Concrete Component Strength Design/Check

PVC PIMA Manhole Project

Prepared by

Xiaosong Vincent Wang P.Eng.

Independent Checked by

2018 08 31

Introduction:

This design/check is to reinforce the concrete lid of the PVC Manhole. H20 wheel load is considered with live load factor of 1.7. Wheel load location is shown in the figures and a-wheel-width-design strip is used to calculate Maximum load effect (moment and shear). Deflection of the lid under the wheel load is also estimated using Code-defined-Procedure. Base slab reinforcing steel is same as the standard design drawing, which is specified in ASTM C478M standard.

The Design Load:

Concrete unit weight 2400kn/m^3, normal density concrete

H20 wheel load: 16000lbs (71.26kn)

Contact area: 20"x10" (500mmx250mm)

Design standards:

CAN/CSA S6 Canadian Highway Bridge Design Code

CAN/CSA A23.3 Design of Concrete Structure

ASTM C478 Precast Reinforced Manhole Section

Load Factor and Material Resistance Factors:

For ultimate limit State

Live load factor of **1.7** *CSA S6 CL 3.5 Table 3.1*

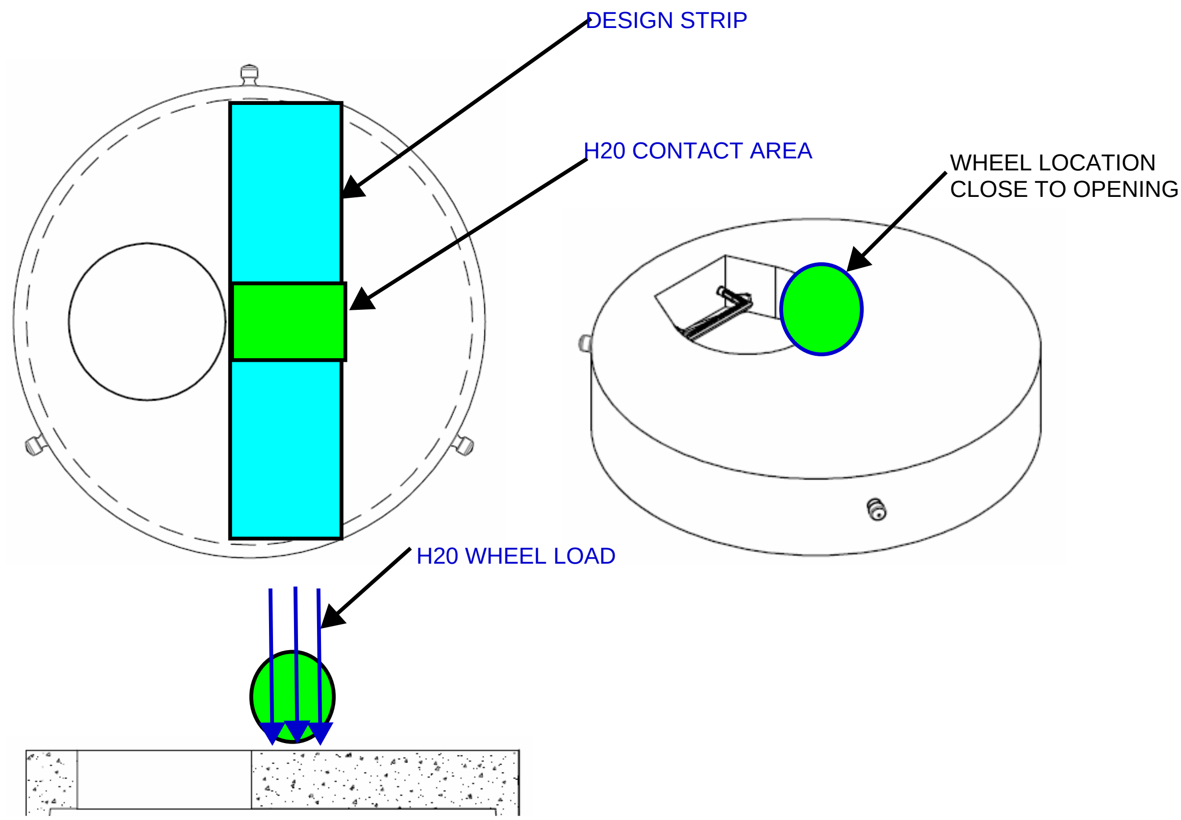
Concrete resistance factor of **0.65** *CSA A23.3 CL 8.4.2*

