Design of a Box Culvert using ETABS Software

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Abstract — When it is necessary to make the intersection of channels or canals, the main problem is how to prevent the overflow of the canals because during the rainy season the water rises and floods occur, threatening the roads and vehicles. For this purpose, a culvert needs to be built at the intersection. A culvert is a structure designed to allow water to flow through it. The Kut-Petera irrigation project requires the construction of a culvert box at the intersection of the main drainage system (MD-A) and the Al-Dejaili asphalt road. The design is based on hydraulic and structural parameters. The hydraulic design is based on hydraulic data obtained for the site. The dimension of the culvert box is based on the hydraulic design. The culvert box consists of two plates with a length of 27 m and a total width of 3.14 m. The design is defined as the stability and safety of the culvert box under applied loads.

Keywords: Canal, Box Culvert, Safety, Stability, Bending moment and Shear value

I. Introduction

A hydraulic structure is a submerged or partially submerged structure in a body of water that interferes with the natural flow of water. They can be used to interrupt, block, or completely stop it. Hydraulic structures can be built into rivers, oceans, or any body of water where the natural flow needs to be altered. A culvert is a hydraulic structure that allows water to flow across a road, railroad, sidewalk, or similar obstruction. It is usually buried so that it is surrounded by land. Culverts can be constructed from a variety of materials, including castinplace or precast concrete. Culverts are commonly used as water crossings for canals and to convey water through rivers and streams. A culvert can be a bridgelike structure designed to allow vehicles or pedestrians to cross a waterway when sufficient water is allowed. Culverts are available in many sizes and shapes, including round, oval, and box designs. The selection of culvert type and shape depends on many factors, including hydraulic performance, surface water flow restrictions, levee height, etc. The design takes into account the condition of the cargo (empty container, full, overloaded, etc.) based on load, width, braking force, load distribution by filling, influencing factors, soil pressure coefficient, etc. time and shear strength. Relevant regulations must be consulted.

II. Literature review

Creamer(2007)Define a culvert as a buried structure, usually surrounded by soil, that allows water to flow from one side to the other, such as in a road, railway, road or both. Culverts can be made from a variety of materials, including castinplace or precast concrete (lightweight or weak), galvanized steel, aluminium or plastic (usually highdensity polyethylene). Culverts are available in many sizes and shapes, including round, oval, flatbottomed, pearshaped and boxshaped. The selection of the type and shape of culvert depends on many factors, including hydraulic performance, restriction of surface water flow and road profile, flood damage assessment, cost of construction and maintenance and expected life.

Kilgore,et.al(2012 shows that culverts serve a variety of hydraulic and nonhydraulic functions. The main hydraulic function is to divert water flow into the river channel. Other hydraulic features include flood plains, where culverts can be installed along the banks of flood plains to divert water to the river bank during major floods. Such culverts usually have no net flow or downstream flow and may remain dry for years. Smaller culverts are often used to supply water to channels along the route, thus diverting some of the discharge from the channel. Nonhydraulic features include passage structures for humans or animals, such as pedestrian or crosswalks, animal crossings, agricultural equipment access, and artificial crossings that facilitate the movement of wildlife.

Creamer (2007) explained that culvert may be a bridge-like structure designed to allow vehicle or pedestrian traffic to cross over the waterway while allowing adequate passage for the water. The major benefits of the culvert are: - Decreased traffic interruption time due to roadway flooding. Increased driving safety. Comparing culverts to bridges the designer must determine which type of structure is best for a particular location, and then decide how to analyze the crossing. For example, in many respects a large box culvert begins to resemble a small single-span bridge with vertical wall abutments, so culverts are used: - Where bridges are not hydraulically required.

– Where debris and ice potential are tolerable.
– Where more economical than a bridge.
– Safety, aesthetic and economic considerations are involved in the choice of a bridge or culvert.
– Economic Considerations

Kilgore, et al. (2012) reported that economic considerations were of primary importance in deciding between the use of a bridge or a culvert at stream crossings where either will satisfy hydraulic and structural requirements. The initial cost for a culvert is usually less than a bridge since the use of increased headwater at a culvert installation normally permits the use of a smaller opening compared to a bridge which is normally designed with freeboard at the design discharge. However, this advantage must be balanced against possible flood damages associated with increased headwater, especially at higher discharges.

III. Results and Discussion

According to the Design Manual for Irrigation and Drainage by Pencol Engineering Consultants (1983), the thicknesses of the box culvert were assumed to be based on table (11.5), as showing below.

TABLE 11.5 DRAIN BOX CULVERTS

Drain Design Discharge (m^3/s)	Size of Barrel (m)	Roof, wall and floor thickness (m)
1.5 - 2.1	1.2	0.25
2.1 - 2.8	1.4	0.25
2.8 - 3.6	1.6	0.25
3.6 - 4.6	1.8	0.30
4.6 - 5.7	2.0	0.30
5.7 - 6.9	2.2	0.30
6.9 - 8.2	2.4	0.30
8.2 - 10.4	2.7	0.35
10.4 - 12.8	3.0	0.35

Member	Load source		Load factor	Area load (kN/m2/m)	Total area load (kN/m2/m)	Total linear load (kN/m2/m)
Top Slab	Self-weight		1.25	7.5	115.15	115.15
	Backfill		1.35	107.65		
Exterior side walls	Lateral earth pressure	Top	1.5	39.87		
		Bottom		52.92		
Bottom slab	Self-weight of walls		1.25	8.57	123.72	123.72
	Total top slab loads		-	115.15		

Table 1: Summary of factored distributed loads.

Member	Joint	M^-	V_u @support face	M^- @support face
AB	A	11.99	75.15	-3.50
	B	24.08	91.81	-13.50
BC	B	24.08	91.81	-13.50
	C	11.99	75.15	-3.50
DE	D	13.07	80.94	-3.92
	E	25.77	98.46	-14.86
EF	E	25.77	98.46	-14.86
	F	-13.07	80.94	-3.92
AD	A	11.99	31.31	-8.43
	D	13.07	35.96	-8.96
CF	C	11.99	31.31	-8.43
	F	13.07	35.96	-8.96

Table 2: Negative moment at face of support.

Member	Joint	Support moment (KN.m/m)	Mid – Span moment (KN.m/m)
AB = BC	A = C	-3.5	+12.2
	B	-13.5	
DE = EF	D = F	-3.92	+13.1
	E	-14.86	
AD = CF	A = C	-8.43	+0.37
	D = F	-9.05	
BE = EB	B	0	
	E		

Table 3: Moments summary.

IV. Conclusions

The size of the culvert box is based on the hydraulic design.The box culvert is designed as a doublechamber culvert with a total length of 27 m and a total width of 3.15 m. The length of each chamber is 1.2 m measured from the support center. The bottom of the culvert box is 0.2 m below the bottom of the main drainage ditch (MDA). Delivery condition 4 provides the least head loss. The features of the culvert box are top plate, bottom plate, two side walls and one inner wall. The structural design of the box culvert is the maximum bending moment and shear force of any structural unit. The design was analyzed using ETABS software, which gives similar results to manual calculations.

Acknowledgement

This paper has been prepared under the guidance of Prof. Parshottam Sarathe and Prof. Deepak Garg., Assistant Professor, Department of Civil Engineering, Oriental Institute of Science and Technology, Bhopal, are warmly acknowledged for their continuous support.

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