PRECAST CONCRETE MANHOLES- A REVIEW AND UPGRADE OF CURRENT PRACTICE

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ABSTRACT

Stormwater manholes and access chambers are traditionally constructed using precast concrete components supplied by concrete pipe manufacturers. Many years of good performance has provided confidence in the adopted approach. As a result manhole components have been accepted as fit for purpose and most TA specifications are related to hydraulic and operational requirements rather than the structural design.

The recent development of new performance design standards in New Zealand, has increased serviceability life expectancy of main infrastructure components to 100 years. Recent NZTA and TA specifications require a review of existing product designs to ensure compliance for "strength" and "durability".

This paper presents the results of intensive research work conducted by the authors to achieve this goal. The main design parameters investigated were loading, load factors for the design of lids to suit various infrastructure construction conditions, lateral load on manhole walls, foundation stability and buoyancy.

Durability design is defined in the terms of the existing New Zealand Standards which define exposure conditions for which manhole components are designed to achieve 100 years life.

The paper also lists service conditions which allow designers to specify standard manhole components for safe bearing capacity, traffic loads and depth of installation. The conditions cover existing design and construction practices allowing designers to select the correct product or carry out an alternative specific design.

KEYWORDS

Manholes, access chambers, precast concrete, structural design, loading

PRESENTER PROFILE

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Since 2009 Husham has been working as a senior civil engineer with Humes Pipeline Systems, where he is involved in Research And development, management of technical projects, sales training and technical support.

1 INTRODUCTION

Precast Concrete Manholes were introduced to New Zealand more than 50 years ago. Pipe manufacturers simply add a precast base to flush joint pipes to produce "risers" at different lengths ranging from 2440mm to 300mm and produced special flat slab lids to suit various manhole sizes and live load applications.

History has proven the structural stability, durability, and economical feasibility of using precast concrete manholes in both stormwater and wastewater applications, typically to provide access to buried pipelines, as junction chambers at the intersection of pipelines, and to construct reservoirs or wetwells for pumpstations.

In spite of the long use of precast concrete manholes in New Zealand there is no national standard that details analysis and design for manhole components, or a standard that states a performance acceptance criteria. Most Territorial Authorities (TA) accept manholes produced in New Zealand by major reinforced concrete manufacturers as fit for purpose, having performed their functions without any recorded problems.

While the record of standard precast manholes in "Normal" applications is well known and appreciated, questions arise when manholes are intended for use for other than "Normal" applications where designers need to know design limitations of standard manholes to enable them to decide if any modifications are required.

To clarify the design concept of the existing standard manhole range and to upgrade that process to meet the latest performance requirements of the industry, the Authors have prepared a draft proposal for the Concrete Pipe Association of Australasia (CPAA) to develop design guidelines for precast concrete manholes in New Zealand. The guidelines were subjected to intensive technical reviews by the member companies and a final version of the guidelines is due for publication soon.

This paper is an attempt by the authors to present in some detail the theoretical back ground of the CPAA Guidance Note (NZ)(CPAA-GN) (2016), provide examples of calculations to achieve guideline requirements and summarizes the design limitations of standard products. Many of the methods presented in this paper could be followed by designers to advise Precast Manhole Suppliers of any modifications required to meet "Special" service conditions.

The typical precast concrete manhole consists of a riser with a factory cast base slab, riser sections, flat slab lid, and adjustment rings. Figure 1 illustrates typical manhole components used in New Zealand.

2 DISCUSSION

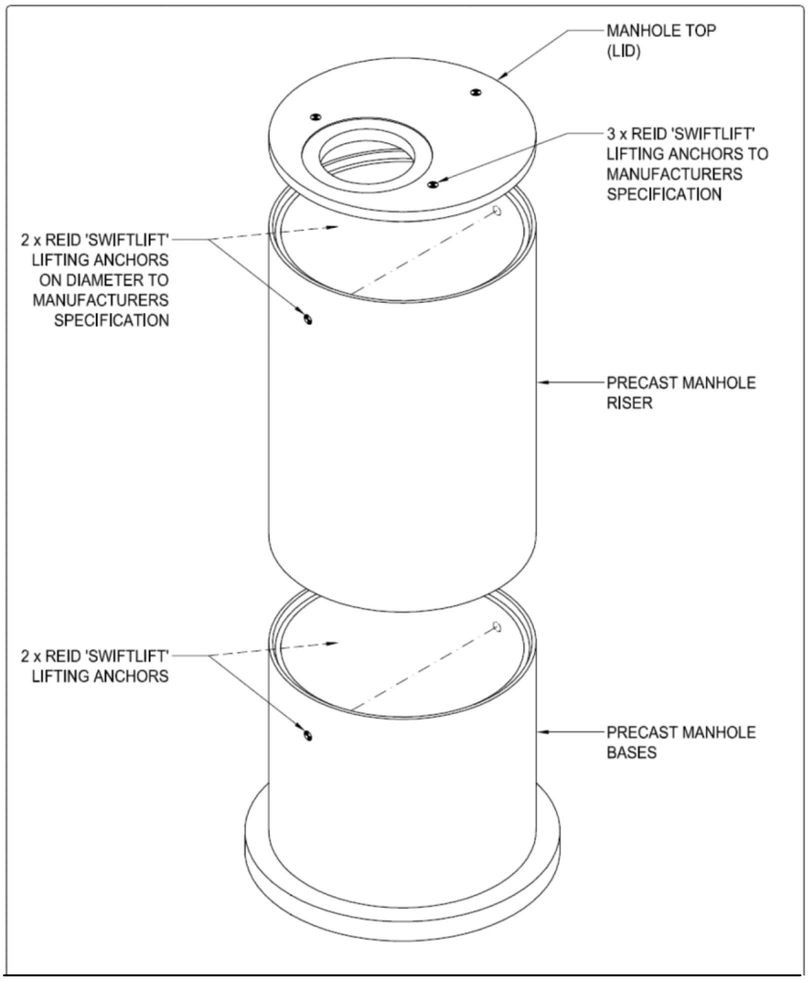
2.1 STRUCTURAL DESIGN OF MANHOLE COMPONENTS

