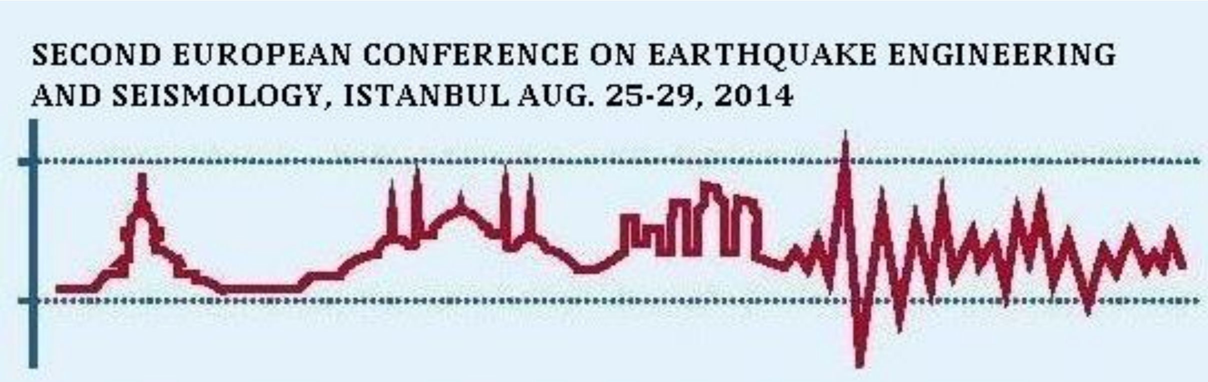

THE FAILURE PERFORMANCE OF THAMES WATER PIPELINE AT FAULT CROSSING IN KOCAELI EARTHQUAKE

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Kocaeli Earthquake (Mw 7.4) occurred on the North Anatolian fault in the northwestern Turkey on August 17, 1999. The Thames Water butt-welded steel pipeline is a raw water pipeline from Yuvacik Dam to Kullar water treatment plant, with 2.2 m diameter and 0.018 m thickness. The water pipeline crossed the Sapanca Segment of the North Anatolian fault and was damaged at the fault crossing. Within a few days after Kocaeli earthquake, this pipe was exposed to allow a better understanding of the nature and extent of pipe damage. A manhole was cut into the pipeline at the excavation to allow for access and emptying of the pipeline. Damage was observed at three locations: Point A, Point B and Point C. As shown in Figure 1, a small surface leak was observed in the pipe at point A near the fault crossing; a significant leak occurred at point B and the minor leak happened at Point C (Eidinger, 2001). Usually a water pipeline suffers two leakage points under the fault displacement, the failure performance of THAMES water pipeline with 3 leakage points is studied in this paper.

