Lessons learned from one of New Zealand's most challenging civil engineering projects: rebuilding the earthquake damaged pipes, roads, bridges and retaining walls in the city of Christchurch 2011 - 2016.

Predicting Earthquake Damage to Gravity Pipe Networks

Story: Pipe Damage Assessment Tool (PDAT)

Theme: Design

A Conference Paper about the Pipe Damage Assessment Tool (PDAT).

Programme funded by

PREDICTING EARTHQUAKE DAMAGE TO GRAVITY PIPE NETWORKS

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INTRODUCTION

Christchurch is the largest city in New Zealand's South Island, with a population of about 360,000. It was struck by a series of major earthquakes in 2010 and 2011 which took 185 lives and caused extensive damage to land, property and infrastructure.

As part of the response to the earthquakes an extensive Closed Circuit Television (CCTV) inspection programme was commenced to identify earthquake damage to wastewater and stormwater pipes. The availability of CCTV data became a critical constraint to the rebuild. A desktop method that could predict CCTV outputs would speed up the rebuild process by providing estimates of damage based on CCTV. A Pipe Damage Analysis (PDA) Tool was developed for this purpose and its development and use will be described in this paper.

METHODOLOGY

The PDA Tool predicted what the outcome of CCTV survey would be, if a CCTV survey was undertaken. CCTV survey analyses returned four results, the first three results were used by the PDA Tool:

- Renewal (where a pipe was to be renewed from manhole to manhole),
- Repair (where localised repairs were required),
- No Action (where the pipe was not damaged), and
- Abandoned (where the CCTV survey could not be completed for any reason).

A group of about 20 indicators of earthquake damage was initially proposed. Indicators that were not available in a geospatial format or required significant geoprocessing were not considered further. The remaining indicators were compared to CCTV results and tested for statistical significance. Eight indicators were selected as they showed significant correlation and referred to as "measures". They were:

- Depth,
- Diameter,
- Direction,
- Liquefaction Resistance Index (LRI),
- Pipe Material,
- Proximity to an Open Watercourse,
- Subcatchment, and
- Road Damage Score (RAMM).

Each measure was given a weighting based on its ability to predict the outputs of CCTV survey and these weightings were normalised with a range of 0 to 1. Individual measures generally predicted the outcome of the CCTV correctly for between 50% and 60% of the pipes surveyed.

A set of discrete values was identified for each measure and the probability of every recommended action was calculated for all the pipes with complete CCTV surveys. For example, two of the values for the measure "Material" were "earthenware" and "PVC". The probability of recommending an earthenware pipe for renewal was 76.7% and the probability of recommending a PVC pipe for renewal was 8.7%.

The PDA Tool was applied at a rebuild catchment level, which involved the study of 200 to 2,000 pipes.
A geospatial process was undertaken to identify the value for each measure at every pipe in the rebuild area.

The probabilities for the three possible actions were identified and multiplied by the weighting for the measure; then the values for each action were summed. As the probabilities and the weightings were between 0 and 1, the resulting score for the action was also between 0 and 1 and represented the probability of the action being recommended by CCTV. The action with the highest score was recommended.

Rebuild catchments generally had CCTV results for 5% to 40% of the pipes. Area-specific attributes (e.g. geology) were used to improve the match of predicted recommendation to CCTV-based recommendation in a process akin to calibration of a model. Other considerations such as pipe age and gradient (where a pipe may have lost grade) were incorporated once the data fitting process was complete.

A final recommendation was made for every pipe using the other considerations, CCTV records and PDA predictions. A table of unique Pipe ID, recommended action and the source of the recommendation was produced as the output. This table was thematically mapped in GIS and an example is provided in Figure 1. Summarised data for the outputs of an example catchment are shown in Figure 2.

RESULTS

Outputs of the PDA were used to:

- assist with the scoping and prioritisation of further CCTV work
- assist with the scoping and prioritisation of rebuild works
- provide estimates of turn-out costs for parts of the rebuild works
- provide input data to the budgeting process for the overall rebuild
- estimate areal quantities of damage and provide data for damage mapping
- support designers in the investigation concept and detailed phases of the design process

The PDA Tool has been shown to accurately predict the output of CCTV survey for 75% to 95% of a rebuild catchment's pipe length based on CCTV samples of 5% to 30% of the total length of pipe.

CONCLUSION

The PDA Tool has proven to be an invaluable method for supporting the rebuild of Christchurch City's wastewater and stormwater pipe infrastructure. Cost savings in the order of tens of millions of dollars have been identified through its development and application.

