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Reinforced Concrete Structural Design and Analysis of a Single Cell Box Culvert Using Manual Method

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ABSTRACT: Box culvert is a hydraulic monolithic reinforced or non-reinforced concrete structure. [1]Culvert's classification by material is not limited to concrete but includes steel, alluminium, plastic, timber and high density polyethylene. Culverts permits the flow of water from through an inlet and an outlet under a normal roadway, railway. Because culverts main function is to accommodate and withstand various types of loads generated by traffic through human activities, soil fill, amongst others, this article is an exercise that deals with [3]holistic manual analysis and design of a single cell box culvert through the consideration of effects of earth pressures, surcharge pressures, hydrostatic and excess hydrostatic internal pressure, uniformly distributed permanent and live loads (of self-weight of the critical element/component and vehicular loads). Abstractedly, the dept of fill is 1.6m, the thickness of top, bottom, vertical side walls, the wing walls and apron slab floor are all uniformly 0.25m. The single cell culvert length is 6m and constructed across an asphalt surface finished roadway. BS5400 part 1, BS8110 part 1 (1985/1977), [3]Reynold and steelman's reinforced concrete designer's hand book are some of the codes and manuals used in the design and analysis of all the critical components to withstand maximum bending moment and shear force to specifications and standards. Summary of result of the manual design and analysis of the single cell culvert becomes main reinforcement bars: Y16mmθ@200 c/c for all components except for apron slab and distribution bars of Y12mmθ @ 200 c/c.

Keywords: HA, HB, Axle, top, slab, bottom, walls, apron, hydrostatic, reinforcement.

I. INTRODUCTION

[6]A hydraulic structure that permits the flow of water from and through an inlet and an outlet which can be under a normal road, highway, railway or any flow obstructing elements/facility defines a culvert.

[4]Culverts are in many sizes and shapes such as box –like elliptical and circular round. Choice of shape and types is dependent on requirement such as limitations on upstream water, surface elevation, road way embankment height and requirement for hydraulic performance amongst others.

[5]In the structural design of culverts, load issues such as when the culvert is full of water and when the culvert is empty are considered. [3]Considered also are surcharge loads, earth pressures, hydrostatic and excess hydrostatic internal pressures. [9]Most important to be considered is the live load that will be passing through the culverts top (roof) slab. Other factors to be considered will include but not limited to the sizing (especially effective depth), [5]dispersal of load through earth fill, co-efficient of safety and earth pressure factors.

[10,7]The structural elements of a culvert such as top (roof) slab, bottom slab, the side vertical walls, wing walls, apron slab and head wall must be designed to withstand maximum bending moments and shear forces with adherence to relevant codes.

[1]The aim of this article or presentation is to showcase the design of the structural elements of a box culvert on the bases of structural requirement. The design of this box culvert will not include hydraulic consideration and requirement.

This presentation main objective is the suitable structural design of a single cell box culvert across Obibi drive road project off Alaka Avenue, Etevie community, Ozoro, Delta State through the determination of the total permanent and live loads acting on the structural components members of the box culvert to enable/facilitate the design and subsequent determination of reinforcement bars for the single cell box culvert.

[4]Culverts are in various geometric shapes and types classification that includes box culvert, pipe culvert, pipe arch culvert, bridge culvert and arch culvert.

Box culverts are preferred and more widely used because of its outstanding merits over the other types of culverts. This is because amongst other of its merits, it can cope with budget flows, situations and available headroom is limited. [1,5,7]Box culverts can also be designed to suit a particular site situation by reducing or increasing its size easily than will be done in the case of other types of culvert.

The culvert will be analyzed with respect to critical loading conditions. The ultimate limit state will be with respect to the collapse of the culvert's structural elements while the serviceability limit state will be with or in respect to condition beyond which concern for loss of utility or for public concern over cracks and other serviceability concerns.

Loads on culvert includes;

i. Permanent loads of self-weight (dead loads), the superimposed dead loads, the horizontal earth pressure load, loads due to hydrostatic pressure, the dead loads as a result of buoyancy and differential settlement effects.
ii. Vertical live loads of HA or HB which acts on the carriageway/highway and includes cycle track loading, footway loading, accidental wheel loading and as well as construction traffic. [11]A formula for loading that represent normal traffic is referred to as HA loading while HB loading represent an abnormal vehicle unit loading(according to Vincent T. H. Chu's "A self-learning manual mastering different fields of civil Engineering Works (VC-Q-A-Method)".
iii. Horizontal live loads of surcharge, traction, temperature effects, parapet/head wall collusion, accidental skidding and centrifugal load.

In general concerning culvert loading, B5400: part 2 1978 contains the requirement for culvert loading. The above are also contained in [3]Reinforced concrete design manual by Reynolds and Steelman's 1994 edition.

[7]The concept of type HA loads first came into awareness in the year 1945 while that of HB (highway bridges) loading was introduced in BS53 in the year 1954.

Type HA loads (normal traffic loading) covers vehicles up to 44 ton and are represented by uniformly distributed load with a knife edge load and:

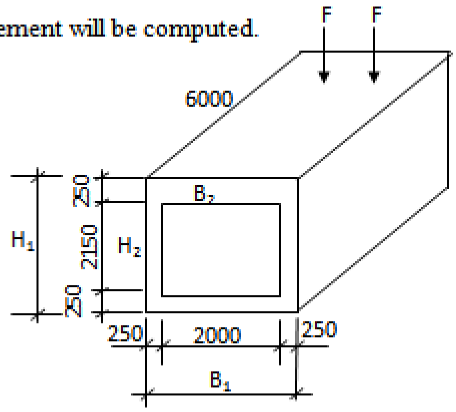
a. Covers more than one vehicle occupying the width of a lane.
b. Covers overloading in normal vehicles
c. Covers impact load that are induced when car wheel bounce as at when travelling across potholes.

