Defect Assessment of Sewer Pipes

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Highlights

- Eight categories of defects were identified in 2817 sewer pipes in Auckland, New Zealand based on recent CCTV inspection reports.
- The correlation between eight defect categories and several physical and environmental factors, including age and groundwater level were investigated.
- Statistically significant relationships were found between defect categories and factors that provide new insights into the drivers of deterioration processes in sewer pipes.

Keywords

Sewers, CCTV inspection, defects, deterioration modelling, asset management.

Introduction

Sewer pipes are affected by various internal and external factors, and therefore need to be maintained and monitored to keep their performance at a desirable level. CCTV is playing an essential role in monitoring, assessing, and condition scoring of sewers. Conventionally, each sewer pipe is assigned a condition score based on the quantity and quality of defects observed through CCTV inspections.
Various deterioration models have been developed in order to study the impact of different factors on the condition score. However, contradictory results regarding the effect of various factors on the condition score of sewers are stated.

All these complexities and conflicting findings raise questions about the adequacy of the condition score as a comprehensive index for the overall condition of sewers. Indeed, despite this approach being widely used, it is limited in what it can describe. While the condition score is based on type, quality, and quantity of various defects inspected through CCTV, it does not describe the detail of observed defects, and this might be a limitation. It may be beneficial to directly study the observed defects instead of the condition score in order to improve understanding of the deterioration processes of sewer pipelines.

The aim of this study was to investigate the effect of various factors, including age, pipe material, diameter, and groundwater level on the prevalence of eight defect categories in the transmission sewer network of Auckland, New Zealand. A dataset with the defects identified through recent CCTV inspections of 2817 sewers was gathered, combined, cleaned and linked to a range of physical and environmental variables. Defects were grouped into the following eight categories, gas attack, material damage, infiltration, roots, debris, total joint, structural, and dipped pipe.

METHODOLOGY

CCTV Dataset

The latest CCTV inspection reports of transmission sewers were used as the basis of this study. The transmission sewer dataset consisted of 4870 pipes with a total length of 246 km, representing about 3% of the entire Auckland sewer network.

The CCTV footages include asset ID's, sewers' physical characteristics, details related to 16 various identified defects, and the evaluated condition score. While detailed descriptions, such as the distance and quantity of each defect were provided in CCTV spreadsheets, defect details and counts were ignored, and merely the prevalence of defect categories in sewers was considered.

For facilitating the analysis, the 16 defects categories provided with the CCTV dataset, were grouped into eight categories by grouping similar defects. Figure 1 provides a summary of the main eight defect categories and their sub-categories. As it can be seen from the figure, material damage and dipped pipe have the highest and lowest percentage of defects in the transmission sewers, respectively.

