C33 Inward Deformation Under Outward Pressure: Failure of a Ductile Iron Pipe Joint

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After attending this presentation, attendees will understand the causes of joint failure in boltless pipe systems.

This presentation will impact the forensic community and/or humanity by creating awareness of the failure modes, and differentiation of root failure causes, in the construction industry.

A new 600 MW natural gas power plant, the Metcalf Energy Center, is under construction in south San Jose. The plant will use 3.5 million gallons/day of reclaimed wastewater in its cooling towers. Up to 80% of the water will evaporate, but 700,000 gallons per day will be expelled to the municipal wastewater system. Part of the wastewater pipeline runs along side a bridge crossing a creek. The pipeline rises vertically from below grade, crosses the creek horizontally, and returns vertically to below grade. At this location the pipeline is constructed from 30-inch diameter ductile iron pipe segments. The pipe segments are attached using boltless, pushon flanges, which use metal wedge retainers to form the joint.

During a pressure test of this segment, the joint between one vertical pipe segment and the elbow at the top failed catastrophically. The damaged vertical pipeline was removed and replaced. Subsequently, a similar failure occurred at the joint between the vertical pipe and the elbow at the other end of the bridge. The two failed pipe segments were dented inward where the metal wedges were positioned. While it seemed counterintuitive that a pipe under pressure could have failed by deforming inward, inspection revealed that movement of the metal wedges could have caused the inward deformation to the pipe.

Misalignment of the components that make up the joint, specifically the pipes and/or the retainers, can lead to this failure mode. As the joint is pressurized, it expands, and the retainers can shift position if the parts weren't aligned during installation. Once they move, the outward force on the retainers and the inward force of the bell socket are no longer balanced, and the joint can fail. The same problem can occur if the pipes are allowed to move during pressurization. This movement could cause misalignment of the retainers, leading to this type of failure. For this reason, concrete thrust blocks are required at 90° bends and 45° bends to restrain the pipe from movement.

Failure can also occur if the pipe properties do not meet industry specifications. The subject ductile iron water pipe was specified as grade 60-42-10, which, according to the ANSI/AWAA C151 standard, has a minimum tensile strength of 60 ksi, minimum yield strength of 42 ksi, and minimum elongation of 10%.

Inspection revealed grinding marks at several locations on the outside surface of one pipe, resulting in the pipe being out of round. Its overall diameter, and its thickness at several locations, was less than specified. Mechanical testing revealed tensile strength to be 10% below, and elongation 55% below the specified values.

The inspection and testing showed that this pipe did not meet the manufacturer's specification, with respect to strength, ductility and thickness. It appears that the pipe was manufactured out of round, and was subsequently ground down. Non-uniform grinding, and reduction of thickness to below spec, resulted in decreased effective strength. That, in conjunction with the substandard mechanical properties, led to the initial failure. Movement of the horizontal pipe caused by the initial failure may have caused movement at the other end of the bridge, despite the thrust blocks, resulting in misalignment of the joint and subsequent failure of the other joint.

Ductile Iron, Push-On Joint, Wastewater Pipe

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