TABLE 1: DESIGN INFORMATION

1.	Culvert sizing:	2000mm x 2150mm single cell in-to-in with 250mm uniform thickness of top slab, invert slab and walls with a total span of 6000mm
2.	Location:	Km 0 + 0.00 at Obibi drive Off Alaka Avenue, Etevie Community, Ozoro Delta State.
3.	Relevant Design Code:	i. BS5400: Part 2 1978 (load specification) ii. BS8110: Part 1: 1997 (Code of practice for design and construction) iii. Reinforced concrete designer's hand book (Reynold & Steelman)
4.	Soil Parametre:	Allowable bearing capacity; 200kN/m^2
5.	Characteristic strength material data:	(i) Concrete fcu: 25N/mm^2 (ii) Main steel bars (fy): 460N/mm^2 (iii) Distribution bars (fy): 460N/mm^2
6. A.	**General Loading Conditions** **Dead load:** (i) Weight per m^2 (ii) Dead load Values of partial factor of safety BS5400-1	 (i) Weight of concrete: 24kN/m^2 (ii) Weight of soil: 18kN/m^2 (iii) Weight of asphalt: 23kN/m^2 (iv) Weight of water: 10kN/m^2 (i) Self weight of culvert: 1.15 (ii) Earth fill (earth pressure): 1.50 Asphalt: 1.00

B	**Imposed load** (i) Design HA loading combined with design HB 45 units loading (ii) Imposed load values of partial factor of safety	(i) **HA:** single wheel load of 100kN of square contact area of 300mm by 300mm of 1.1kN/mm^2 effective pressure. (ii) **HB:** a four axle vehicle of 10kN per axle, with four wheels equal spacing on each axle of 2.5kN per wheel of four wheel per axle of 45 units: HA (HB45) (i) HA vehicles (ULS) 1.50 (ii) HB vehicles (ULS) 1.30 (SLS) 1.10

DESIGN OF BOX CULVERT

Ref		Output
	In this paper, structural analysis and design of culvert with details as shown in figure 1 will be discussed and analyzed for maximum bending moment and maximum shear force caused by the result of the application of vehicle wheel load, hydrostatic pressure, earth pressure, and self-weight of the culvert after which the reinforcement will be computed.  **Figure 1: Single Cell Culvert size details**	

	From figure 1, effective depth: $Deff = t - \text{Concrete cover} - \frac{\theta}{2}$ $\therefore deff = 250 - 50 - \frac{20}{2}$ $= 250 - 50 - 10$ $= 190mm$	(where θ is assumed diameter of rebar = 20mmθ) cover = 50mm (for severe conditions of exposure).

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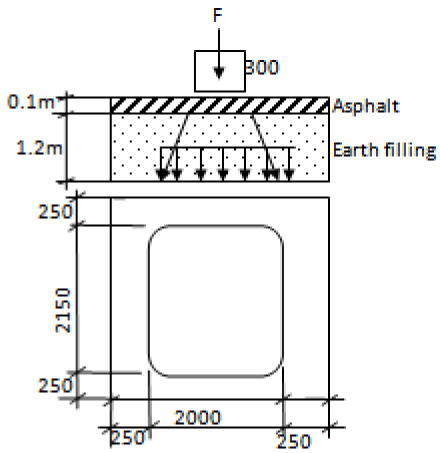
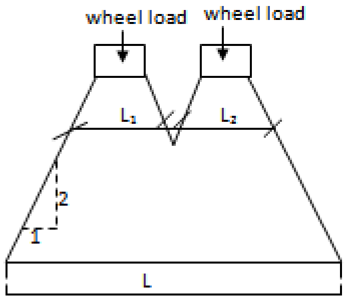
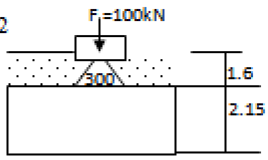
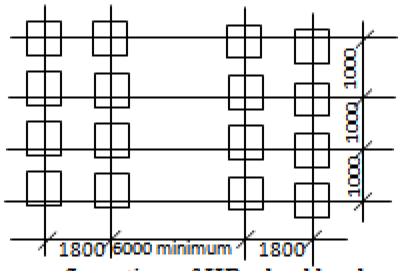
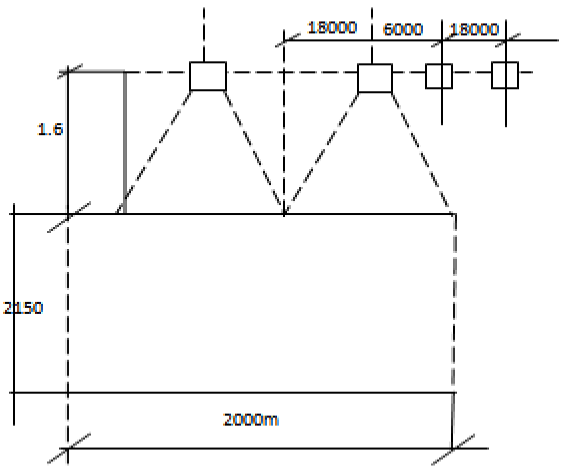
	LOADING	
	(a) Dead load:	
	(i) Top slab = 1.15 x 24 x 0.25	6.9kN/m^2
	(ii) Bollous slab = 1.15 x 24 x 0.25	6.9 kN/m^2
	(iii) Walls = 1.15 x 24 x 0.25 x 3 x 2.15	44.51 kN/m^2
	(iv) Weight of Asphalt = 1.0 x 0.1 x 23	2.3 kN/m^2
	(v) Weigh of fill = 1.5 x 1.6 x 18	43.2kN/m^2
	Total dead load	103.81kN/m^2
	(b) Imposed load:	
BS5400 Part 2 6.2.5 6.2.6 6.4.1.5	 Figure 2a: Wheel load dispersion on culvert	Cover depth >0.6m HA UDL/KEL not applicable 30 units of HB loading rules OR Wheel load dispersal on box culvert single 100kNHA

