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A Comparative Study of Causeways and Culverts

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ABSTRACT: Hydraulic structures needs more survey before designing the structures. In India, there are so many villages near by the river. Hence, heavy rains and flood can destroy whole villages. Also, due to the submersible roads by flood, villages disconnects from cities. Therefore, providing a suitable water crossing for rural areas is important need. In this paper, water crossings such as causeways and culverts are studied. Causeway is a track, road or railway on the upper point of an embankment across a low or wet place or piece of water. Culvert is a structure that allows water to flow under a road, railroad, trail or similar obstruction from one side to other. Design of a suitable water crossing is provided. At first analysis is done in the STAAD Pro software and then manual design is done according to the IRC specification.

Here, A box culvert is designed with 28m span multi-cell along with different types of load such as dead load, live load, earth pressure, varying loads of vehicle such as 70 R wheeled vehicle etc.

This design will surely help the mankind to avoid the damage due to the heavy rains and flood. After the construction of this box culvert, transportation will be convenient for the villages even in the rainy seasons. Both the humans and animals will get benefits from this structure.

KEYWORDS: Causeway, Culvert, Earth pressure, hydraulic structure, live load, multi-cell, IRC.

I. INTRODUCTION

For the feasible transportation in rainy days water crossing in rural area is essential. There are various types for low volume and less significant roads such as submersible bridges, causeways, culvert, fords, gabions etc.

A causeway is one such paved submersible structure with or without openings, which allows flood to pass through and over it. These are proposed on rural and less important link roads not likely to generate much traffic in near future. The causeway may be proposed on streams of flashy nature with high frequency of short duration floods or at sites where construction of submersible bridges is not economically viable.

Figure no 1: Causeway

A culvert is a structure that allows water to flow under a road, railroad, trail or similar obstruction from one side to other. Typically embedded so as to be surrounded by soil, a culvert may be made from a pipe, reinforced concrete or other material.

Culverts are commonly used both as cross drains to relieve drainage of ditches at the roadside and to pass water under a road at natural drainage and stream crossing. When they are found beneath roads, they are frequently empty.

A culvert may also be a bridge like structure designed to allow vehicle or pedestrian traffic to cross over the waterway while allowing adequate passage for the water.

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Figure no 2 : culvert

II. METHODOLOGY

To design any hydraulic structure first we have to do its hydraulic design. The workability and life span of structure is mostly depends on its hydraulic design.

- HYDRAULIC DESIGN

Catchment area – 35.775 sq. m
Manning's constant (n) – 0.035
Hydraulic mean depth ® - 1.617
Bed slope (s) - 1/245
Lowest bed level (LBL) – 97.220 m
Highest flood level (HFL) – 100 m
Ordinary flood level (OFL) – 98.180 m

- Velocity calculations

$V = 1/n \times R^{2/3} \times s^{1/2}$

Where,
V= velocity in m/s
n= Manning's constant
R= hydraulic mean depth
S= bed slope

$V= 1/0.035 \times 1.617^{2/3} \times (1/245)^{1/2}$
V= 2.515 m/s

- Discharge calculations

Q= A x
Where,
Q= discharge in cummecs
A= area in sq. m
V= velocity in m/s

Q= 35.775 x 2.515
Q = 89.964 cummecs

- HYDRODYNAMIC FORCE OF WATER CURRENT

Water current causes hydrodynamic force on the submerged part of a body. These forces on a member can be calculated by the following formula given in clause 2.13 of IRC 6

P = 52 KV

Where,
P = intensity of pressure due to water current in kg/m^2
V = velocity in m/s
K = constant (K=1.5 for rectangular pier)

