Structural Testing and Remaining Service Life of Sewer Access Chamber Frame/Covers

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Abstract

Water Corporation's wastewater network contains approximately 200,000 sewer access chambers. Located where maintenance is likely to be required, each access chamber is sealed by an access chamber cover at ground level. These covers vary in age and design. The most common type of access chamber cover is a two-part reinforced concrete type, consisting of two rectangular reinforced concrete slabs supported in a frame. Focusing on this type of cover on the smaller diameter reticulation sewers (i.e. <300mm), a remaining service life model is to be built. Along with this, a remaining load capacity model to relate the observable defects in a given cover to an expected capacity is to also be established. These models will be developed using a sample set of 90 covers. The in-situ conditions are to be logged, physical condition assessed, and ultimate load capacity determined. Initial testing has found most older covers to be generally very sound, even with some major defects such as spalling. Inconsistency in the physical condition of covers is also prominent with respect to age. This project seeks to improve renewal planning information and understanding of remaining service life of reinforced concrete sewer access chamber covers.

1. Introduction

The Water Corporation is directly involved in managing a wastewater network of over 17,500 kilometres in length. Primarily along gravity flow portions of this network, sewer access chambers are situated to allow for maintenance. Such areas include T-junctions, changes in grade, changes in direction and changes in pipe diameter. There are approximately 200,000 access chambers situated on the network with approximately 156,000 situated within the Perth metropolitan area.

Sewer access chambers are an underground structure used to access sewer pipelines for maintenance purposes. An example is shown in Figure 1. Access chambers are typically constructed from reinforced concrete, brick or a combination thereof. Many access chambers are plastic lined to protect against the corrosive sewer environment. Access chambers are sealed with a cover to prevent unauthorised or accidental access. A failure of this component could result in a fall from heights and exposure to noxious gases both of which can pose a threat to public safety.

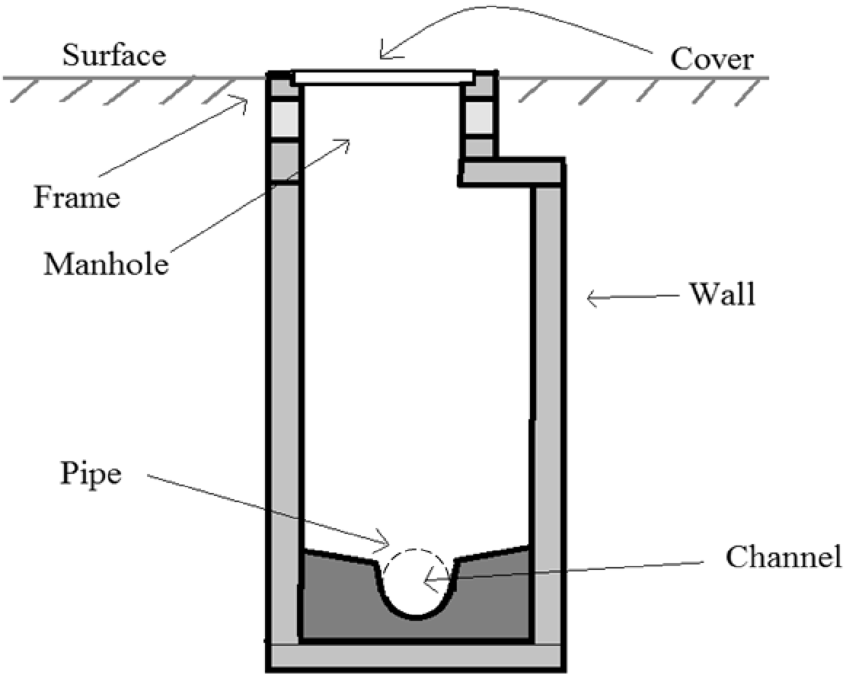

Figure 1 An example of a simple sewer access chamber.

Water Corporation's replacement of access chamber covers can be either an age or condition-based renewal. However, little, detailed water-industry information exists on the remaining service life or structural condition of a given access chamber manhole based on the in-situ conditions.

