

Advanced Condition Assessment & Pipe Failure Prediction

Optimal management of water infrastructure

Fact Sheet No. 21, March 2015

Progress on Activity 1



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Monash Pipe Burst Testing Facility

Objectives

One of the key research questions to be addressed in Advanced Condition Assessment and Pipe Failure Prediction (ACAPFP) Project is *How, where and when critical pipes fail in a water pipe network*. In response to this, physically-based pipe failure prediction models are being developed for analyzing failure state of corroded water pipelines. However, it is important to validate these models against observed failures in the field, but in many instances, all the necessary information is not available to the required accuracy. In this regard, laboratory burst testing of pipes simulating field conditions is conducted.

This factsheet outlines a pipe burst facility developed at Monash for testing prototype large diameter water pipes. A similar facility has been previously developed for simulating small diameter water pipes, which are affected significantly by soil reactivity and climate effects.

Further, this set-up will be used to identify failure mechanisms (e.g., fast fracture, fatigue) of water pipelines and understand the performance of these pipes with the presence of corrosion. It can also be used to examine once a fracture and associated leak is initiated how long it will take for a major break to take place. Since water pressure is identified as the governing factor for pipe bursts, only water pressure is simulated.

Design of test set-up

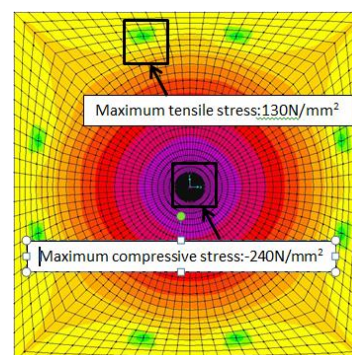


Figure 1. Stress distribution in one of the steel end plate due to 5 MPa internal pressure

The experimental set-up consisted of two large steel plates with rubber gaskets on both ends of the pipe samples, which are bolted together by high tensile bars in order to maintain the internal pressure during tests. The size of the steel end plates and strength of the tensile bars were determined from finite element analysis as shown in Figure 1. The proposed arrangement was shown in Figure 2.

The experiment was conducted in the underground concrete chamber equipped with adequate drainage facility at Monash University, so that the risk due to high pressure and unpredictable failure corroded material and flash flooding after a potential catastrophic failure were minimised. For OHSE requirements, the test area is only accessible when the pipe is depressurised and during burst testing, the pipe assembly is isolated

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by two layers of (movable) polycarbonated sheets that run right across the width of the room. Furthermore people are not allowed to enter the facility room or stand close to the front of the facility. Rubber gasket was used to seal the contact surface between steel plate and pipe wall in order to avoid water leakage. Finally, set-up was axially compressed using tread bars and nuts to make sure it is capable to withstand desired water pressure during testing. The setup is designed to accommodate pipes in the range of 300 to 900 mm diameter.

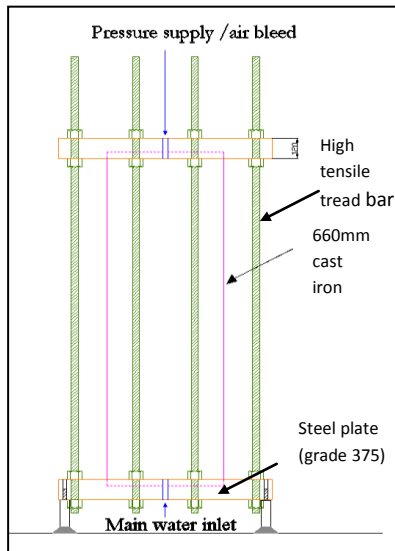


Figure 2. Burst test experimental setup

Assembling the experimental test set-up

Figure 3 shows the assembling procedure of the experimental set-up.

01. 3D laser scanning of the sample before testing
02. Finished bottom plate with inlet hose
03. Placing bottom plate in underground chamber
04. High tensile tread bar arrangement and rubber gasket
05. Placing 660 mm cast iron pipe specimen in position
06. Placing top plate in position
07. Experimental set-up assembled
08. Polycarbonate cover at the main entrance.