P= 52 x 1.5 x 2.515
$P= 493.368 kg/m^2$

- ESTIMATION OF AFFLUX BY EMPIRICAL FORMULA

$h= [(V^2/17.9)+0.015] \times [(A/a)^2 - 1]$

Where,
h= Afflux in m
V= velocity in m/s
A= natural waterway area in m^2
a= constructed area in m^2

h= -0.231 m

- BOX DETAILS

Maximum clear height of box = 5350 mm
Side wall thickness ($D_{w)}$) = 650 mm
Thickness of partition walls ($D_{p)}$ = 300 mm
Thickness of deck slab (D_d) = 500 mm
Thickness of raft (D_b) = 750 mm
Clear span of 1^{st} and last cell = 9025 mm
Clear span of middle cell = 9200 mm
Idealised span of 1^{st} and last cell (L) = 9500 mm
Idealised span of middle cell = 9500 mm
Idealised height of box H = 5320+ 500/2 + 750/2 =
H= 5975 mm

Width of structure (b) = 15000 mm
Width of footpath + railing = 1800 mm
Thickness of crash barrier = 500 mm
Thickness of fill overdeck=
(0.025x7500)+65=187.5+65= 253 mm

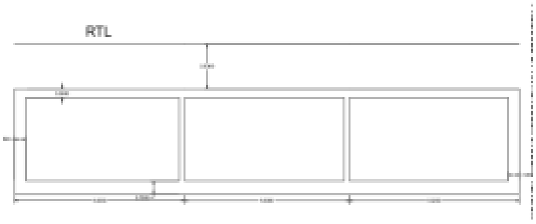

Figure no 3: box details

From figure we can see that, this model of RCC box culvert has three cells.

- LOAD CALCULATIONS
- Dead loads

Self-weight of structure = Input by STAAD PRO software (density of RCC = 25 KN/m^3)
Load due to crash barrier = 8.25 KN/m
Over burden over deck = 4.13 KN/m /m width
Surfacing over deck = 1.43 KN/m /m width
Earth pressure = 20 KN/m^3
Live load surcharge = 1.2 m
Horizontal pressure intensity = 12 KN/m

- Live loads

Structure is modelled in STAAD PRO and analysed for 70R & Class-A loading to find position of loading for maximum bending moment and shear force.
Width of carriageway at location of structure= 12200 mm

- Design impact factors

condition	Impact factor
For 70R tracked vehicles	10.00 %
For 70R wheeled vehicles	25.00 %
For class A vehicle	29.03 %

Table no 1: impact factors

- DESIGN OF BOX CULVERT
- Check for ultimate limit state

Check for flexure- ULS
Design moment = 474.3 (KN-m/m) Top slab
d provided = 500-50-8= 442 mm

d required =

$$\frac{Mu}{0.133 \times f_{ck} \times b}$$

= 319 < d provided = 440 mm hence OK

A_{st} required =

$$0.5 \times \frac{fck}{fy} \quad 1 - \quad 1 - \frac{4.6 \times Mu}{fck \quad b \, d^2} \quad b \quad d$$

=2719mm^2

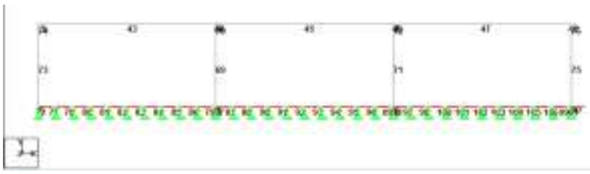

Figure 4: cross section of box showing members

Limiting value for depth of neutral axis X_{umax} = 0.46d=202.4 mm

X_u =

$$\frac{0.87 \times fyk \times Ast}{0.36 \times fck \times bf}$$

= 92.55 mm < X_{umax} 202.4 mm

Hence, section is under reinforced

- Deck slab

Deck slab is checked only for shear force due to dead load

Near External wall-
Depth provided = 500mm
Effective depth = 440 mm
Shear force = 163 KN for unit width

V_{RDC} =
$0.12K(80\rho f_{ck})^{0.33}$ b_w d
= 244.6 KN

$V_{RDC,min}$ =
γ_{min} + 0.15 δ_{cp} b_w d
= 174.8 KN

$V_{RDC} > V_{RDC,min}$

Hence, no shear reinforcement is required.