	 Figure 2b: Wheel load dispersion on culverts diagram	
	CASE I: 100kN HA wheel load (stress due to HA vehicle)	
BS5400 Part 1 6.2.5 6.2.6 6.4.1.5 htt://strudrile.com	Single wheel load of 100kN @ 1.1N/mm² effective pressure will produce contact area (A_{CT}): $A_{CT} = \sqrt{\frac{100\times10^3}{1.1}} = 302 \times 302$  Figure 3: Stress due to HA vehicle,	
	@  gradient, Dispersal area to the top slab of the culvert (Adsp): $\therefore Adsp = A_{ct} + 2\times\left(\frac{F_d}{2}\right)$ $= 302 + \left[2\times\left(\frac{1600}{2}\right)\right]$ = 302 + 1600 = 1902 X 1902 @ top slab thickness = 250mm then neutral axis (F_{dsp}) = 125mm(F_{dsp}) ∴ Dispersal width to neutral axis of culvert (W_{dsp})	A_{dsp} = Dispersal area A_{CT} = Contact area

	Thus $W_{dsp} = A_{CT} + F_d + 2F_{dsa}$ $= 302 + 1600 + 2(125)$ $= 2152mm$ ∴ wheel load (F_{ds}) on dispersed area: $F_{ds} = \frac{100}{2.152 \times 2.152} = 21.6kN/m^2$	F_d = Fill depth F_{dsa} = Neutral axis is at half F_d.
htt://strudrile.com	**CASE II:** 45 units of HB Load (stress due to HB vehicle) Wheel load = $45 \times \frac{10}{4} = 1125kN$ $A_{CT} = \sqrt{\frac{112500}{1.1}} = 320 \times 320mm$	
BS5400 Part 2 6.3.1 6.3.2 6.3.3 Reynold T11	 Figure 4: The configuration of HB wheel load	
	 Fig 5: Stress due to HB vehicle	

	Total fill depth (F_{dT}); For neutral axis = ½ top slab thickness (250mm) provided the structure have no longitudinal joints. $F_{dT} = F_d + F_{dna}$ $= 1600 + \frac{250}{2} = 1600 + 125 = 1725mm$	
	@ $\frac{2}{1}$ gradient. Transverse dispersal lines will overlap at a depth of: T_{dd} = 1000 – 320 (4 wheels on each axle at a spacing of 1000mm for HB loading figure 5) T_{dd} → Transverse dispersal depth depth = 680mm < 1650mm → (ok, 4 wheels considered) ∴ Total width that an axle will dispersed (T_{wad}): $T_{wad} = A_{CT} + (n-1) S + F_d + F_{dna}$ Where: $T_{wad} = 320 + (4 - 1) 1000 + 1600 + 2 (125) = 5170mm$	T_{dd} = Transverse dispersal dept T = total w = width a = axle d = disperse n = number of axles s = spacing c/c of axle 250
	Or $T_{wad} = 3000 + 320 + \left(2 \times \frac{1600}{2}\right) + \left(2 \times \frac{250}{2}\right)$ = 5170mm (from figure 6)	
	@ $\frac{2}{1}$ gradient. Longitudinal dispersal liens overlaps at a depth of; L_{dd} = 1800 – 320 (front and rear pair of axles are spaced at 18000) = 1480 < 1650mm (ok, front and rear pair of axles are considered) ∴ $L_{dd} = A_{CT} + (n - 1)S + F_d + 2F_{dna}$ (Ldd = longitudinal	L_{dd} = Longitudinal dispersal dept

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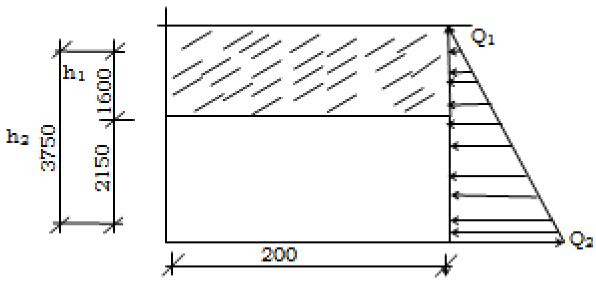
	dispersal depth) = 320 (z – 1) 1800 + 1600 + 2 (125) = 320 + 1800 + 1600 + 250 = 3970mm ∴ the axle load on dispersal area of top slab of culvert (F_{da}); $F_{da} = \frac{Nw \times W_F}{A_d}$ $\Rightarrow F_{da} = \frac{8 \times 1125}{5.170 \times 3.970} = 43.85kN/m^2 > 21.6kN/m^2$ $\Rightarrow 43.85 \times 1.5 > 21.6 \times 1.5$ $= 65.78kN/m^2 > 32.4kN/m^2$ Thus between case I and case II, case II is critical @ $43.85kN/m^2 > 21.6kN/m^2$	Nw = number of wheel W_f = wheel load A_d = dispersal area F_{da} = axle load for F = load d = dispersal a = axle
BS5400 Part 2 6.2.7	∴ UDL acting on top of the culvert that is appropriate for the design = $43.85kN/m^2$	
	ACTIVE EARTH PRESSURE ON WALLS Let active earth pressure = K	
BS54000 Part 2 5.81 Reynold T16	$k = \frac{1 - Sin\theta}{1 + Cos\theta}$, $\theta = 30^0$ (angle of slope of bank of retained material) K = 0.333  Figure 6: Active pressure on vertical wall of culverts	