The primary objective is to develop a remaining service life model, a remaining structural capacity estimation model based on damage inspection and to identify key areas of interest that have a strength profile that suggests closer inspection or replacement may be required. The scope of this project is limited to access chambers with rectangular two-part reinforced concrete covers on reticulation sewers, the most common type.

1.1 Background

One very common type of access chamber cover is the rectangular two-part reinforced concrete variety as shown in Figure 2. These covers are essentially two reinforced concrete slabs supported in both directions as a two-way slab. This type of cover has been used for many decades with records indicating some may be over 90 years old. They are most commonly found, although not exclusively, on reticulation sewers. This type of cover was originally specified for shallow, non-trafficable access chambers (M.W.S.S & D.D 1948). Although over time, these covers can be found on access chambers of any depth.

This type of cover has been one of the more constant designs over the years. It has followed the same general design principles its entire existence, with the size and shape as well the two keyholes remaining largely constant. While visually, the cover has remained largely unchanged, the steel reinforcement configuration has changed to various degrees an unclear number of times.

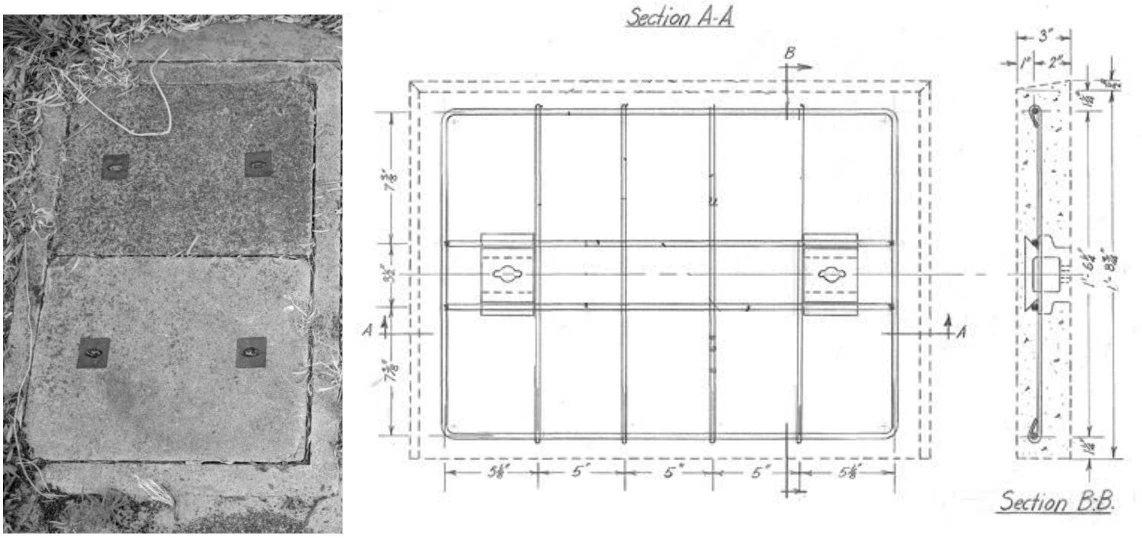

Figure 2 **A rectangular two-part reinforce concrete cover shown with an example of a typical reinforcement configuration (M.W.S.S & D.D 1948).**

The load capacity of a reinforced concrete cover can be degraded by both physical and chemical processes. The production and build-up of hydrogen sulphide gas (H_2S) and subsequent formation of sulphuric acid (H_2SO_4) is one such issue. The acid formed can be highly concentrated with concentrations typically greater than 10% (Gourley & Johnson 2017). Sulphuric acid is highly corrosive to most concretes. However, in small reticulation sewers, H_2S concentrations are expected to be relatively low in most cases. It is suggested that H_2S concentrations in excess of 2 ppm are required for sulphide oxidation to occur (O’Dea 2007).

