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Failure Analysis of forty-eight Inch Cast Iron Water Main Pipe due to Overload

Key words: Cast Iron Pipe, Water Main, Mechanical stress

Material: Cast Iron

Introduction

Two sections of failed 48 inch underground water main were submitted for failure analysis. The two pieces appeared to be the parent pipe piece. The main break had occurred on April 19, 2005 adjacent to the Street Bridge over a River in New Jersey. The pipe line had been laid in 1929 and was cement lined subsequently. Visual examination, chemical, mechanical and metallographic analyses was performed on the submitted pipe sections to look for root cause of the failure.

Visual examination

The pipe was observed to have failed by brittle fracture. The fracture originated at two locations in the bell and propagated in the longitudinal direction with the two paths converging to tongue tip profile, as seen in Figure 1.

The outside and inside surface were coated with a tar like product. There was no evidence of any corrosive attack, such as pitting. The fracture edges showed no evidence of any localized thinning of the wall. The fracture surface at the bell was power brushed and examined, Figure 2. There were no remnants of any cement coating found on the inside surface.

Figure 1: Fractured off section of submitted pipe

Figure 2: Cleaned fractured surface at Bell End

Thickness of the pipe was measured at the fracture edge. There was no significant variation observed.

Chemical Analysis

A chemical analysis conducted on the pipe drillings yielded the following composition.

	Failed Pipe	Typical Grey Cast Iron
Carbon	3.96	2.5 / 4.0
Manganese	0.63	0.2 / 1.0
Phosphorus	0. 63	0.002 / 1.0
Sulphur	0.084	0.02 / 0.025
Silicon	1.7	1.0 / 3.0
Chromium	< 0.04	---------
Nickel	0.04	---------
Molybdenum	<0.01	---------
Copper	0.12	---------

Mechanical Test

Test pieces were machined and subjected to tensile testing. Following values were obtained.

	Location 1	Location 2
Tensile Strength	17,500 psi	15,200 psi

Hardness was checked on Brinell scale using 3000Kg load. The values obtained were

	Location 1	Location 2
Hardness	HB 137	HB 134

Microscopic Examination

Specimens were prepared from Location 1 and Location 2 for micro examination of the pipe cross sections.

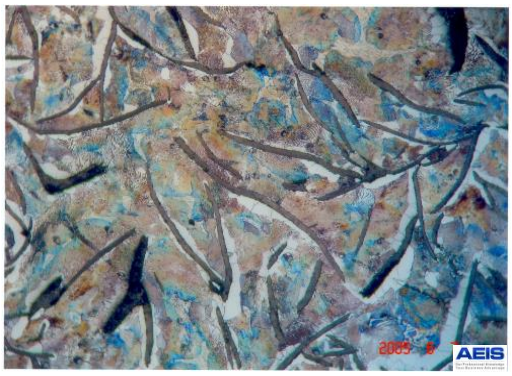

Figure 3: Microstructure of Middle of Wall
125x Magnification

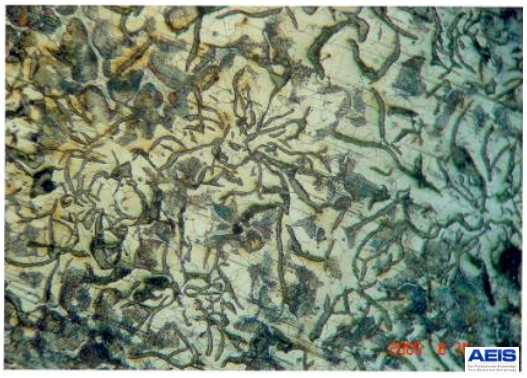

Figure 4: Microstructure at Outer Surface
125x Magnification

At location 1 presence of graphitization on the inner surface to a maximum depth of 0.08 inch was observed, Figure 3. No graphitization was observed on the outer surface. The matrix consisted of Pearlitic plus ferritic structure, predominantly pealitic in the middle, Figure 4 and gradually changing into ferritic towards the surfaces. The graphite flakes were found to be of type A/C and were finer near the surfaces.

Microstructure at Location 2 was similar, though the size and proportions were not exactly the same. Spherodization was observed at locations, generally towards the outer surface. No significant graphitization was observed.

Discussion

The pipes were laid in 1929. The prevailing specification at the time was AWWA Standard Specification for Cast Iron Water Pipe and Fittings set in May 1908, later revised in 1939. The microstructure observed at Location 1 and Location 2 is typical of Pit Cast Pipes and hence it is clear that the failed pipe section is of original vintage and is not a later replacement.

The tensile strength obtained at the two locations of the failed pipe section is lower than specified 20,000 psi in AWWA Standard Specification for Cast Iron Water Pipe and Fittings set in May 1908. However the tensile strength in the specification was specified on one inch thick bars separately cast from the same melt as the pipe. Pipes are likely to be weaker than the test bars themselves because of higher cooling rate encourages smaller graphite flakes and hence stronger material. The material of the failed pipe section therefore can not be classified as sub standard, with sufficient confidence.

The profile of the fracture suggests a mechanism where a wedge of the pipe at the bell is split off to relieve the bending stresses. Figure 1 taken at the failure site shows that the split had taken place on the side.

Conclusion

The subject pipe has not suffered any appreciable deterioration in service. The failure has taken place due to excessive mechanical stresses due to external force such as loss of support.