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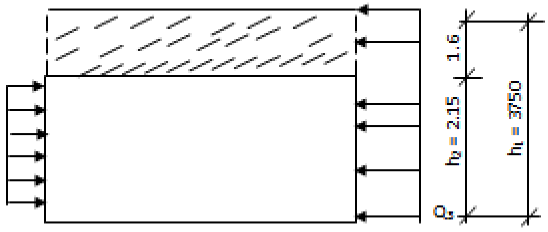
	$Q_2 = Kh_2\rho 1.5 = 0.33 \times 3.75 \times 18 \times 1.5 = 33.4kN/m^2$ $Q_1 = Kh1\rho 1.5 = 0.33 \times 1.6 \times 18 \times 1.5 = 14.3kN/m^2$ **HYDROSTATIC PRESSURE ON INVERT FLOOR** $\rho_w = 9.801kN/m^3 \simeq 10kN/m^3$ $h_2 = 2.15m$ (@ a maximum flooring of 2.15m at peak period that culvert is full of water) $\therefore P_{HY} = P_{hy} \Rightarrow$ hydrostatic pressure $\Rightarrow \rho hy = \rho wH = 10 \times 2.15 = 21.5kN/m^2$	
	SURCHARGE PRESSURE ON CULVERT WALLS  Figure 7: Surcharge pressure on walls $Q_3 = K(F_{da} + N_{FL})$ $= 0.33 \times (43.85 + 43.2)$ $\therefore Q_3 = 0.33\ (43.85 \times 1.5) + 43.2$ $= 108.0kN/m^2$	Q_3 = surcharge pressure F_{da} = load dispersal due to axle of vehicle on walls W_{FL} = weight of fill on walls
	CHECK FOR ADEQUACY OF SOIL BEARING CAPACITY i. Allowable soil bearing capacity = $200KN/m^2$ ii. Total design load on the soil = Dead load + imposed load $= 11.35 \times 103.81 + 43.85 \times 1.5$ $= 146.1435 + 65.775$ $= 206KN/m^2 > 200KN/m^2$	

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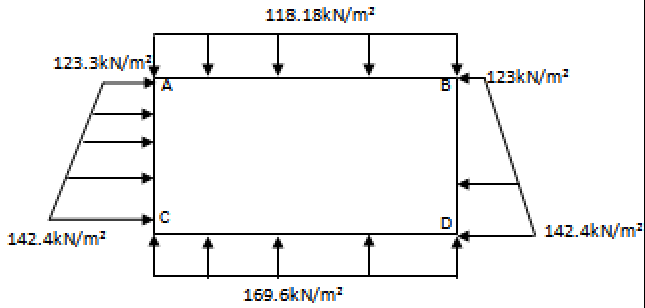
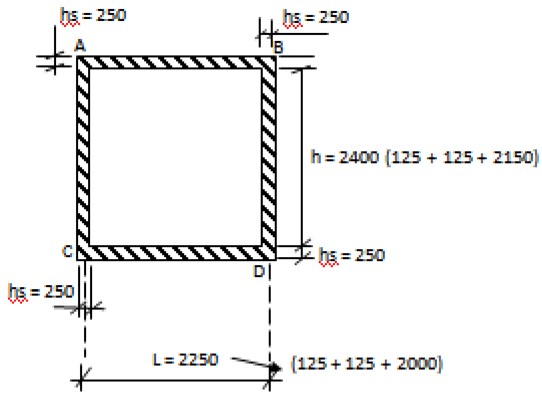
	TOTAL BENDING PRESSURE ON CULVERT MEMBERS  Figure 8: Bending pressures on culvert members (total) Top slab = (slab wt. + fill wt + Asphalt wt + HB) $= 6.9 + 43.2 + 2.3 + 65.78 = 118.18 KN/m^2$ Bottom slab = Tob slab wt + invert slab wt + walls wt $118.18 + 6.9 + 44.51 = 169.59 KN/m^2$ Side walls: $Q_1 = Q_1$ + surcharge pressure $= 14.3 + 109 = 123.3 KN/m^2$ $Q_2 = Q_2$ + surcharge pressure $= 1334 KN/m^2 + 109 KN/m^3 = 142.4 KN/m^2$	
Reynold & steelman page 473 T 187	**BENDING MOMENTS PER UNIT LENGTH OF CULVERT**  	(i) Rectangular box culvert (ii) highly compressible soil (iii) $M_A = M_B, M_C = M_D$