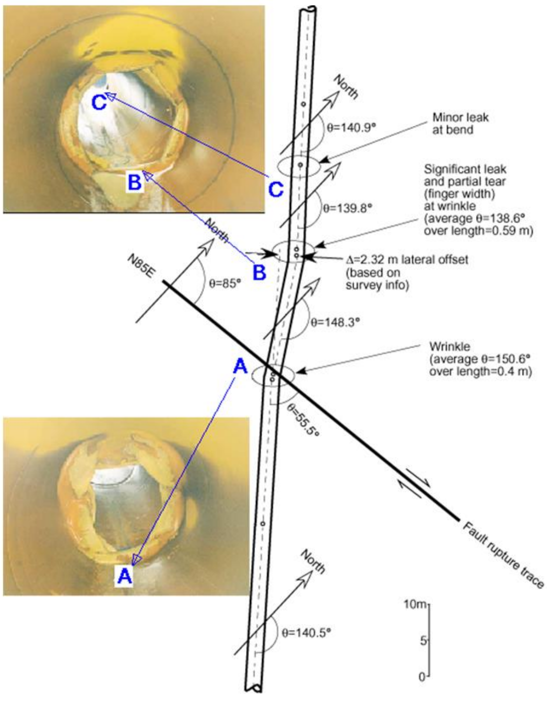

Figure 1. Damage of Thames Water Pipeline at the fault crossing

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Since it is difficult for the cable or beam model to analyze the large deformation in the pipe crossing section, The shell FEM model with an equivalent boundary (Liu et al., 2004) has been proposed to study the failure performance of THAMES water pipeline at fault crossing in Kocaeli Earthquake. Based on field survey, parameters of soil springs around the pipe shell model were determined by the guideline (ASCE, 1984): the friction force between soil and pipeline (f_s) is $2.76*10^5$ N/m and the yield displacement(x_u) is 0.00465m; The horizontal soil pressure (p_u) of the fault southern side is $4.82*10^5$ N/m and the yield displacement (y_u) is 0.162 m; Considering the softer soil condition, the horizontal soil pressure (p_u) of the northern side is one half of southern side.

Considering that THAMES water pipeline was on service with 10 Mpa pressure, the bending stiffness of pipe is larger than a hollow pipe, the wall of pipe is purposely increased from 0.018m to 0.028m in the pipe FEM model. As shown in Figure 2, the simulation result is agreed with the real damage performance of Thames water pipeline. It is very clear that three buckling points occurring in the pipeline. Buckling point A is very near the fault crossing on the rigid soil side. The others (Points B and C) are located on the soft soil side. The compression strain of Point B is the largest of three buckling points, agreeing with the significant leak observed at Point B. Although the compression strain of Point C is the smallest, about 4.3%, it is also larger than the theoretical strain (0.0098) to reach the onset of wrinkle, this is why the minor leak at Point C was observed.

