to be tallied with observed highest flood level which involves several manual calculations repeatedly (Atrey, 1973; Guidelines of Bridge Design published by PWD, Govt. of Maharashtra in 2000; Jagadeesh & Jayaram, 2019). While going through frequent and long calculations there is likelihood of error and process becomes tedious. The advantage of 'ALLEN Bridge 174' specially created in MS Excel Program is that since all calculations are interlinked and if trial flood level is changed all calculations up to percentage obstruction and afflux are instantaneously updated and correct picture is before us. Various programming functions have been used in the MS Excel Sheets that are referred from Price & Grath, 2016. Since this program is extended to workout cost of bridge and results can be verified for their correctness at any stage that can be of great utility.

The procedure adopted in this study is as under:

a. Survey data such as bed levels of defined cross section (c.s) of stream, lowest bed levels for several hundred meters both on upstream side and downstream side of defined cross section, bed and bank width at defined cross section and at proposed bridge site etc. are fed in the program in new case
b. Type of bridge proposed i.e. high level or submersible is also selected in this sheet
c. Type of foundation proposed is also required to be fed in this sheet
d. Trials of HFL carried out in sheet HFL @ Def. c.s.
e. Trials of OFL carried out in sheet OFL @ Def. c.s. which will be about 30% of discharge at HFL
f. Trial span arrangement, required vertical clearance is fed in new case sheet
g. RTL and obstruction and afflux for given span arrangement is automatically calculated for different cases such as soffit of slab is above HFL, or RTL is at HFL, etc.
h. Scour depth is calculated in sheet GAD
i. Detailed Survey Data complete report is available at Sheet DSD
j. General Report of Bridge proposal displayed at sheet GD
k. Technical Note of Bridge proposal is available at Sheet TN
l. Approximate cost is worked out at sheet Cost
m. Stability of piers, abutment, return walls and maximum stresses developed are displayed at sheets named with respective name of bridge component. Error due to mismatch while feeding data is displayed at sheet named Check. Error is also displayed in this sheet when calculated value goes beyond acceptable range

7. RESULTS AND CONCLUDING DISCUSSION

All the data obtained during survey is entered into MS Excel sheets that are specially designed, where cells are interlinked so a change in any cell is reflected in all calculations. The methodology of planning a bridge is converted into computer programming, i.e. MS Excel. To cross check the correctness of result, a special check list sheet is also added where results are compared and if results are not within acceptable range, program indicates an error sign. Presently, the design is carried out for a case study considering construction of bridge on Umred Chimur (NH-353E) on river Kavathala at Ch. 45+490 Tal. Chimur Distt. Chandrapur and program output is illustrated in Figures 1 & 2 below.

The interesting part with this case is that this bridge is already in an EPC project and contract for its construction was already given to an agency. The Contractor carried out its own investigation and claimed that such high level of deck slab is not required as HFL is 0.80 m low. When Contractor's claim was verified using the MS Excel program, it was observed that they have not considered effect of back water of Uma river to which Kavthala river meet 700 m on downstream. When Uma river gets flooded, its backwater spreads up to bridge location on Kavthala river. Therefore, observed HFL was higher than HFL due to its own discharge. Discrepancy in Contractor's proposal was quickly detected due to several trial of HFL in program 'ALLEN Bridge 174'.

Name of work:-Reconstruction of Bridge on Umred Chimur (NH-353E) on river Kavathala at ch. 45+490 Tal. Chimur Distt. Chandrapur

SALIENT FEATURES

1	Catchment Area.	:	5.070	sq. miles		
2	Location of Defined Cross- section	:	70.0	m on	d/s	
			At Proposed site		At Defined c/s	
3	Bed width	:	20.000	m	8.00	m
4	Bank width	:	45.000	m	40.00	m
5	Q' by Modified Inglis formula	:	190.680	Cum./sec		
6	H.F.L. R.L. (Observed) at Defined c/s	:	226.419	m including. Back Water		
7	Gradient	:	0.0048	.i.e. = 1 :	208	
8	Nature of Bed	:	Sandy / slushy bed			
9	Nature of Banks	:	Habitated urban land in Chimur town			
10	Rugosity Index adopted		0.03	for Bed and	0.035	for Banks
11	H.F.L. R.L.(Tallied) at Defines c/s		225.35	m		
12	Q' by Manning's formula at H.F.L. R.L. 225.350 at defined c/s	:	190.015	cum/see		
13	Q' by Manning's formula at O.F.L. R.L 224.044 at defined c/s	:	57.43	cum/sec		
14	H.F.L. R.L. carried to proposed c/s	:	225.686	m		
15	L.B.L. at proposed Bridge site		222.686	m		
16	O.F.L. at proposed c/s	:	224.380	m		
17	Linear waterway at H.F.L.	:	14.98	m		
18	Linear waterway at O.F.L.	:	11.24	m		
19	Span Arrangement of existing Bridge		7	Span of	4.90	m
20	R.T.L. of Existing Bridge	:	225.632	m		
21	Carriageway width of existing bridge		14.50	m		

.....2

Calculation of Economic span

Pier height from Raft Top to Cap Top	=	227.019	-221.759	=	5.26 m
Economic span 1 to 1.25 times pier height =		1.00 x	5.26	=	5.26 m
		1.25 x	5.26	=	6.58 m

Fixing of R.T.L.

Span Arrangement 6 spans of 7.00 m c/c

	At Defined c/s	@ 70 m on d/s	At bridge site:
BWL	226.419		226.419
V.C.	0.300		0.300
Slab th.for given span	0.500		0.500
Afflux	0.300		0.300
w.c. th.	0.075		0.075
R.T.L.=	**227.594 m**		**227.594 m**
		Say	**227.590 m**

Selectiom of span arrangement :-

6 spans of 7.0 m

8. IMPORTANCE OF WORK

This Program is in Excel sheet hence easy to operate and calculations can be checked at any point manually, if in doubt. Thus, this program can be helpful while planning a bridge to a great extent. Also, different options of locating a bridge and its cost effectiveness, feasibility data is available before final approval to the proposal of bridge, which is of great advantage.

This program can be used for high level bridges, with or without effect of backwater, box culverts, pipe culverts, submersible causeways, arch bridges, with open or raft type foundation, etc.

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