	Figure 9: culverts (sizes) measurement From figure 9, $k = \frac{h}{l}\left(\frac{hs}{hw}\right)^3 = \frac{2.4}{2.25}\left(\frac{25}{25}\right)^3 = 1.1$	
Reynold and steel man T187 page 473 Reynold & steelman T197 page 473	K coefficient values computation From K = 1.1; (1) ki = k + 1 = 2.1 (2) k2 = k + 2 = 3.1 (3) k3 = k + 3 = 4.1 (4) k4 = 4k + 9 = 13.4 (5) k5 = 2k + 3 = 5.2 (6) k6 = k = 6 = 7.1 (7) k7 = 2k + 7 = 9.2 (8) k8 = 3k + 8 = 11.3 Bending moments 1. UDL on top slab, Q = 118.8 kN.m^2 Moment due to UDL load on top slab For $\vec{M}_A = \vec{M}_C = \frac{QL^2}{12k_1} = \frac{118.8\ x2.25^{\ 2}}{12\ x\ 2.1} = -24KN-m$ 2. Weight on bottom/invert slab (and the water in the culvert) are directly carried by the ground underneath the invert slab ∴ moment due to load on bottom slab = 0kN-m 3. Moment as a result of weight of vertical walls i. $Q_1 = \frac{2G}{1+hw} = \frac{2\ x\ 44.51}{1.25} = 71.2kn/m^2$ ii. Moment due to Q_1 in 3(i) $\vec{M}_A = \frac{Q_1L^2k}{12k_1k_3} = \frac{71.2\ x2.25x1.1}{12\ x2.1\ x4.1} = 1.71KN-m$ $\vec{M}_c = \frac{k_5}{k}MA = \frac{5.2}{1.1}x\ 1.71 = -8.1KN-m$	

4. moment as a result of earth pressure on walls:

$Q_2 = 33.4KN/m^2$

$$\vec{M}_A = \frac{Q2\ h^2 kk_2}{60k_1k_3} = \frac{33.4x240^2 x1.1x9.2}{60x1.1x4.1}$$

$= - 7.1KNm$

$$\vec{M}_C = \frac{k_3}{k_7} MA = \frac{11.3x7.1=}{9.2}\ 8.7KN-m$$

5. Moments due to earth surcharge pressure on vertical wall

$Q_3 = 109KN/m2$

$$\vec{M}_A = \vec{M}_C = \frac{Q_3 h^2 k}{12ki} = \frac{109x2.46^2\ x1.1}{12x2.1} = -27KN-m$$

6. Moment due to hydrostatic internal pressure; phy = hydrostatic pressure = 21.5kn/m2 =

$$\vec{M}_A = \frac{phy\ h^2 kk_2}{60k_1k_2} = \frac{21.5\ x\ 2.40^2\ x\ 1.1\ x\ 2.1}{60x\ 2.1x3.1} = 0.73$$

$$\vec{M}_C = \frac{k_3}{k_7} MA = \frac{11.3}{9.2}\ x\ 0.73 = 0.90KN-m$$

7. Moment due to excess hydrostatic internal pressure

$Phy = Q_{lp} = 21.5kN/m^2$

$\vec{M}_A =$

$$\frac{Qlp(h^2\ kk + L^2k_2)}{12k_1\ k_2} = 21.5\left[\frac{2.40^2x1.1x4.1)+(2\ ^2x4.1}{12x2.1x4.1}\right] = 9.21kN-m$$

$$\vec{M}_C = \frac{Q_{lp}K(h^2k_2 - L^2)}{12k_1k_2} = \frac{21.5\times1.1[2.45\ \times4.1 - 2^2]}{12\times2.1\times4.1}$$

$= 4.44kN\text{-}m$

TABLE 2: BENDING SUPPORT MOMENTS PER UNIT LENGTH OF CULVERT SUMMARY

S/N	Loading	Ma=MB	Mc = MD	Remarks
1.	UDL on top slab: $118.18KN/m^2$	-24KN-m	-24KN-m	$M_A = M_B = M_C = M_8$
2.	Weight of walls on culvert: $71.2KN/m^2$	+1.71KN-m	-8.1KN-m	$M_A = M_B$ $M_C = M_D$
3.	Earth pressure on walls $33.4KN/m^2$	-7.1KN-m	+8.7KN-m	$M_A = M_B$ $M_C = M_D$
4.	Earth surcharge pressure on walls $109K/m^2$	-27KN-m	-27KN-m	$M_A = M_B = M_C = M_D$
	Total if culvert is empty	**-56.39KN-m**	**-50.4KN-m**	**Culver is without water**

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5.	Hydrostatic internal pressure: 21.5KN/m^2	+0.73KN-m	+0.98KN-m	$M_A = M_B$ $M_C = M_D$
6.	Excess hydrostatic internal pressure 21.5KN/m^2	+9.21KN-m	+4.44KN-m	$M_A = M_B$ $M_C = M_D$
	Total if culvert is full	**-46.46KN-m**	**-44.98KN-m**	**Culvert is full with water**

MAXIMUM SPANS MOMENTS

Span moment will be computed for $\overline{AB}$, $\overline{CD}$, $\overline{AC}$, and $\overline{BD}$

Reff: Mosely, Bungey and hulse 7th edition

i. Maximum span moments of AB

(a) $R_A = \frac{wl}{2} = \frac{118.18x2.25}{2} = 132.96KN$

R_B = 132.96kN

(b) Distance to zero shear $\Rightarrow \chi$

$\chi = \frac{R_A}{w} = \frac{132.96}{118.18} = 1.13m$

(c) maximum span moment (M_{max}) will occur at zero shear,

Thus at χ = 1.13m,

(i) $M_{max(full)} = \frac{R^2{}_A}{2w} + M_A \ (culvert\ is\ \ full)$

$= \frac{132.96^2}{2x118.18} + (-46.39)$

$= \frac{132.96^2}{2x118.18} + (-46.46) = 28.33KN - m$

(ii)