2.1.1 MANHOLE LIDS

2.1.1.1 LD 20 Lids

Lids that are proposed to replace the existing traditional light duty lids. They are designed to the requirements of NZS 3101 (2006) for non-trafficable areas where only light live loads from lawn mowers and light vehicles may possibly run over the manhole. Loading and load factors for LD20 lids are as follows:

Figure 1: Typical Precast Concrete Manhole Components



Live Load = 20 KN Single Wheel Load (4T axle)
Impact Factor = 1.3
Ultimate Strength Load Factors AS/NZS 1170.0:2002 Section 4 (NZS 2002):
Live Load = 1.5 & Dead Load = 1.2
Serviceability Limit State Load Factors AS/NZS 1170.0:2002 Section 4 (NZS 2002):
Live Load = 0.7 & Dead Load = 1.0

2.1.1.2 HD 60 Lids

Lids that are proposed to replace the existing traditional Heavy Duty lids. They are designed to the requirements of NZS 3101 for road application, previous work by the Author (Al Saleem, 2012) indicates that maximum shear and bending moment on manhole lids up to 2500mm diameter installed in the majority of roads could be calculated using a 60 KN single wheel double tire load component which represents 99.9 % of truck loads measured in New Zealand motorways as shown in Table 1. As manhole lids cannot be classified as bridges due to their size, importance, consequences of failure, and inspection requirements as stated by NZTA, load factors specified in AS/NZS 1170.0:2002 Section 4 should be used for design. This approach is in line with the ASTM-C 478-09 method where the appropriate sections of ACI 318 are used for design of manhole lids (ASTM, 2009) and has been adopted by the CPAA-GN (CPAA, 2016). Loading and load factors for HD60 lids are as follows:

Live Load = 60 KN Single Wheel Load (12T axle)
Impact Factor = 1.3
Ultimate Strength Load Factors AS/NZS 1170.0:2002 Section 4 (NZS 2002):
Live Load = 1.5 & Dead Load = 1.2
Serviceability Limit State Load Factors AS/NZS 1170.0:2002 Section 4 (NZS 2002):
Live Load = 0.7 & Dead Load = 1.0

Load testing to AS 4198:1994 (AS 1994) of 1050mm and 1200mm diameter HD60 lids designed to the above specifications indicates that all 8 lids tested meet the requirements of Class H which is equivalent to Class D of AS 3996:2006 (AS 2006) for ultimate and proof loads.

Table 1: Traffic Load Distribution of New Zealand Highways (NZTA 2007)

Table 7.4.1 Presumptive traffic load distribution for New Zealand (rural) state highways.

Load (kN)	Axle Group Type				
	SAST (%)	SADT (%)	TAST (%)	TADT (%)	TRDT (%)
10	0.611	1.783	0.007	0.106	0.000
20	13.478	11.672	0.143	0.841	0.045
30	16.815	17.773	0.253	2.718	0.177
40	14.411	18.999	0.829	4.804	0.513
50	31.016	20.810	1.742	5.950	1.571
60	20.520	11.624	5.431	6.832	3.449
70	2.843	7.855	17.583	6.831	4.521
80	0.222	5.848	22.432	6.907	5.364
90	0.048	2.612	21.742	8.049	5.974
100	0.023	0.733	19.555	9.528	6.681
110	0.008	0.193	8.283	10.857	7.622
120		0.067	1.497	10.630	8.751
130		0.018	0.251	9.182	9.458
140		0.009	0.112	7.295	9.582
150		0.006	0.067	4.956	9.446
160			0.043	2.629	8.458
170			0.029	1.230	6.980
180			0.022	0.466	5.033
190			0.006	0.156	3.154
200				0.047	1.690
210				0.014	0.870
220					0.388
230					0.175
240					0.071
250					0.038
260					0.014
270					0.011
280					0.006
290					0.005
300					0.005
Sum	**100.00**	**100.00**	**100.03**	**100.03**	**100.05**
Proportion	**0.334**	**0.105**	**0.093**	**0.412**	**0.056**

2.1.1.2 NZTA BM (HN-HO-72) Lids

Lids that are proposed to replace the existing traditional Extra Heavy Duty Lids. They are designed as bridge components to NZTA Bridge Manual (NZTA 2013) HN-HO-72 loading and load factors. They are recommended in applications where owners such as NZTA specifically request bridge loading and design for manhole lids. Loading and load factors for NZTA Bridge Manual lids are as follows:

Live Load = 120 KN Axle and 240 KN Axle (NZTA Bridge Manual Load Components)
Impact Factor = 1.3
1A -Ultimate Strength Load Factors: Live Load = 2.25 (HN)
Dead Load = 1.35
1A- Serviceability Limit State Load Factors: Live Load = 1.35
Dead Load = 1.0
Load case 1A is critical and fatigue normally governs.