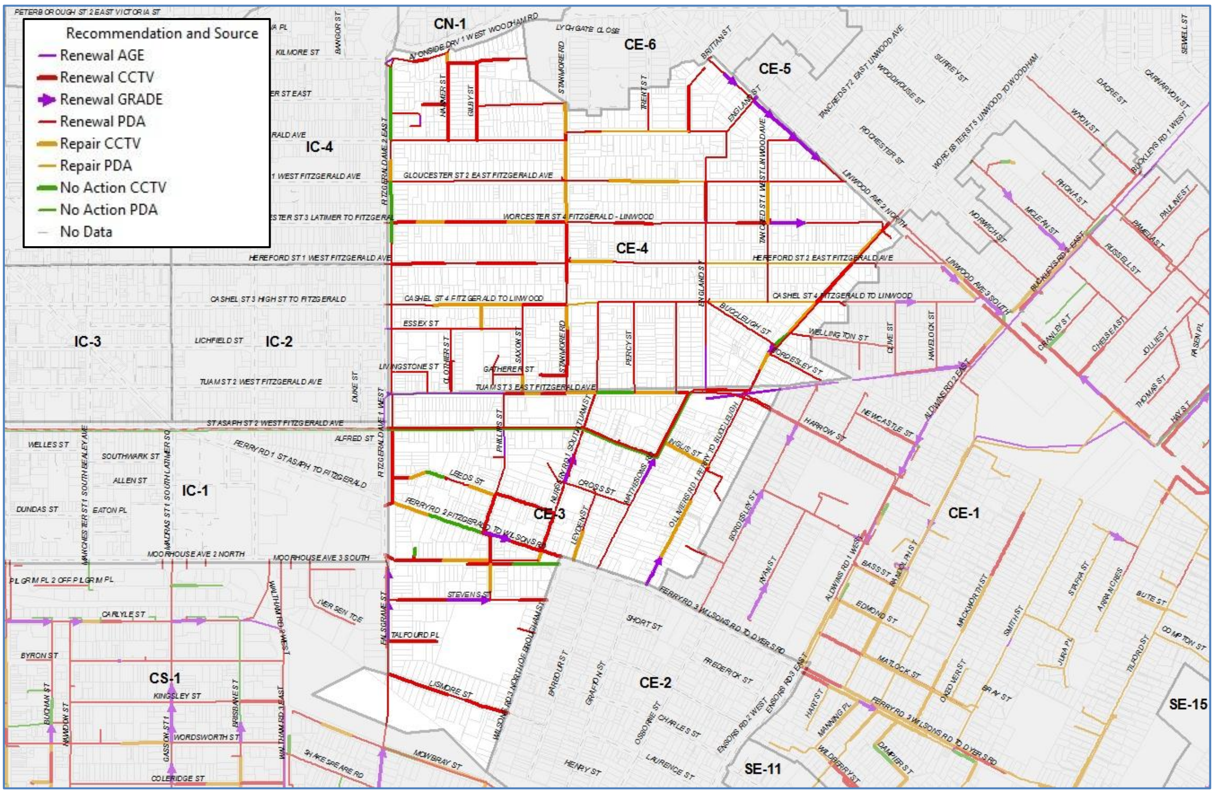

Figure 1: Example of a thematic map of outputs from the PDA Tool.

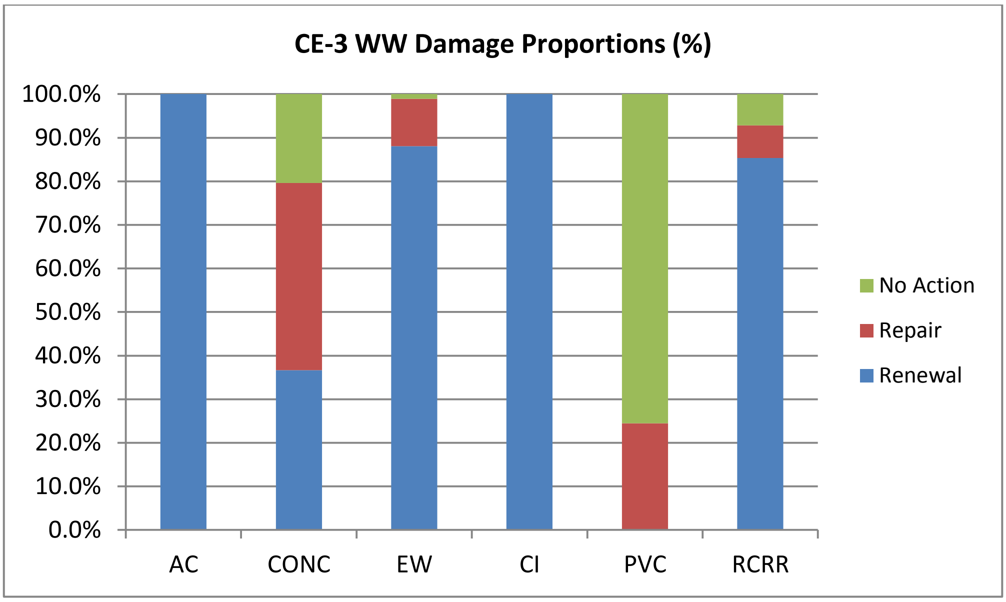

Figure 2: Example of a pipe damage summary graph.