$M_{max(empty)} = \frac{132.96^2}{2x118.18} + (-56.36) = 18.4KN \ (culvert is empty)$

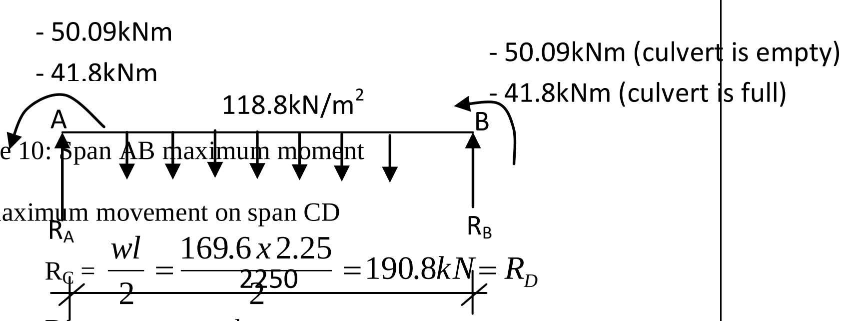

Figure 10: Span AB maximum moment

(ii) maximum movement on span CD

(a) $R_C = \frac{wl}{2} = \frac{169.6x2.25}{2} = 190.8kN = R_D$

(b) Distance to zero shear $\Rightarrow$ x

$x = \frac{R_C}{w} = \frac{190.8}{169.6} = 1.13m$

(c) Maximum span moment (M_{max}) will occur at zero shear

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(i) $M_{max\ (full)} = \dfrac{R^2{}_c}{2w} + M_c\ (culvert\ is\ full)$

$$= \frac{190.8^2}{2\,x\,169.6} + (-46.46) = 56.93kNm = 60.9kN - m$$

$$(ii)\,M_{max\ (empty)} = \frac{190.8^2}{2x169.6} + (-50.4)\ (culvert\ \ is\ empty)$$

$$= 56.93kN - m$$

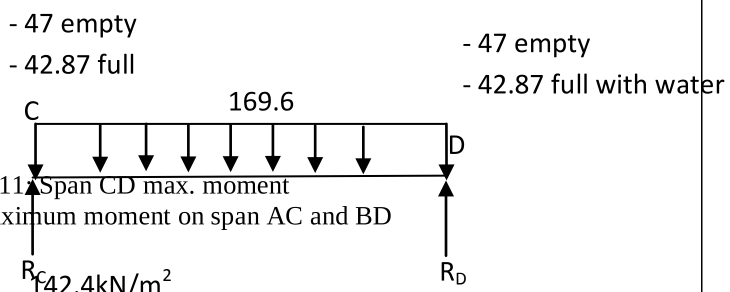

Figure 11: Span CD max. moment

(iii) maximum moment on span AC and BD

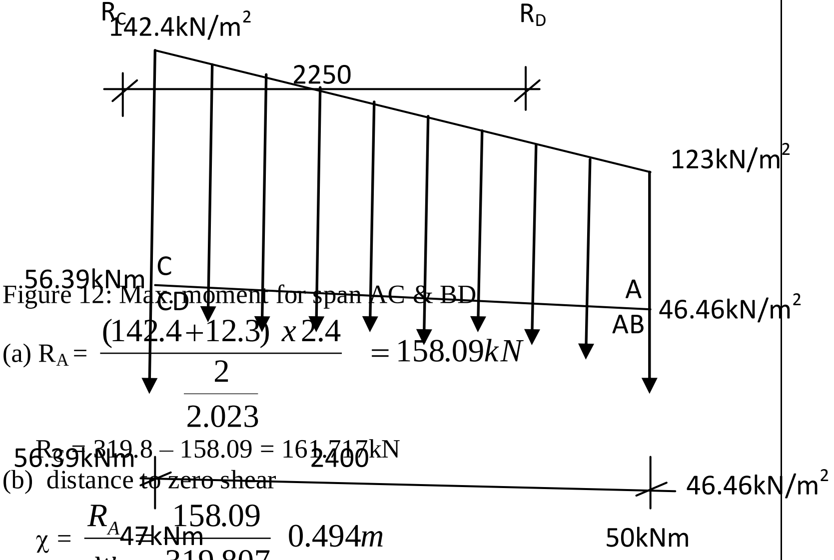

Figure 12: Max moment for span AC & BD

(a) $R_A = \dfrac{(142.4 + 12.3)\ x\, 2.4}{2} = 158.09kN$

$\dfrac{}{2.023}$

R_B = 319.8 – 158.09 = 161.717kN

(b) distance to zero shear

$$\chi = \frac{R_A}{w} \frac{158.09}{319.807}\ 0.494m$$

(c) (i) $M_{maxfull}$ =

$$\frac{161.717}{2\ x319.807} - 46.46\ = -5.57\,kNm\,(culvert\ is\ full)$$

(ii) $M_{maxempty}$ =

$$\frac{161.717}{2\ x\ 319.807}\ 56.39\ = 15.5kNm(culvert\ is\,empty)$$

Mosley Bungey Hulse	**DESIGN WING WALL** Wing walls prevent scour effects, soil erosion, retains the embarkment and directs water flow. Earth pressures from the back fill material, surcharge pressure from live load or compacting machine and hydraulic loads from saturated seal conditions are all design considerations. Also to be considered in the design of wing wall is the lateral earth and surcharge pressure factors. Lateral earth pressure factor = 1.35 ⇒ ϒτ The horizontal force (F) due to earth pressure is given by:	

<table>
<tr><td></td><td>

$F = \Upsilon\tau\ 0.5Kaph^2$
$= 1.35 \times 0.5 \times .33 \times 18 \times 2.4^2 = 23.1kN$

This force is acting approximately @ $\frac{h}{\Im}$ from the base apron of wingwall.