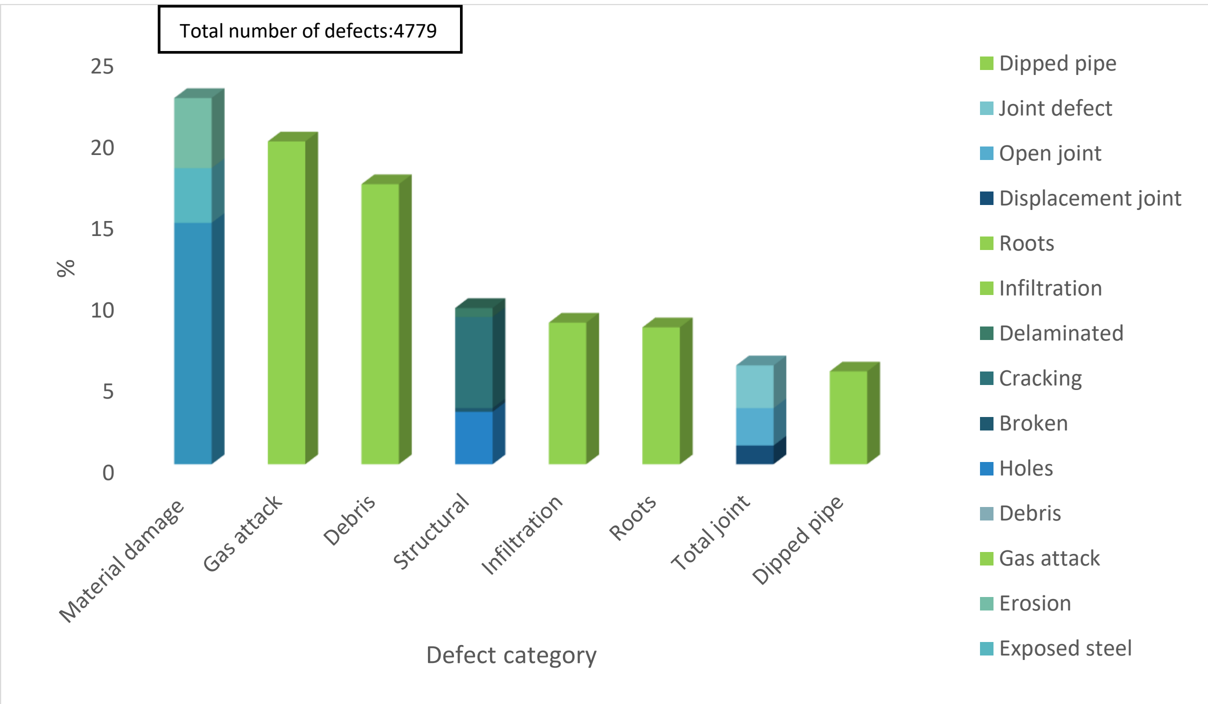

Figure 1. The percentage of defects categories based on the CCTV footage report

Factors

Several factors including pipe age, diameter, depth, slope, length, pipe material, groundwater level, liquefaction susceptibility index, and population density were investigated. The study variables were grouped into three categories; design and construction, operational and environmental (Tizmaghz et al., 2022).

Merging and preparation of dataset

After merging the dataset through the spatial analysis feature in ArcGIS, in order to clean the resources, the following steps were taken to ensure the integrity of dataset. Firstly, pipes with missing information were identified and omitted. Secondly, pipes with linings were omitted in order to avoid the inconsistency that might cause when considering pipe age. Thirdly, pipes with the negative dataset such as negative age and length were omitted. Fourthly, the box plot technique is used to remove outliers, which are those data that are typically larger or smaller than other observed present continuous datasets (Seo, 2006). These steps reduced the number of datasets from 4779 to 2817 pipes.

Results & discussion

In the first step cross-correlation between various factors and defect categories were investigated to evaluate correlation and facilitate the interpretation of results. The strongest positive correlation was found between pipe depth and slope of 0.5 and the second highest positive correlation is between pipe diameter and length of 0.3, indicating that deeper pipes are steeper and larger pipes are longer in the Auckland sewers network, respectively. The results show that there is no strong correlation between defect categories, indicating that the selected categories are more or less independent from each other.

The linear regression was utilized to describe the relationships between factors and each of the defect categories, since there was no indication that other sophisticated methods could better describe the underlying trends. Each factor was split into a convenient number of groups, and fractions of pipes with each defect were calculated for each group and plotted. Data outliers were identified using Tukey's fences method (Thompson, 2000), i.e. any point that lies more than 1.5 times of the interquartile range (Dümbgen & Riedwyl, 2012). Outlier data points were identified and marked on each graph and then excluded from the trend line regression.

The extent of the significance of different defect categories as dependent variables was approximated through p-value at the 5% significance level. A total of 72 linear relationships between defect categories and factors were developed and analysed, leading to a number of insightful findings. Some of the results are presented and discussed as below.

In respect of age, while a significant upward trend was identified between five defect categories, including material damage, gas attack, infiltration, structural, and roots, a significant downward trend between debris defect and age was reported as shown in Figure 2, b. Material damage and Gas attack showed the greatest growth with aging of 0.71 % and 0.62 % per year, respectively. This is followed by infiltration, structural defects, and roots with growth rates of 0.16%, 0.16%, and 0.15 % per year, respectively. The downward trend observed on debris defects by aging of sewers might be due to the increasing flow rate over the years, which might facilitate the debris movement and result in fewer debris defects reports.