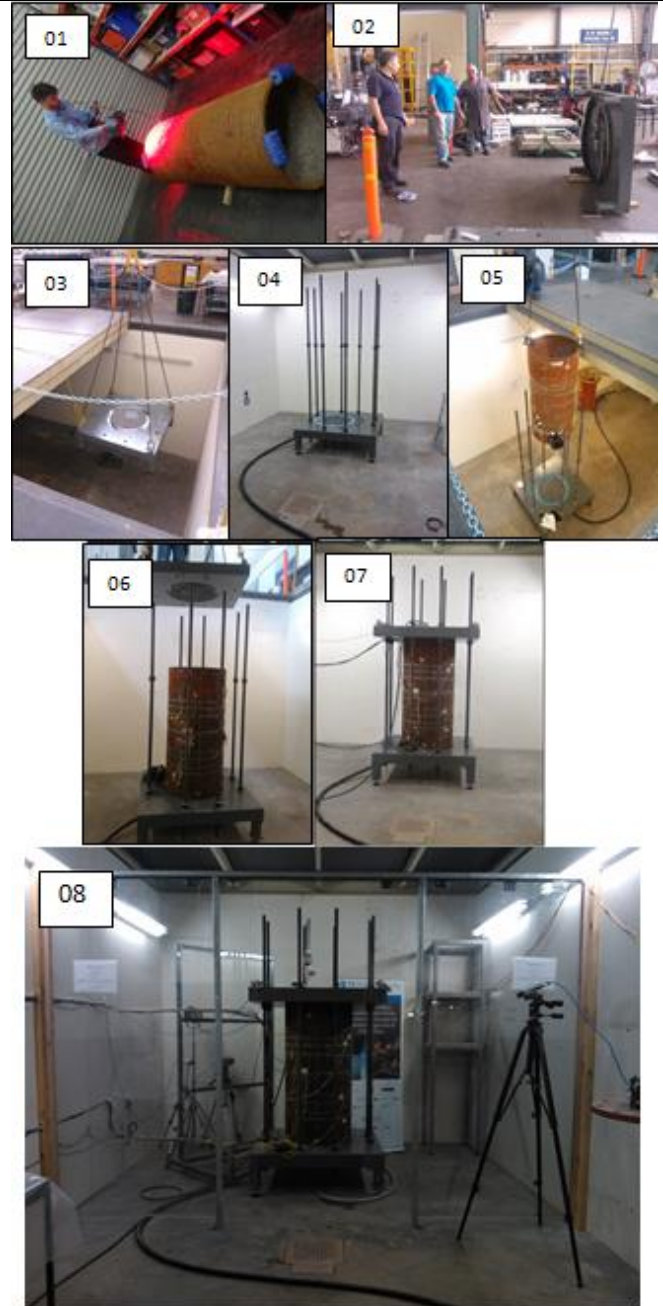


Figure 3. Assembling the experimental test set-up

Instrumentation and capability of experimental test set-up

The facility is equipped with various sensors and a data acquisition system, which includes a 20 channels datalogger. Two pressure transducers were installed at the top and bottom plates to measure internal pipe pressure. Typically up to 18 strain gauges can be connected to the logger during experimnt. Two high

speed video cameras and a HD video camera were set up to record the test and capture the specimen failure. In addition, two internet cameras are also set up for live broadcasting the pipe test via internet when required.

The experimental set-up is designed to withstand 5 MPa internal water pressure with a safety factor of 1.5. Air pressure driven pump was used to amplify the standard 600 kPa air pressure supply to the pipe with a regulator. Several safety valves were installed to quickly release the pressure when required. Analog pressure gauge were installed close to the pump to measure the internal pipe water pressure, while the pump is in the process of pressurizing the pipe. A larger pump and a water reservoir are currently sourced to maintain the pressure when the pipe undergoes initial failure such as cracking during testing leading to a burst. Furthermore, the test set up is to be upgraded to accommodate automatic cycling of water pressure to simulate fatigue loading.

Example of Test procedure

The first pipe specimen tested was an insitu lined spun cast iron pipe section of diameter 660 mm and original pipe wall thickness of 25 mm, obtained from the decommissioned pipeline from the Sydney Water test bed. The specimen was cut to the length of 1340 mm from the original size. The specimen was grit blasted and scanned by a 3D laser scanner to obtain the corrosion profile both on outside and inside. The cement lining was removed during preparation. Since the pipe was insitu cement lined, it had internal corrosion that had occurred prior to lining. Figure 4 shows an image of the scanned pipe specimen along with the co-ordinate system used for identification of corrosion patches.