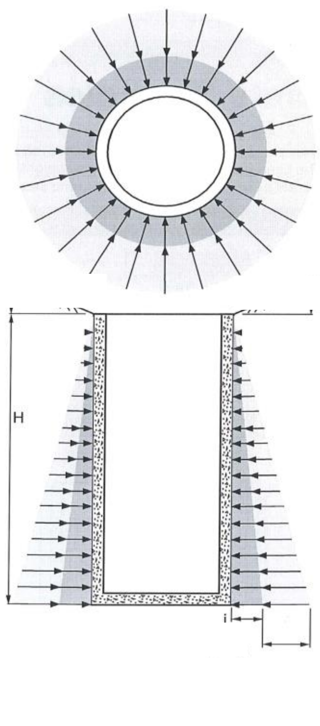
2.1.2 MANHOLE RISERS

2.1.1.2 Lateral earth pressure

Because manhole risers are manufactured in standard diameters with the minimum wall thickness it is generally expected that the design vertical depth will be limited. The most severe loading condition on a riser section occurs when the ground water elevation is at the same level as the surface of the ground.

The forces acting on the riser section are illustrated in Figure 2. The total active force consists of two components; active lateral earth pressure and hydrostatic pressure. Both components of the load act in a radial direction and are distributed uniformly around the manhole risers. Radial forces acting on a circular cross-section result in only compressive forces on the section. Based on the radial load distribution, the lateral earth pressure and hydrostatic pressure at any depth could be calculated by the following equation:

Figure 2: Lateral Earth and Hydrostatic Pressure on Manholes



$p = \gamma sHKa + \gamma wH$ (1)

where:

p = total earth and hydrostatic pressure, kPa

γs = effective unit weight of backfill material, kN/m^3 = (for saturated soil) unit weight of soil – unit weight of water

H = depth of manhole, m

$Ka = (1 - \sin\phi)/(1 + \sin\phi) = 1/3$ for $\phi = 30$

γw = unit weight of water, = 9.8 KN/m^3

The compressive stress in any portion of the manhole section is found by using the following equation:

$f_c = pD/2t$ (2)

Where:

t= Manhole wall thickness, mm

D= Manhole diameter, mm

f_c = compressive stress in manhole wall, kPa

Substituting p in the above equation by the value from equation (1), the maximum allowable manhole depth could be found for any manhole of known diameter and wall thickness. Calculations using various manhole diameters and wall thickness commonly used in New Zealand indicates that the maximum allowable depth for a buried precast manhole riser is, for all practical purposes, unlimited.

2.1.1.2 Lateral earth pressure (Live Loads)

Manholes in roads are subjected to lateral pressure on one side of the manhole. These lateral loads will subject manhole risers to bending moment and shear stresses that should be considered in riser design.

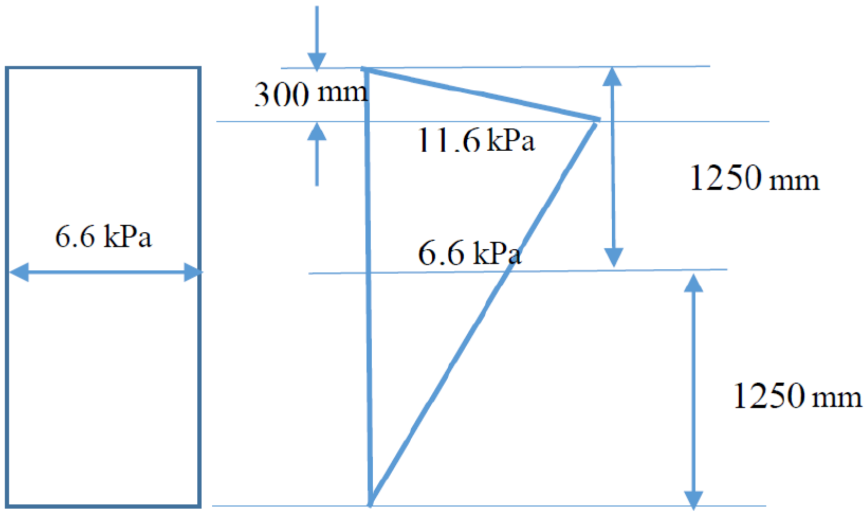
Calculating localised wheel load or other point load effect acting on a retaining structure using the principles of theory of elasticity is usually based on Boussinesq equations as applied to the specific soil properties and loading conditions. However, due to the complicity of calculations, many specifiers have proposed simple conservative approaches by converting the live load to an equivalent surcharge load on the side of the structure (NZTA 2013, AASHTO 2012). The CPAA-GN has adopted another simplified approach used by the American Society of Testing Materials (ASTM) to calculate lateral surcharge pressure on utility structures in roads (ASTM 2014). This approach calculate the lateral surcharge pressure as follows:

P (Pound/Square feet) = 0.005 X Wheel Load (Pounds)

Where P =Uniform lateral pressure on the side of the structure acting from 0 to 2.5m depth (Figure 3-a)

The above approach has been used to calculate the required nominal strength of manhole risers installed in New Zealand roads and motorways where normal design traffic may run on one side of various sizes of circular manholes. The following analysis has further modified the ASTM approach to cover manholes less than 2500mm deep. The modification uses the principles of theory of elasticity to predict more realistic pressure distribution acting on shallow manhole risers of 300mm height (Figure 3-b).