Concrete generally provides a high degree of corrosion protection to steel reinforcement due to the presence of calcium hydroxide, providing high alkalinity. Carbonation is the process of carbon dioxide (CO_2) from the air dissolving with moisture in concrete pores. The CO_2 reacts with the calcium hydroxide present in most concretes to form calcium carbonate (Department of Transport and Main Roads 2016). This has the effect of increasing concrete compressive strength but reducing the alkalinity, thus increasing the electrochemical corrosion rate of the reinforcement (Department of Transport and Main Roads 2016). Further to this, well consolidated concrete with a low water-cement ratio has lower permeability, reducing the penetration of corrosive agents such as chloride, carbon dioxide and moisture (Ahmad 2002). High concrete electrical resistivity also reduces the electrochemical corrosion rate (Ahmad 2002). Corrosion of steel reinforcement causes issues not only due to loss of cross-sectional area, but also due to the corrosion products being two to four times larger than that of the steel (Ahmad 2002). This volume expansion causes tensile stresses in the concrete, resulting in cracking and spalling of the concrete cover over the reinforcement. Physical damage such as cracking or spalling from shrinkage, impacts, vibration and thermal expansion may also reduce the load capacity or expose steel reinforcement to the atmosphere, potentially increasing the reinforcement corrosion rate.

2. Process

A distinct lack of historic failure data, or a consensus on what constitutes a “failure”, present significant issues. To develop the various models, a sample set of covers must be analysed. In this case, two-part reinforced concrete covers are to be selected randomly from reticulation sewers and supplied by the Water Corporation for structural testing. This process involves selecting 10 to 15 covers from 10-year age intervals to reduce the significant bias to certain time periods where more access chambers were installed. Some attrition due to inaccessible manholes is expected to reduce the total to a maximum of 100 access chambers.

2.1 Inspection

The sampling of reinforced concrete covers involves replacing the sampled access chamber's covers with new covers. To allow for a more varied sample set, one of the two covers shall be removed for structural testing from each access chamber sampled. Both covers are taken if both are seen to be in poor condition. Due to practical limitations, the selected manholes must be readily accessible thus excluding buried manholes, those requiring traffic control to access or those located on private property. The general condition of these covers is assessed and recorded.

2.2 Load Testing

For simplicity, load testing is to be performed based upon the guidelines laid out in AS3996: Access Covers and Grates Appendix C (Standards Australia 2006). This calls for the covers to be supported in their frame or as they would be in the frame. Due to test machine size limitations the exact frame cannot be used, and a two-way simple support is simulated.

AS3996 calls for a test block sized according to the clear opening (the minimum distance between supports). As the clear opening is greater than 390 mm the standard calls for a test block of 250 mm diameter. This is placed centrally on the cover. The test block is to be constructed from a rigid distribution plate over plywood. A displacement is applied by the loading frame until the ultimate load is reached. Load and displacement are to be recorded. The Baldwin test machine is used for all load testing.

AS3996 specifies an ultimate limit state design capacity of 80 kN for Class B covers, the category for which two-part reinforced concrete covers belong to, being non-trafficable. Whilst it is important to realise this type of access chamber cover pre-dates this standard, it provides a good reference point.