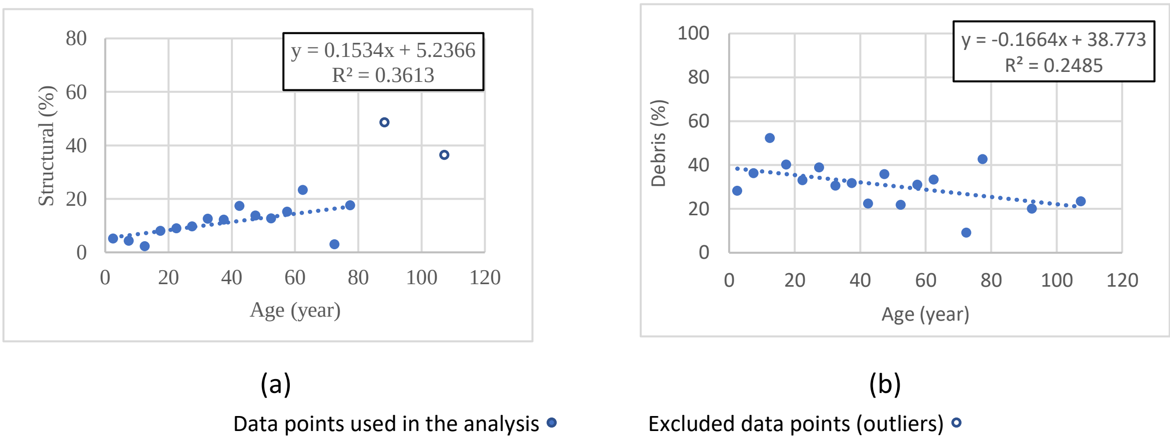

Figure 2. The fraction of pipes with structural and debris defects as a function of age

The slope between length and four defect categories, including gas attack, structural, infiltration, and roots, were significant. Except for roots, all other three slopes were positive and between 0.04% and 0.012 % per meter length, showing an increase in defects by increasing sewer length. Referring to the determined correlation coefficient between length and diameter, it can be interpreted that as the pipe length increases, the pipe diameter rises in the studied dataset. As a result, sewers will be deeper, and the possibility of tree roots reaching the pipe decreases.

Several defect categories including gas attacks, material damage, structural, and dipped pipes are showing a significant decreasing trend with an increasing of the slope of 1.58%, 1.01%, 0.50%, and 0.44% per percent, respectively. This might be due to the reality that flat pipes have lower velocities, and thus wastewater stays longer inside the pipe. Hydrogen sulphide can be converted to sulfuric acid, which is able to attack cementitious pipes, including concrete, and increase the possibility of corrosion inside the sewer pipes and by decreasing the wall thickness of sewer pipes lead to material damage and structural defects and subsequently forming dipped pipes (Ana et al. 2009).

Regarding groundwater, total joint defects show a significant and positive relationship trend of 0.48% per meter groundwater level, confirming that the availability of groundwater levels at or above sewer pipelines has an adverse effect on the sewer condition. However, debris and gas attacks represented a significant and negative trend of 1.26% and 1.11% per meter groundwater level. This indicates that when groundwater level is higher than sewers, the chance of being affected by the gas attack and debris is less. The reason might be due to infiltration of groundwater level into the sewers that might facilitate the debris movement and deter the formation of that by increasing the velocity of sewage. The negative correlation of groundwater level with debris may be explained by higher sewer flow rates caused by infiltration and that of a gas attack by fuller and faster flowing sewers that reduce the possibility of hydrogen sulphide oxidizing to sulfuric acid.

Conclusion

To the best of our knowledge, this is the first study that has quantitatively shown correlations between a large range of defect categories and various physical and environmental factors. Different defect categories were considered as dependent variables including gas attack, material damage, infiltration, roots, debris, total joint, structural, and dipped pipe.

The results are mostly aligned with some studies that have looked at the effect of different variables on condition prediction models of sewers. However, it should be noted that all compared studies considered condition scores as their output variable and reported contradictory results. The approach of this study provides greater insight into the underlying causes of sewer pipe deterioration. This has the potential to improve sewer asset management through a better understanding of the specific factors responsible for sewer pipe deterioration and how to estimate and manage them.

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