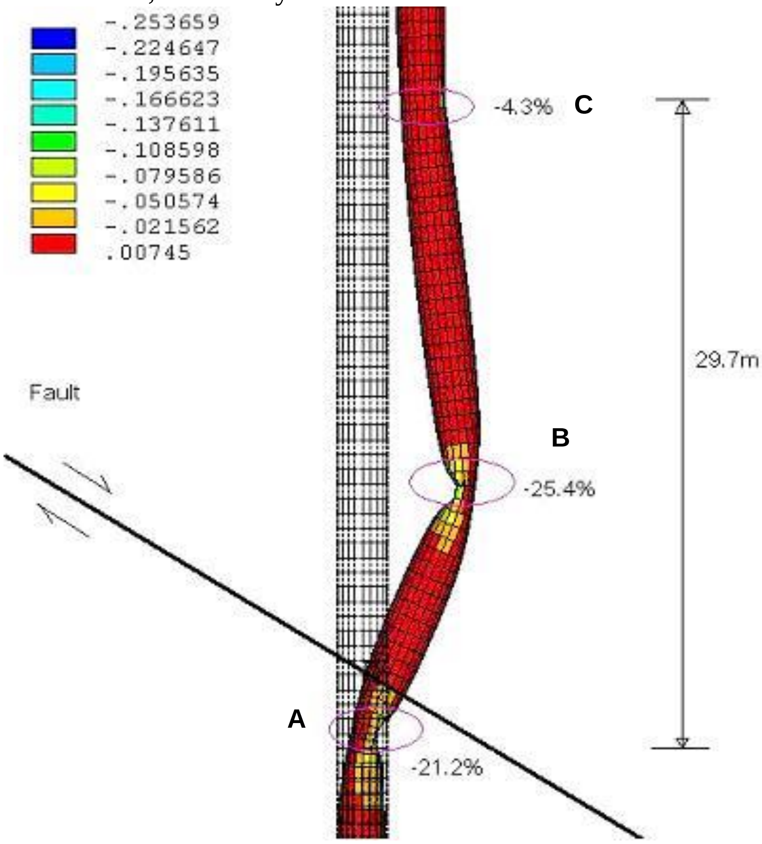

Figure 2. Numerical Simulation for Thames Water Pipeline

North Anatolian fault is a nearly strike-slip fault, and the fault displacement was up to 3 m. It is clear that the amount of fault offset imposed on the pipeline was large enough to initiate the wrinkles of the pipeline because that the crossing angle is 125°. The locations of two closest observed wrinkles (Point A and Point B) are what would be expected due to high bending moments in the pipeline. The question is why the third wrinkle occurred. Figure 3 shows why and how the third buckling point occurred. Buckling points A and B occur at the beginning of fault movement. They can be thought as two hinges in the pipeline. The pipe segment between these two hinges behaviors like a rigid beam. With the increase of fault displacement, this pipe segment would rotate around the hinges (Points A and B) under the compression loading. Because the different soil conditions on two sides of the fault, the lateral displacement of point B on the soft soil side becomes larger than the lateral fault movement, therefore the third buckling point occurs.

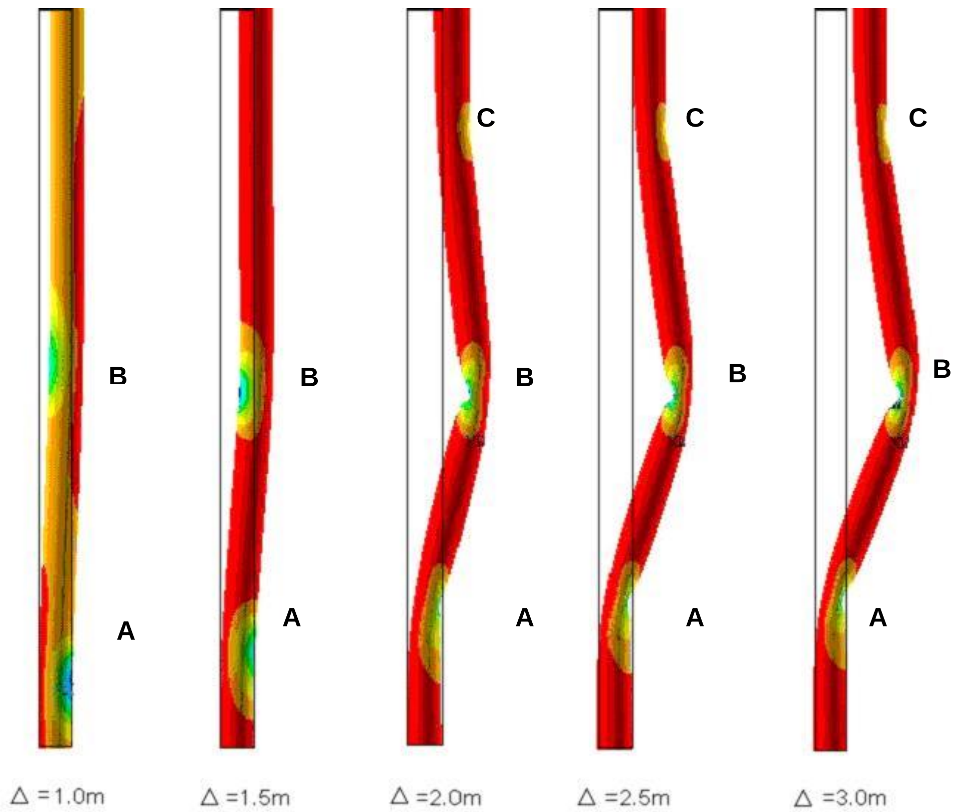

Figure 3. Deformation process of Thames water pipeline with the fault movement (Δ)

In conclusion, the failure performance of Thames Water pipe in Kocaeli Earthquake is a typical damage case for different soil conditions on both sides of the fault. One of the main buckling point is very near the fault offset on the side with more rigid soil. When the fault displacement is large enough, the third buckling point may occur on the soft soil side further from the fault.

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