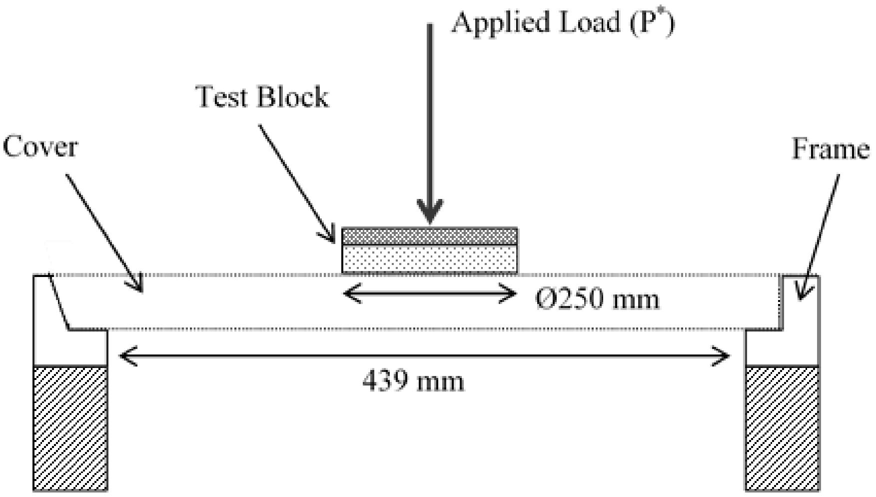

Figure 3 Load test apparatus cross section. The cover is supported as a two-way slab.

3. Results and Discussion

Load testing has been performed on approximately 30% of samples. This data is preliminary internal structural information to be reviewed by Water Corp Engineering/Asset Management Branch. As such, quantitative data and analysis is not discussed.

The overall performance of these covers is highly dependent on the reinforcement configuration. It was found that several minor variations of the general reinforcement configurations specified by Water Corporation plan sets exist. Specifically, increased diameters of the reinforcement bars used. More modern variations such as those found on newly manufactured covers contain additional steel bands around the exterior edges.

The general performance trend with respect to both load-displacement response and ultimate load capacity is relatively consistent within each reinforcement configurations. It has been found that most covers tested were in good condition with some minor wear to the edges. Some forms of observed damage included edge wear, missing corners and minor spalling around the edge rebar. However, the ultimate capacity of these damaged covers is typically found to be within the range of performance seen by negligibly damaged, identically reinforced covers. In some cases, such as those with significant edge spalling, the load – displacement response shows some irregularities compared to undamaged covers. Test observations indicate that whilst one edge was unsupported initially due to the missing concrete, as the cover deformed under load, the remaining rebar became a supported edge as it overlapped the support.

What has become apparent is that age alone is a poor indicator of condition. Other factors such as the quality of the concrete used, and the conditions of the surrounding environment are likely to have a more significant role on the corrosion rate of each cover. Given this and the large number of sewer access chambers in existence, remaining service life modelling will likely require an expansive data set to be reliable.

4. Conclusions and Future Work

Initial structural testing has indicated that older covers are generally performing well, even with some major damage. To perform meaningful analysis on any performance trends that may exist, additional covers are to be assessed. 90 manholes have been inspected and covers taken. Ideally this information can be used to help identify covers that are structurally inadequate based on more objective means than those currently used. Inspection data indicates a significant amount of randomness in the condition of covers. This may impact the ability to develop a meaningful remaining service life model based on variables such as geographical location and age from a relatively small sample set of 90 access chambers.

5. References

Ahmad, S 2003, ‘Reinforcement corrosion in concrete structures, its monitoring and service life prediction – a review’, *Cement & Concrete Composites,* **25** (4) pp. 459-471. Available from: ScienceDirect. [29 January 2018].

Department of Transport and Main Roads 2016, *Structures Inspection Manual Part 2: Deterioration Mechanics,* State of Queensland. Available from:

https://www.tmr.qld.gov.au/-/media/busind/techstdpubs/Bridges-marine-and-other-structures/Structures-Inspection-Manual/SIM-Part-2.pdf?la=en. [29 January 2018].

Gourley, J & Johnson, GB 2017, ‘The Corrosion Resistance of Geopolymer Concrete Sewer Pipe’, *Concrete In Australia*, **43** (1) pp. 38-43.

Metropolitan Water Supply Sewerage and Drainage Department (M.W.S.S & D.D) 1948, *Reinforced Concrete Manhole Cover & Frame for Shallow Manholes*, M.W.S 4376.

O’Dea, V, 2007. ‘Understanding biogenic sulfide corrosion’, *Materials Performance*., **46 (**11) pp. 36–39.

Standards Australia 2006, *Access covers and grates*, AS3996-2006. Available from: Australian Standards. [29 January 2018].