Two critical patches were identified from the scanned pipe profile (see Figure 5 for more details). All critical patches were instrumented using resistance based strain gauges in both axial and hoop directions.

The pipe was initially pressurized to 300 kPa to check its response and to check all instrumentation.

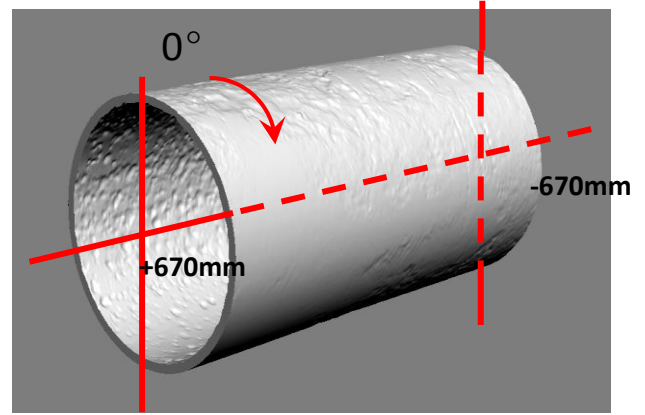


Figure 4. Scanned pipe specimen

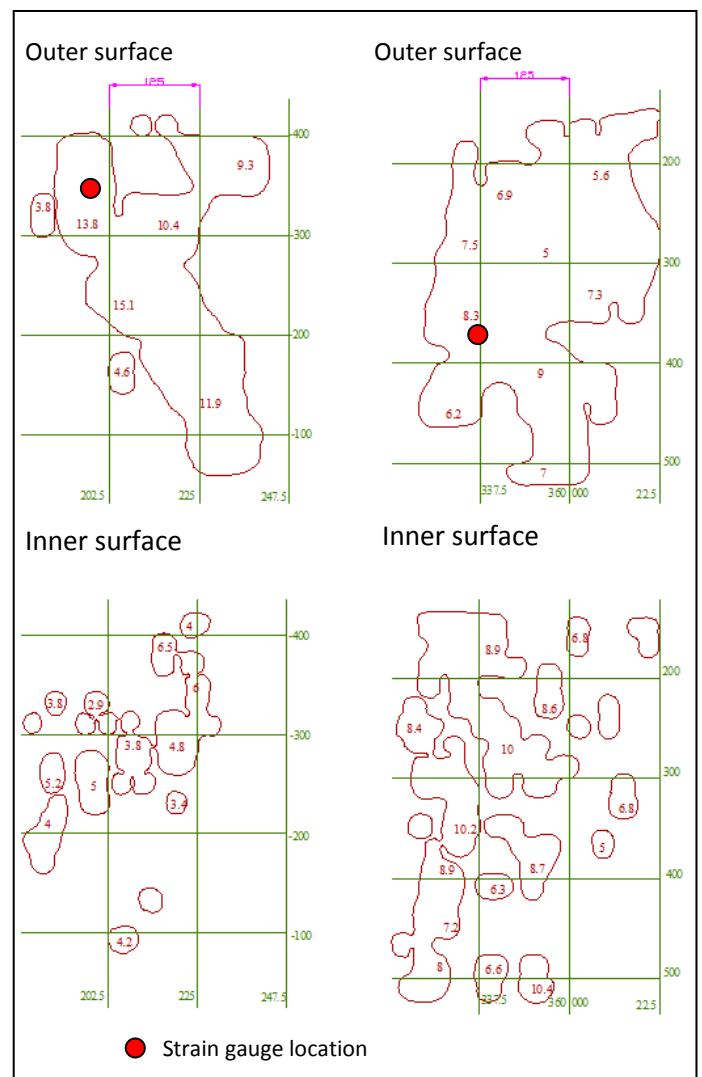


Figure 5. Critical corrosion pits

Experimental results

The Pipe sample was pressurized until major leak or break occur. Both patch 2 and patch 3 started leaking water, when the internal water pressure was between 3.2-3.4 MPa (exact pressure could not be identified). This observation was a much higher than the value expected. Strain gauge reading recorded during the testing in patch 2 and 3 is shown in Figure 6 and 7 respectively. Readings were significantly higher than the maximum recorded values during tensile testing of similar cast iron specimens. Figure 8 shows how water leaked after crack had been initiated at patch 3.