Thus for F, acting at $\frac{h}{\Im}$ from base of wall;

$\therefore$ Moment, M = F $\frac{h}{\Im}$

$= 23.1 \times \frac{2.4}{3}$

$= 20.53kNm$

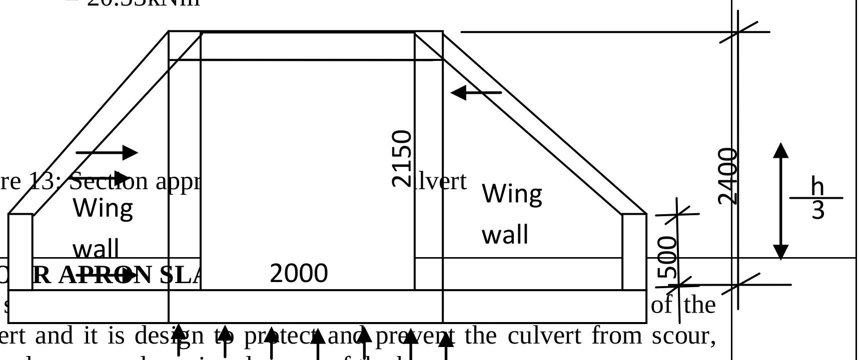

Figure 13: Section appr lvert

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SC R APRON SL

The of the culvert and it is design to protect and prevent the culvert from scour, storm damage and erosion damage of the base apron

There is an upward pressure (Q) at the base of the bottom slab (figure 13).
Q = self-weight of the apron slab itself = 0.25 x 24
$= 6kN/m^2$ per linear metre

$\therefore M = \frac{QL^2}{8} = \frac{6 \times 6}{8} = 27kNm$

</td><td></td></tr>
</table>

TABLE 3: DESIGN RESULT SUMMARY

S/no	Culvert component	Moment (kN-m)		$K = \frac{M}{bd^2F_{cu}}$		$Z = d\left[0.5 + \sqrt{0.}\right.$		Asreq $= \frac{M}{0.87\ fyz}$		As provided
		Support	Midspan	Support	Midspan	support	Midspan	support	Midspan	
1.	Top slab (a) culvert is full (b) culvert is empty	-46.46 -56.39	28.33 18.4	0.051		181		641		Y16 mmθ @ 200 c/c $1010mm^2$
2.	Bottom slab (i)	-44.98	60.9		0.07		177		850	Y16 mmθ @ 150 c/c

	culvert is full (ii) culvert is empty	-50.4	56.93	0.056						$1340mm^2$
3.	Side walls weight (i) culvert is full (ii) culverts is empty	-46.46 -56.39	-5.57 -15.6							
4.	Earth pressure on walls (i) full (ii) culvert is empty	-46.46 -56.39	- -							
5.	Earth surcharge pressure	44.48 56.38	-							
6.	Hydrastic pressure internal pressure	-44.98	-							Y10 mmθ @ 200 c/c 393 mm^2
7.	Excess hydrastic internal pressure	-44.98 -50.4	-							
8.	Wing wall	-	20.53	0.022		186		276		
	Apron slab	-	27		0.03	184		367		Y12 mmθ @ 200 c/c 566 mm^2
9.	Distribution bars		Area of steel = 0.13%bh = $\frac{0.13 \times 190 \times 1000}{100} = 247mm^2$							Y10 mmθ @ 200 c/c 393 mm^2

Mosley Bungey & hulse table 6.10	**CHECKING FOR SAFETY OF THE DESIGN** (a) Check span – effective dept ratio: The steel ratio ρ, is defined as; $\rho = \frac{100Asreq}{bd}$ When ρ >1.5%: the level of concrete stress under serviceability condition is highly stressed When ρ = 0.5%: the level of concrete stress under serviceability condition is lightly stressed

	Hence $\rho = \frac{100\ x850}{1000\ x190} = 0.447 \simeq 0.5\%$ (hence ρ is lightly stressed and >0.13% minimum ok) Basic span – effective dept, ratio = 24 For fy = 460 is < 500 Thus basic span – effective dept ratio = 24 x $\frac{500}{460} = 26$ (i) actual = $\frac{Span}{effective\ dept} = \frac{2250}{190} = 11.84$ Limiting $\frac{Span}{eff\ .dept} \Rightarrow basic\ ratio \times \frac{Asprov}{Asrq}$ = 26 x $\frac{1010}{850} = 26\ \times 1.2 = 31.2 > 11.84,\ ok$ Hence (ii) $\frac{Allowable\ span}{effective\ dept} = 31.2 > \frac{actual\ span}{effective} = 11.84$ ∴ effective dept = 190mm is adequate and acceptable	
B58001 Part 1:3.4.4.4(b)	**CHECK FOR DEFLECTION** For deflection check; modification factor (M_f) = $\frac{0.55 + 477 - fs}{120(0.9 + \frac{M}{bd^2})} \leq 2.0$ But $fs = \frac{2}{3} fy \frac{Asrq}{As\ prov} (\frac{1}{\beta_1})\ \beta_1 = 1$ (where redistribution is not required $M_f = \frac{0.55 + 477 - 258.1}{120\ (0.9 + 1.7)} = \frac{219.55}{315} = 0.7 < 2.0, ok$ From M_F = 0.7 and Basic span – effective dept ratio = 26 ∴ limiting M_F value = 0.7 x 26 = 18.2 But: Actual $\frac{span}{effective\ dept}$ Value $\frac{2250}{190} = 11.84 < 18.2$ Thus limiting value > actual value: 18.2 > 11.84, ok And d required = $\frac{span}{2\ x \frac{span}{eff.\ dept}\ ratio} = \frac{2250}{2 \times 26} = 43.3mm < 190mm\ ok$ ∴deflection check is satisfied ok	
Mosely Bungey Hulse B58110 – 1:1997	**(C) CHECK FOR SHEAR REQUIREMENT** For V_u = the ultimate shear force V_s = the shear stress (shear reinforcement) $V_u = \frac{V_s}{bd}$	