Reinforcing Bar resistance factor of **0.85** *CSA A23.3 CL 8.4.2*

Structural Analysis and Design for Concrete Lid

Assumptions:

1. Concentrated wheel load is transferred directly onto the surface of slab for maximum load effects.
2. Location of contact area on the slab is shown in the figures to maximize the design moment.
3. A 500 mm width beam-in-slab is selected for flexural design due to the 45 degree load distribute.
4. Punch shear is resisted by a three-edge-concrete-block with a uniformed shear stress distribution



For Ultimate Limit State

Bending Moment Design:

Factored concentrated load LL= 71.26*1.7=121.14 (kn)

Estimate lid weight 2500lbs

Factored dead load DL=2*2500*0.454*9.81*1.1=25.5kn
(* 2 to consider the backfill soil on top of lid)

The lid diameter D=1.524m

The Factored Moment Mf exists when the wheel load located at middle of design beam,

Mf= 121.14*1.524/4+25.5/1.524*1.524^2/8=48.49 (knm)

ULS Flexural Bending Moment Design is shown in following table

TO CAN/CSA A23.3-14 ***Prepared by:*** ***Xiao Song Wang P.Eng.***

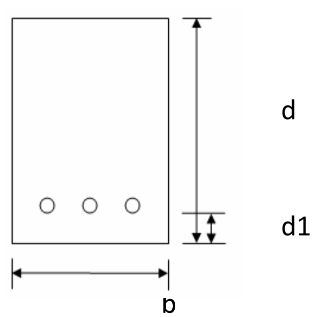
CONCRETE FLEXURAL MOMENT CAPACITY-with tension bar only -***Retan. Beam Section***

fc' Mpa	30	
fy Mpa	400	
Es Mpa	200000	*A23.4-14-8.5.4.1*
Ec Mpa	24648	*A23.4-14-8.6.2.3*
cover d1 mm	25	
α_1	0.805	*A23.4-14-10.1.7*
β_1	0.67	*A23.4-14-10.1.7*
width b mm	500	
depth d mm	219	
effective depth	186	
ϕ_c	0.65	*A23.4-14-8.4.2*
ϕ_s	0.85	*A23.4-14-8.4.3*
max. conc. strain	0.0035	*A23.4-14-10.1.4*
number of rebar	5	
rebar dia. mm	16	
rebar cross area mm^2	1005	
a=β1*c	43.55	
c mm	65.00	
c/d max.	0.64	*ductile failure*
c/d tension strain criteria	0.35	*A23.4-14-10.1.4*
1.2* Mcr kn*m	15.76	
As,min mm^2	299.88	
demand Mf kn*m	50.82	*A23.4-14-10.5.1.1*
ρ ratio	0.0459	*A23.4-14-10.5.1.2*
Mr kn*m	56.13	
d/c ratio	90.53%	OK!

Note:

ULS Strength check only to meet ρ min,max; one layer of rebar in tension

Rebar placement, Crack control, and Skin reinforment are not included



Conclusion:

Use 5-15M bars at 500mm wide section for flexural design.
The bars will be welded to anchor plates for anchorage requirement.
The anchor plate to be 6mm thickness and 75mm wide, ring shape.

Punch Shear Design:

Vf=121.14kn

Vr=∅c*β*sqrt(f'c)**b*o**d*v **CSA A23.3 CL 13.3.6.2**

Vr=0.65*sqrt(30)*(230/(1000+219))*(250*2+500)*219=147.11(kn)

Vr>Vf , Ok!

For Serviceability Limit State

Concrete crack check under sustained load (dead load and backfill)

Moment under sustained load, Msus = 2*2500*0.454*9.81/1524*1524^2/8=4.24knm

Crack moment for the 500*219 design section,
Mcr=0.6*sqrt(30)*500*219^2/6=13.13knm

Msus<Mcr, so Concrete will not crack under sustained load

∆sus=5*2*2500*0.454*9.81/1524*1524^4/(384*24648*(500*219^3/12))=0.01mm OK!

With time dependent creep factor of 3, ∆sus < 1mm OK!