Figure 8. Water leaking from patch 3

Finite element modelling

Scanned pipe data was imported into ABACUS finite element program to simulate the experiment. Model prediction confirmed that maximum stress occurred at the patch 2, which one of the patch failed during the test. Figure 9 below shows finite element model of the sample and location of maximum stress for 3.6 MPa pressure.

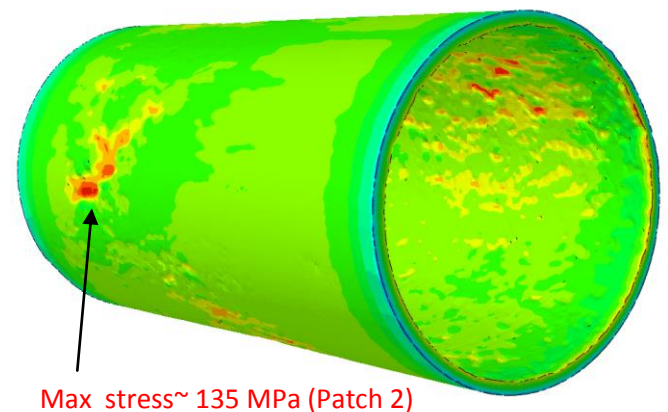


Figure 9. Finite element model of test pipe specimen.

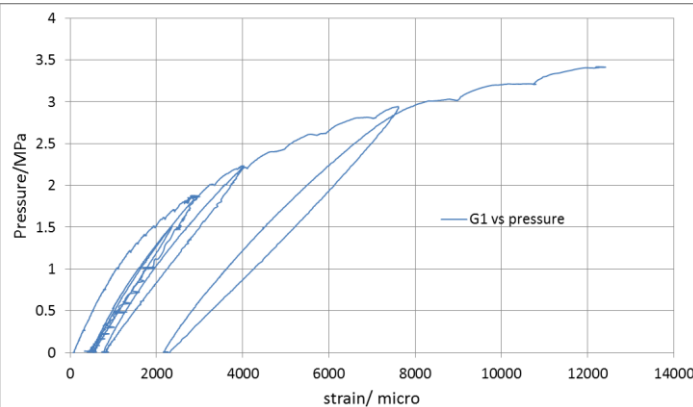


Figure 6. Variation of hoop strain vs pressure at patch 2 (see figure 5 for location of strain gauge in the patch)

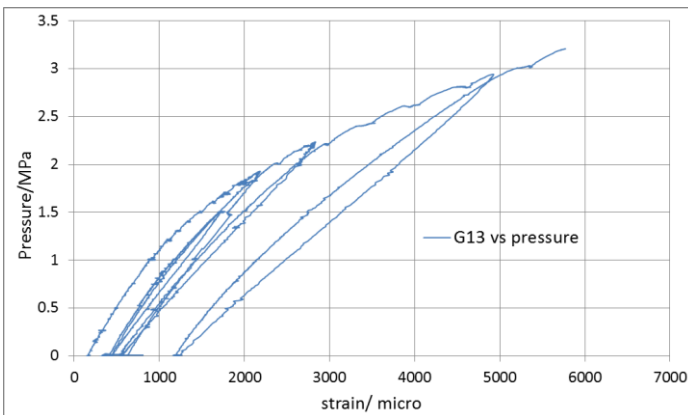


Figure 7. Variation of hoop strain vs pressure at patch 3 (see figure 5 for location of strain gauge in the patch)

Summary

A pipe burst test facility was developed at Monash University and a preliminary test was successfully carried out. The experimental set-up is capable of testing the pipe specimens with diameter range 300 to 900 mm and up to a maximum water pressure 5 MPa. The value of the testing is highlighted by a decommissioned pipe being able withstand and fracture at 3200 to 3600 kPa range when the operational pressure is around 600 kPa. Further developments are planned to make the facility versatile for fatigue testing.

Partners

The partners in this research project include Sydney Water Corporation, UK Water Industry Research Ltd, Water Research Foundation of the USA, Water Corporation (WA), City West Water, Melbourne Water, South Australia Water Corporation, South East Water Ltd and Hunter Water Corporation. Monash University leads the research supported by University of Technology Sydney and the University of Newcastle. Other collaborators include Dr Balvant Rajani from Canada.

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