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Clause 3:4:5.12 B58110-1:1985 Clause 3.4.4.4	V_c = ultimate concrete shear resistance $V_c = \frac{100Asp}{bd}$ $V_u < V_c$, shear reinforcement not required $V_u = \frac{V_s}{bd} = \frac{190.8}{1000\ x190} = 0.001$ $Vc = \frac{100\ x1010}{1000\ x190} = 0.53 > V_C = 0.001$ $\therefore$shear reinforcement is not required ($V_u - V_c$, ok)	

BENDING MOMENT DIAGRAM

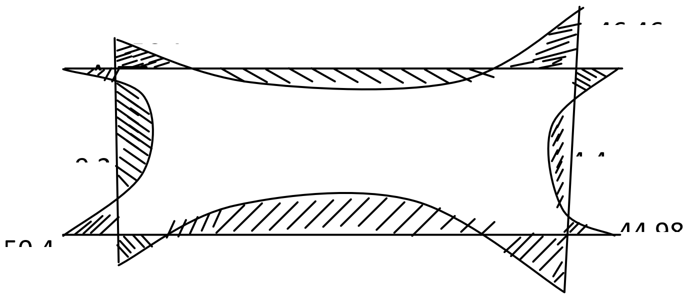

Figure 14: Bending moment diagram

CONSTRUCTION OF CULVERTS

[1]Service life of culverts should equal the service life of the highway hence a culvert should be designed and constructed to equal the service life of the structure it is serving.

There are reasons why culverts can [1,7,9]fail, reasons such as poor or no maintenance, environmental conditions, improper and non-engineering compliance during construction and structural failure leading to collapse or erosion. Therefore, to avoid and prevent failure, accurate engineering design and construction methods consideration should be a priority.

[1]Economic analysis and consideration in the design and construction of culvert include an economic analysis such as construction cost factors amongst others.

Culvert location should be an economical and effective need for usage. Location must be where construction is convenient for construction and in a location where required gradient must be achieved.

BENEFIT TO HUMANITY

[1,9,7]Culvert functions range from hydraulic and structural safety performance such as provision of cross drainage for stream channel, flood plain relief drainage during flood periods, and non-hydraulic function such as acting as a crossing structure for humans/animal traffic as in pedestrian crossing, vehicles and rails crossing and cow and other animal's crossing. [7, 1]These functions of culvert benefit human in decreasing traffic interruption period as a result of road route flooding including the increasing confidence of safe driving.

II. CONCLUSION AND RECOMMENDATION

The dimension of the culvert were chosen to suit its location on site and is designed as a single cell with a total length of 6m and a total width of 2m in-to-in, 2.25m centre to centre span with its vertical side walls being 2.4m centre to centre but with in-to-in 2.15m height. The thickness of the culvert is 0.25m for all its structural element members. The single cell box culvert was analysed and designed for the maximum bending moment and shear force in each of the structural element members. The reinforcement provided are: Y16mmθ @ 200 centre-centre for top slab, bottom slab, wing walls and vertical side walls. Y12mmθ @ 200 c/c for apron slab floor and distribution bars.

The results were checked for;

1. Span-effective depth ratio to ascertain adequacy of effective depth,
2. Modification factor to confirm deflections check is satisfied and
3. Shear force, to establish whether there is need for shear reinforcement.

This treatise also discussed requirements for box culvert construction.

In using the manual computation method, the various codes for reinforced concrete design were made use of (such as BS5400, BS8110) including other relevant design manuals such as Reynold and Steelman.

Based on the accurate/precise results using manual calculation for maximum bending moment, shear force and reinforcement bars, it is recommended that any engineer that will opt for software analysis must be experienced in manual computation of the analysis and design for maximum bending moment and shear force because it is what you feed into the computer that will bring expected result.

III. CONTRIBUTION TO KNOWLEDGE

1. The developed unique approach use to present results of analysis and design for Bending Moments, shear forces and reinforcements as shown in table 2 and table 3 is a new concept researchers, practicing engineers and students will find useful and thereby contributing to knowledge.
2. The manual method of designing a culvert as it is done in this article is new to many engineers. Therefore, this work will act as a reference bench work for literature review, hence becoming a document that will continuously contribute to knowledge.
3. This work has contributed to knowledge by the awareness this work has created for the need of manual approach method in the analysis and design of box culvert.
4. This study for the first time ever has provided manual method of analyzing, computing and designing supports, maximum bending span moments, shear forces and reinforcement bars model options for civil engineering works.
5. There is a revelation of previously latent issues in an otherwise known and established problem as is clearly demonstrated in the use of tables to present results and in the method for the analysis of HA and HB loads.

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