Concrete crack check under sustained load and wheel Load

Moment from Live load and Sustained load, Mlsus=71.26*1.524/4=27.15knm

Mlsus>Mcr, Concete is allowed to crack under variable wheel load,

but crack concrete deflection is calculated as following table

Deflection Calculation for Serviceability

Moment ,section and materials

Total M at sectionm	31.39	Knm
As*ϕs*Es	170902640	
b*ϕc*Ec	8010442	
Cover	25	mm
dia	16	mm
effective depth	186	mm

Iteration to calculate the neutral axis location for rectangular section for a given moment

C,mm	εs	ε'c	εc	difference %
10	0.001005503	5.71308E-05	0.0042905	-98.67%
13	0.001011038	7.59739E-05	0.0033185	-97.71%
16	0.001016634	9.56832E-05	0.0027112	-96.47%
19	0.001022292	0.000116309	0.0022959	-94.93%
22	0.001028014	0.000137904	0.0019939	-93.08%
25	0.0010338	0.000160528	0.0017645	-90.90%
28	0.001039652	0.000184242	0.0015844	-88.37%
31	0.00104557	0.000209114	0.0014392	-85.47%
34	0.001051556	0.000235217	0.0013197	-82.18%
37	0.001057611	0.000262628	0.0012197	-78.47%
40	0.001063736	0.000291435	0.0011347	-74.32%
43	0.001069933	0.000321728	0.0010617	-69.70%
46	0.001076202	0.000353609	0.0009983	-64.58%
49	0.001082545	0.000387188	0.0009427	-58.93%
52	0.001088963	0.000422583	0.0008936	-52.71%
55	0.001095458	0.000459925	0.0008499	-45.88%
58	0.001102031	0.000499358	0.0008108	-38.41%
61	0.001108683	0.000541037	0.0007755	-30.24%
64	0.001115416	0.000585136	0.0007437	-21.32%
67	0.001122231	0.000631844	0.0007147	-11.59%
70	0.00112913	0.000681372	0.0006883	-1.00%

ok to stop

Ig=	437644125	mm^4	*Gross section I*
Mcr=	7	knm	
steel transfromed area=	7152	mm^2	*Steel Transfored Area*
Icr=	153406445	mm^4	*Transfored Section I*
Ie=	156009446	mm^4	*A23.3 CL 9.8.2.3*
∆sus+LL=	1.63	mm	*immediate deflection*

<<=L/360, ok

Structural Analysis and Design for Concrete Base

Assumptions:

1. The H20 Wheel load is uniformly transferred to base through PVC Manhole.

For Ultimate Limit State

Concrete Wall Bearing Design Check:

Total gravity load without friction, P=121.14kn+25.5kn=147kn

Bearing Resistance, Fb= 0.85*∅c*f'c *A with t=31mm

A=PI()*1524*t=3.14*1524*31=148346mm^2

Fb=0.85*0.65*30*148346=2459Kn>>P OK!

Concrete over 18"(460mm) invert Channels

Factored load, wf=147/(3.14*1524)/1000=30.72kn/m,

Mf=30.72*0.46^2/8=0.82knm,

Using a (bxd)150mm*200mm concrete section,

Mcr=0.6*sqrt(30)*150*200^2/6=3.29knm>>Mf, OK!, Hoop Rings are needed for concrete spalling at edges.

Concrete Base Slab Design:

Base slab is reinforced use conventional 10M reinforcing bar mesh @150mm as shown in the standard design drawing, which is much greater than required in ASTM C478M.

ASTM C478M requires a 250mm^2/m reinforcing ratio and Base thickness is 200mm based on the design drawing.

Bouyancy Effect Consideration to AASHTO Standard and American Concrete Association

Bouyancy Force B = 9.8*3.14*(1.524^2)/4*3.454=61Kn

It is conservatively assumed that groundwater level exists at the top of manhole structure.

Sliding Resistance R=Ka*(Usoil-Uwater)*H*H/2*f*3.14*1.524

R=0.5*(1600-1000)*3.454*3.454/2*0.3*3.14*1.524=25.18kn

Total counter weight W=10000/2.2*9.8/1000=44.55kn

Assume that soil unit weight of 100lbs/ft3, friction coefficient of 0.3, Ka=0.5

R+W=44.55+25.18=69.72Kn>61Kn,

Safety factor=1.14<1.5,

So adding a extended base of 6" with 8" thickness

Additional soil weight Wext= 3.14*1.524*0.152*3.454*1600*9.8/1000=39.4kn

R+W+Wext=114.27kn

Safety facto=114.27/61=1.87>1.5 OK!