Figure 3: Lateral Live Load Surcharge Pressure on Manholes



a) ASTM C 875 b) Theory of Elasticity

a) Live Load Surcharge Pressures

Clause 4.2.1 ASTM = 0.5% of the wheel load (in imperial units)
For HO = 120 KN = 27400 lbs
Hence Surcharge Pressure = 0.005*27400 = 137 lbs/ft^2 =6.6 kPa

b) Vertical Distribution of Live Load Surcharge Pressure.

- Assuming Boussinesq spread of load – Maximum pressure at approximate 300mm down from pavement.
- ASTM states that surcharge pressure is insignificant at depth of 2.5m = 0
- ASTM assumes that calculated pressure applied to all 2.5m length, for moment calculation pressure value acts at mid depth = 1250mm
- Draw pressure distribution to achieve the above assumptions;

c) Design pressure for critical 300mm top risers

- Assume the riser is not supported by the top lid or the joint with the bottom riser and earth pressure is acting only on the critical side of riser.
- Assume the depth of the top lid and cover = 300mm
- Pressure on the riser is approximately equal to the maximum pressure = 11.6 kN/m^2.
- Live Load effect on riser = 11.6 X OD kN/m
- Bedding Factor LL = 1.5
- The Test Loads for each manhole size to resist HO loading are as per the Table 2

Table 2: Proof Test Load Demand for Risers

	DN 600	DN 1050	DN 1200	DN 1350	DN 1500	DN 1650	DN 1800	DN 1950	DN 2300	DN 2550	DN 3000
CLASS 2 (AS/NZS 4058)	26	42	46	50	54	58	62	66	76	82	94
CLASS 4 (AS/NZS 4058)	52	84	92	100	108	116	124	132	152	164	NA
Nominal Class (Risers)	20	20	20	20	18	25	25	25	40	50	50
OD	700	1200	1360	1525	1675	1845	2010	2150	2570	2880	3410
WL	7.84	13.44	15.23	17.08	18.76	20.66	22.51	24.08	28.78	32.26	38.19
Test Load	5.23	8.96	10.15	11.39	12.51	13.78	15.01	16.05	19.19	21.50	25.46

The American Association Of State Highway Officials (AASHTO 2012) and NZTA Bridge Manual SP/M/022 (NZTA 2013) specify another approach to calculate the effect of live load on buried retaining structures. This approach involves replacing the live load with a specific amount of surcharge load acting on the side of the structure. NZTA BM specifies 12 kPa for HN loading and 24 kPa for HO traffic.

Calculating the test load due to the proposed HO loading on various size manhole risers using same concept as that presented in 2.1.1.2 C above indicates that the calculated loads will be within the proposed nominal class limits proposed in Table 3. A sample of test load calculation is shown in the Table 2:

Table 3: Risers Strength Based on Equivalent Surcharge Approach

Riser Proof Load Demand Based on Equivalent Soil Surcharge Approach

		inputs		Typical live load surcharge loads		
		outputs		HN	12 kN/m^2 equiv to 0.6 m @ 20 kN/m^3	
				1.35HN	16.2 kN/m^2 equiv to 0.81 m @ 20 kN/m^3	
				HO	24 kN/m^2 equiv to 1.2 m @ 20 kN/m^3	
				60 tonne wheel	120 kN/m^2 equiv to 6.0 m @ 20 k	(24 x 60/12 = 12

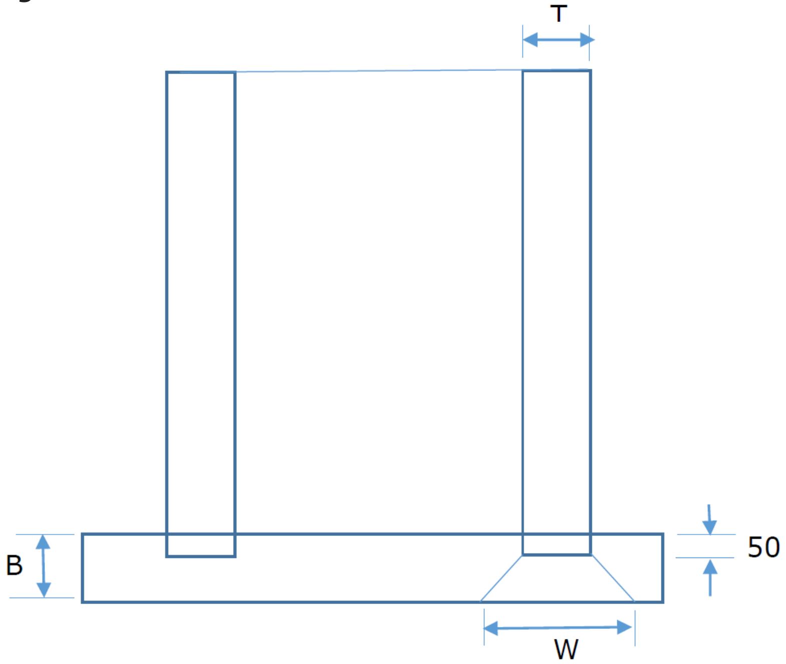
Riser DN mm	600	1050	1200	1350	1500	1650	1800	1950	2300	2550	3000
CLASS 2 AS/NZS 4058	26	42	46	50	54	58	62	66	76	82	94
CLASS 4 AS/NZS 4058	52	84	92	100	108	116	124	132	152	164	NA
Nominal Class (Risers)	20	20	20	20	18	25	25	25	40	50	50
OD	700	1200	1360	1525	1675	1845	2010	2150	2570	2880	3410
Riser loads											
Live load surcharge from			1.2	m	of earth surcharge (from table)						
Fill density			20	kN/m^3							
Ko			0.5								
BF			1.5	LL	2.0	DL					
Tc surcharge	5.6	9.6	10.88	12.2	13.4	14.76	16.08	17.2	20.56	23.04	27.28
Non uniform backfill at depth of			0	m							
Max EP			0								
Min EP			0.00								
Tc earth loads	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL LOAD DEMAND (kN/m)											
	5.6	9.6	10.9	12.2	13.4	14.8	16.1	17.2	20.6	23.0	27.3