Near Interior wall-
Depth provided = 300mm
Effective depth = 217 mm
Shear force = 32 KN for unit width

V_{RDC} =
$0.12K(80\rho f_{ck})^{0.33}$ b_w d
= 130.7 KN

$V_{RDC,min}$ =
γ_{min} + 0.15 δ_{cp} b_w d
= 116.6 KN

$V_{RDC} > V_{RDC,min}$

Hence, no shear reinforcement is required.

III. RESULTS

A RCC box culvert is designed with all the IRC specifications. Results obtained are shown below in the form of tables and graphs.

- Reinforcement details

For deck slab	12 T @ 150 mm c/c
For raft	10 T @ 150 mm c/c
For side walls	10 T @ 150 mm c/c
For interior walls	10 T @ 200 mm c/c

Table no 2 : reinforcement details

- BM for deck slab

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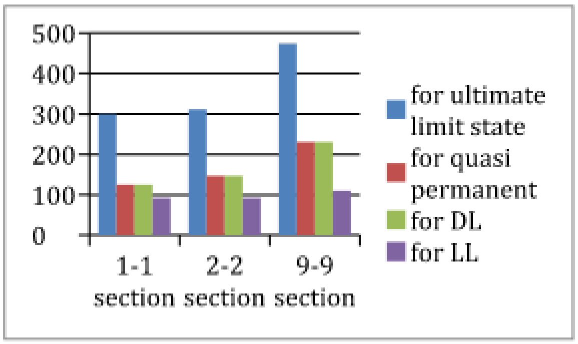


Chart no 1

- BM for raft

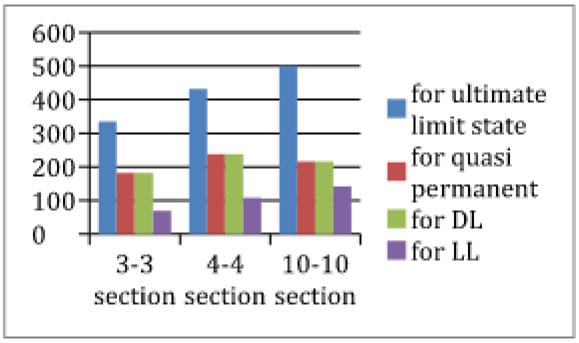
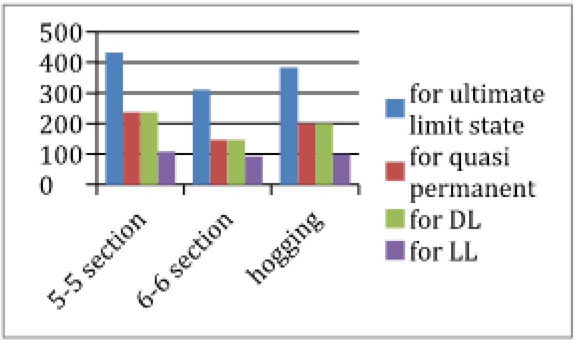


Chart no 2

- BM for external wall



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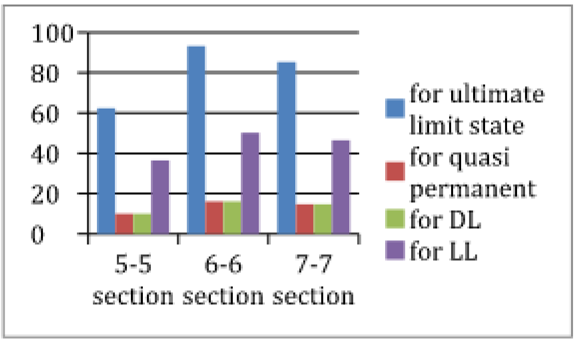
- BM for interior wall



IV. CONCLUSION AND RECCOMENDATIONS

- Box for cross drainage works across high embankment has many advantages.
- Box culvert is easy to add length in the event of widening of the road.
- It is easy to construct, practically no maintenance, structurally very strong, rigid and safe.
- Box culvert is more durable and suitable than causeways.
- Causeways are temporary structures and suitable only for very less important roads but considering future perspective it is convenient to build culverts across river.

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