2.1.3 MANHOLE BASES

Manhole bases are designed for both foundation stability and structural stability. The manhole base functions as a beam on elastic foundation, therefore, depending on relative soil/base stiffness they work between a continuum of assumptions as 100% rigid to 100% flexible. With 100% flexible base load will transfer directly to the soil through part of the base of width = W as illustrated in Figure 3, and length = the periphery of the manhole at the center of the wall. For rigid base assumption the weight of the manhole and the superimposed load is uniformly distributed on the area of the base. In actual applications manhole bases are neither 100% rigid nor 100% flexible, however minimum values of local allowable bearing capacity of 100 kPa for manholes up to 5m deep and 150kPa for manholes up to 10m deep were specified by CPAA –GN to allow a stiff foundation and flexible base condition to control.

An example of calculation of bearing pressure under manhole wall for a standard 1800mm ND manhole at various depths are as follows:

Figure 3: Illustration of Manhole Foundation Details



a) Foundation Stability of 1m Deep 1800mm ND Manhole:

Weight of Riser = 13.4 kN/m

Weight of 250mm thick Lid = 20 kN

Weight of 160mm Base = 13 kN including all base as conservative option

For 1800 manhole two 60 KN wheels at 1200mm c/c may run on top of the lid; However only 140% of the two wheels contact area shall act on the lid top.

Live Load on Manhole = Proportion of Load on Lid = 1.4 X 60 = 84 kN

Hence Total Load = 13.4 + 20 + 13 + 84 = 130.4 kN

Support Bearing under Wall @ width = W = T + 2 (B-50) = 309mm

Hence, Bearing Pressure = 130.4 / 0.309 * π * 1.917 = 70.1 kN/m^2 < 100 kN/m^2 recommended as minimum allowable bearing capacity.

b) Foundation Stability of 5m Deep 1800mm ND Manhole Base:

Total Load = 5 X 13.4 + 20 + 13 + 84 = 184 kN

Bearing Pressure = 184/ 0.309 * π * 1.917 = 99 kN/m^2 100 kN/m^2 recommended as minimum allowable bearing capacity.

c) Foundation Stability of Manholes up to 10m Deep:

Total Dead Load + Superimposed Load = 184 + 5X13.4 = 251 kN

Bearing Pressure = 251 /0.309 * π * 1.917 = 135 kN/m^2 < 150 kN/m2 recommended as minimum allowable bearing capacity.

2.1.4 MANHOLE FLOTATION

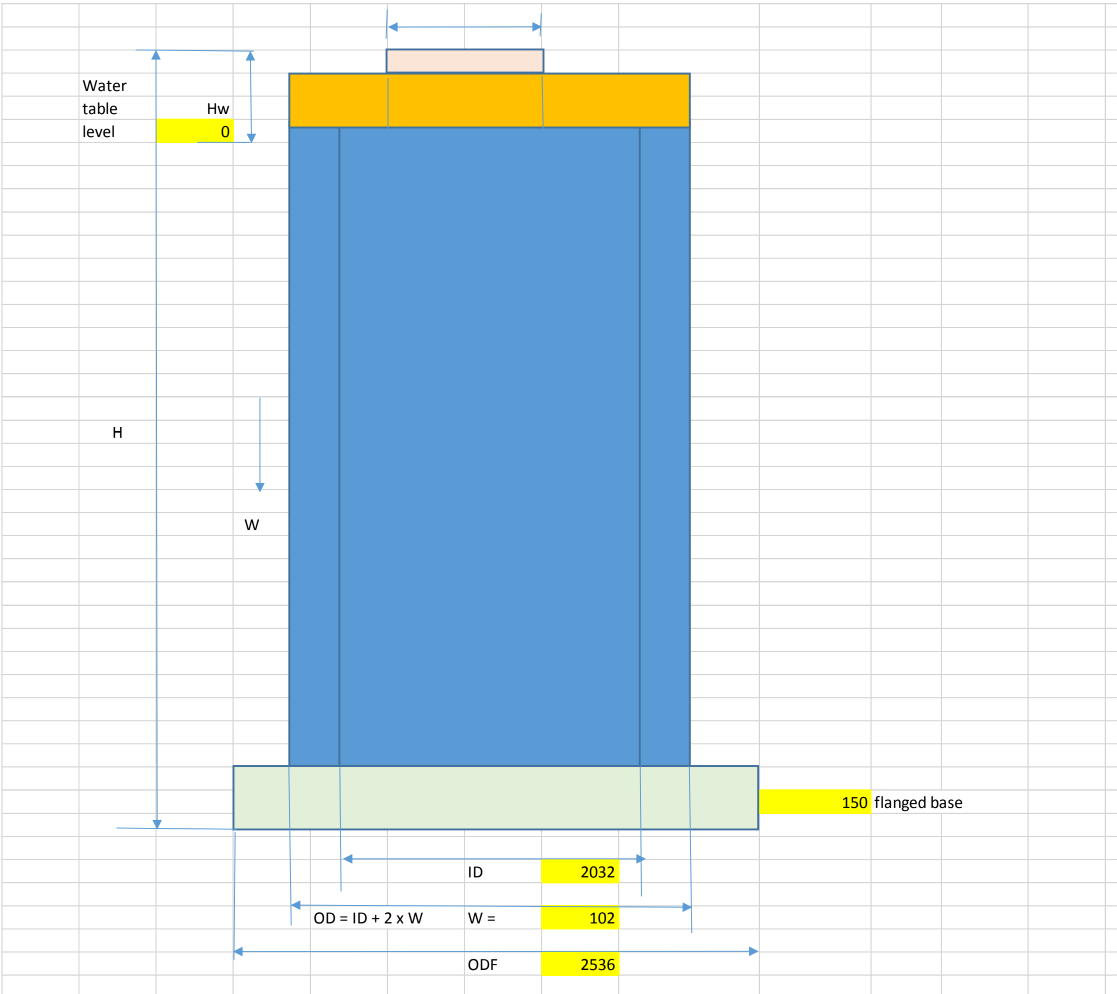
The buoyant force acting on a submerged object is equal to the weight of fluid which that object displaces. In the case of a buried structure or manhole, this concept is applicable when a high ground water table or other subaqueous condition exists. As with the design of buried pipe, flotation should be checked when conditions such as the use of flooding to consolidate backfill, flood planes or future drainage changes are anticipated.

New Zealand manufacturers and designers use a flanged base to provide additional resistance to buoyant forces. These structures are constructed with a lip extending beyond the outer edges of the manhole and are termed flanged base manhole installations. A flanged base manhole uses the additional weight of soil above the lip as well as its self-weight and frictional forces to resist flotation.
Design methods, using basic soil mechanics principles to determine if a manhole is susceptible to flotation are available from various sources (ACPA 2008) where soil friction forces are included and a minimum factor of safety = 2 is specified, however the general practice in New Zealand is to neglect all frictional forces and use a low factor of safety, typically 1.2 or 1.25 (CCC 2015, NZS 2010) which simplifies calculations.

Since buoyancy calculations are specific to site conditions, installation, and expected life history of each individual manhole, manhole manufactures in New Zealand have elected not to specify any design method or flotation resistance values for precast concrete manholes. However, they advise that buoyancy should be assessed by project designers as part of the total drainage design to assure the safety of the proposed installation. Manhole dimensions are available in manufacturer's literature for engineers to use in the buoyancy calculations.

Results of flotation calculations for two common manhole sizes shown in Figure 4 indicates that in some cases the use of simplified calculations may show that manholes as shallow as 1200mm are vulnerable to flotation. However, detailed calculations that include both friction and an assumed sloped failure plane from the flanged base will generally indicate that manholes are unlikely to float in normal service conditions.

Figure 4: Example of Manhole Flotation Calculation Output



RISER				BASE			LID		FRAME AND COVER	WATER TABLE	O/A HEIGHT	SAFETY FACTORS
DN	ID	WALL	HEIGHT R	T3	FLANGE	ODF	T2	OPENING	WEIGHT (kN) (CLASS D)	(Hw)	H (R+T2+T3)	
1050	1067	64	4500	150	150	1495	150	600	0.78	0	4800	1.25
	1067	64	5700	200			200			0	6100	1.25
1800	1828	89	900	150	150	2306	150	600	0.78	0	1200	1.27
	1772	117	2100	250			250			0	2600	1.25

2.2 DURABILITY DESIGN OF MANHOLE COMPONENTS

2.2.1 MANHOLE RISERS

Manhole risers are produced in New Zealand using the same technology and durability performance limitations specified in AS/NZS 4058:2007 for 100 years life for concrete pipes. Manhole risers are machine made of high quality concrete typically using water/binder ratio <0.4 and binder content > 330 kg/m^3 . To Achieve AS/NZS 4058:2007 durability assurance requirements, manhole risers are regularly tested to ensure that the concrete water absorption is less than 6% when tested in accordance with Appendix F of AS/NZS 4058:2007. It is well proven that concrete with water absorption less than 6% will have more than 100 year service life in "Normal" environments (CPAA 2011).

Manhole risers are generally produced with minimum cover to reinforcement of not less than 20mm therefore they are suitable to achieve 100 years life in both "Normal" and "Marine" environments as defined in table 3.1 of AS/NZS 4058:2007. Special durability design may be required when manhole risers are intended to be installed in an aggressive environment where contaminant levels exceed the limits specified in Appendix E of AS/NZS 4058:2007 as shown in Table 4 below (CPAA 2013).

Table 4: AS/NZS 4058:2007 Table E1

Concentration limits applicable to pipe with normal cover to reinforcement
From AS/NZS 4058, Appendix E

Constituent	Soil classification (see Note 1)		
	Clay/stagnant	Medium	Sandy/flowing
Chloride (p.p.m Cl–) max.*			
Unreinforced concrete	No limit	No limit	No limit
Reinforced concrete (see Note 2)	20,000	20,000	20,000
Sulfate (p.p.m SO_4–) max.			
Type GP – general purpose type Portland cement	1 000	1 000	1 000
Type SR – sulfate resisting type Portland cement or equivalent	10,000	10,000	10,000
Acidity			
Acid (pH) (min.)*	4.5	5.0	5.5
Exchangeable soil acid (mL of 0.1 M NaOH consumed by 100 g air-dried soil, max.)	70	50	30
Aggressive CO_2 (p.p.m) max.*	150	50	15

* In groundwater or of soil extract (2:1 water to soil by mass)

NOTES:

1. The groupings used correspond to the classification adopted by AS 1726 as follows:
   (a) Clay/stagnant – Practically impervious (that is impervious soils, for example, homogeneous clays).
   (b) Medium – Poor drainage (for example, fine sands, organic and inorganic silt, mixtures of silt, sand and clay, glacial till, stratified clay).
   (c) Sandy/flowing – Good drainage (for example, clean gravel, sands, mixtures of sand and gravel).
2. Continuously submerged in sea or groundwater. The limit of 20,000 p.p.m. corresponds to the concentration of chloride in sea water. Fluctuating saline groundwater conditions to be treated as separate individual cases often requiring additional protection.

2.2.1 MANHOLE LIDS AND BASES

Lids and bases are precast reinforced elements structurally designed to the requirements of NZS 3101:Part 1:2006. To achieve the target 100 year service life set by many New Zealand TAs conservative exposure conditions that cover all scenarios of "Normal" service environments have been selected from Table 3.1 of the standard (NZS 3101) as follows:

- Base outside face: Surface of member in contact with fresh (not soft) water = B1
- Base inside face: Surface of member in running fresh (not soft) water = B2

- Lid inside face : Surface of member in contact with fresh (not soft) water = B1
- Lid outside face : Surface of member in running fresh (not soft) water = B2

Minimum cover for reinforcement is then selected for each specific elements as per Table 3.7 of the standard which specifies minimum cover requirements and concrete strength for reinforced concrete elements to achieve the intended service life of 100 years.

Manhole lids and bases in an aggressive environment, other than that stated above, or as discussed below (2.2.1), should be specifically designed or protected as required by project designers.

2.2.1 DURABILITY DESIGN FOR WASTEWATER SULPHIDE ENVIRONMENT

Wastewater manholes are generally built with a small mean hydraulic depth (cross sectional area of the stream divided by surface area) which will increase the available area for reaeration and reduce the rate of biogenic sulfide corrosion in manholes (EPA 1985). The only exceptions to this fact are pumpstations wetwells and storage tanks, transmission line manholes and discharge manholes of wastewater pumping mains where special design solutions must be considered.

Standard manholes of wastewater collection net-works are usually subjected to a “Normal” environment where sulphide concentration in wastewater is relatively low. Calculations of the predicted corrosion of a 1050mm manhole, assuming minimum practical surface area and maximum stream surface area, indicates that when Average Annual Sulphide Concentration = 0.2 Mg/L, standard manholes with 20mm minimum cover are expected to have a minimum predicted service life of 150 years as per the design spreadsheet illustrated in Table 5.

2.3 WATERTIGHTNESS DESIGN OF MANHOLE COMPONENTS

Most specifications require manholes to be watertight to both infiltration and exfiltration so that ground water will not be contaminated by the transmitted water and the network will not be overloaded by infiltration of ground water.

As manholes are made of segmental precast sections extra care has been taken in designing joints to achieve the required watertightness level when properly installed. Figure 5 illustrates the three types of joints adopted in New Zealand where water tightness can be achieved for the installed manholes as follows:

a) For joint types 1 and 2 a “Preformed Flexible Joint Sealant” properly located and installed in the joint has been proven by low head watertightness observation in the factory to be watertight for up to 5m water head.

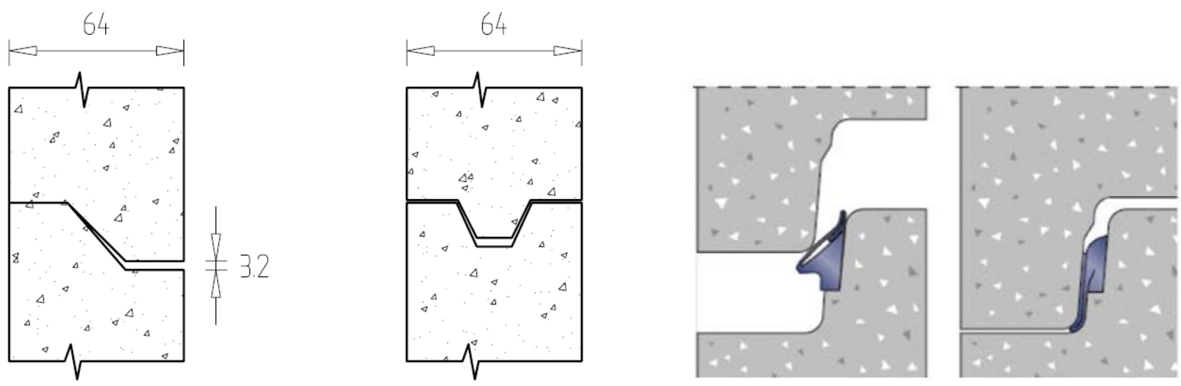
Table 5: Prediction of Service Life of Standard Manhole Components

PREDICTION OF LIFETIME OF CONCRETE SEWERS

INPUT DATA	
Pipe Diameter, mm	1050
Steam Velocity, m/s	0.5
Depth of stream in pipe %	50
Energy Gradient of stream, m/m	0.01
pH of wastewater (select value)	7.5
Average annual dissolved sulphide in wastewater [DS]*,mg/L	0.2
Efficiency coefficient for acid reaction, 0.3 - 1.0	0.8
PIPE DESIGN SELECTION	
Select Degree of Resistance**	2
Select Type of Concrete***	1
Predicted Lifetime of Sewer, Years	**150.23**

* [DS] to be measured, or for design use estimate proposed by ACPA manual = 0.2mg/l
or estimate using predicted sulphide build-up values from below as a gide
**Values 1 - 5 for concrete cover to reinforcement of 10 - 50mm
*** 1 For Normal Silica Aggregate concrete
2 For Calcareous All Aggregate concrete
3 For Calcareous Course Aggregates concrete

Figure 5: Typical Manhole Joints



Type 1 Type 2 Type 3

b) A combination of preformed flexible sealant and grouting the joints with non-shrink grout such as epoxy mortar for Type 1 and 2 joints will further ensure watertightness of the joints for cases of high water head or sensitive environment.

c) Bonding the two parts of the joint with a properly installed high quality non-shrink grout for joints Type 1 and Type 2 also yields a high performance watertight joint.

d) Type 3 joints are water proofed by an "Elastomeric Rubber Ring Seal" which are designed to allow for both joint flexibility and watertightness for up to 5m water head.

2.4 OPENING IN MANHOLE WALLS

In conventional installations, only a small fraction of the strength of a manhole section is required to resist lateral and vertical forces. Therefore the effect of pipe entries on strength capacity and stability of the manhole structure is considered negligible if constructed within the limitations specified in the CPAA Guidance Note (CPAA 2016). The conventional practice in New Zealand of benching manhole bases with mass concrete to improve the hydraulics of the junctions adds further stability to the penetrated manhole walls.

2.5 OTHER SERVICE CONDITIONS

All manhole components are designed for "Normal" service conditions, any service conditions that are generally considered "Specific" including, but not limited to, internal water head and surge, water hammer, industrial waste conveyance, unstable ground conditions, side slopes, geothermal exposure, aggressive ground water exposure, and liquefaction shall be specifically evaluated and designed by project engineers on a site specific basis.

3 CONCLUSIONS AND RECOMMENDATIONS

Standard precast concrete manholes are designed and manufactured in New Zealand for safe and durable service for the design period of most infrastructure projects, typically 100 years' service life. However it is essential for project designers and asset owners to realize that standard products are designed for "Normal" applications which may not match site specific service conditions.

The paper covers design parameters of standard reinforced concrete manholes, provides reference standards and a theoretical basis of manhole component design. Table 6 summarizes the design parameters of various manhole components and manhole structures.

It is recommended that project designers and asset owners take note of the standard design limitations and ensure that standard manholes will be suitable to meet the service conditions for the project. If this is not the case the design should specify special manhole components or modifications to the standard design to meet any special site specific requirements.

Table 6: Summery of Standard Manholes Design Parameters

Manhole Component	Component type	Design Component	Specification and/or method	Value or limitation	Applications
Lids	LD 20	Live Load	CPAA , 1170,3101	20 KN Wheel	Light Traffic
	HD 60		CPAA , 1170,3101	60 kN Wheel	Road all types
	NZTA BM		CPAA, NZTA BM	HN-HO-72	Bridges, Motorways, Specific Installations
Lids	All Types	Durability	3101	B1 inside, B2 outside	Normal Environment
Risers	All Sizes	Lateral Pressure	Principles of soil mechanic, 3101	Unlimited Depth	All Applications
	All Sizes designed to Nominal Load Capacity	Live Load Lateral Pressure	CPAA, ASTM 875	HO Load Components	All Roads
Risers	All Sizes	Durability	AS/NZS 4058	100 years Marine Environment	Marine Environment, Table E AS/NZS 4058:2007
Bases	Flanged Base	Foundation Stability	Principles of soil mechanic, 3101	100 kPa Bearing Capacity	Up to 5m deep
				150 kPa Bearing Capacity	Up to 10m deep
Bases	Flanged Base	Strength	3101	As designed	Up to 10m deep
Bases	Flanged Base	Durability	3101	B2 inside, B1 outside	Normal Environment
Manhole	As installed	Flotation	NZS 4404, ACPA DD 41	Not Appliciable	Site Specific
Manholes	All Components	Sulphide Environment	EPA	Average annual = 0.2 mg/L max.	Wastewater Networks
Manholes	Joints - Flush	Watertightness	Controled Installations as per 2.3 a,b, c	5 m Head, possibly more depending on workmanship	All applications
	Joints - Rubber Ring	Watertightness	EN 1917:2006	5m Head with rubber ring	All applications
Manholes	Risers	Openings	CPAA	As specified	All applications
Manholes	All Components	Service Conditions	N/A	Normal	All applications

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