Polyethylene pipeline performance against earthquake

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1. Material property of Polyethylene
2. Seismic test (Repetitive expansion and contraction test)
3. Real scale simulated test
   3.1 Fissure Experiment
   3.2 Ground Settlement Experiment
   3.3 Hydrostatic strength of strained pipe
4. Investigation of PE pipeline after earthquake
5. Conclusions
In Japan, polyethylene (PE) pipe have been used for a long time, but its usage is limited for water service (low density PE/PE50) and gas service (medium density PE/PE80).

However, after 1995 Hyogoken Nanbu Earthquake, it started to sell PE pipeline (high density PE/PE100) for water distribution applications, because no damage on PE pipes at the earthquake was highly evaluated.

We have been verified the characteristics of PE pipeline (PE100) from the viewpoint of seismic performance.
1. Material property of Polyethylene (Tensile and compression)
Outline of the longitudinal stretch experiment

Material property of Polyethylene

D=90mm
\( t = 8.2\,\text{mm} \)
( SDRI11 )
Tensile stress-strain curve

Material property of Polyethylene
Material property of Polyethylene

Compression stress-strain curve

D=180mm
t=16.4mm
(SDR11)
L=500mm
2. Seismic test
(Repetitive expansion and contraction test)
Seismic test

(Repetitive expansion and contraction test)

EF socket

Expansion and contraction

PE pipe

250mm

D=180mm

t =16.4mm

(SDR11)
3. Real scale simulated test
Outline of the Fissure experiment

- Stopper
- Side view
- 50m
- Test enclosure
- Fissure
- Test enclosure
- Roller
- Hydraulic jacks (Both sides)
- PE pipes
- 25cm
- D = 180mm, t = 16.4mm (SDR11)
- Test enclosure width = 90cm
- Overburden = 68 cm
- Water pressure (0.75 MPa)

Real scale simulated test
Outline of the fissure experiment

Real scale simulated test
Real scale simulated test

Longitudinal strain distribution

Distance from center of pipeline (m)

EF socket  End cap

Axial strain (%)

Fissure width = 50cm
Fissure width = 40cm
Fissure width = 30cm
Fissure width = 20cm
Fissure width = 10cm
Outline of the Ground Settlement experiment

Ground settlement = 50cm

D=125mm PE pipe
D=125mm EF socket

D=125mm t=11.4mm (SDR11)
Outline of the Ground Settlement experiment

Before experiment

After experiment
Outline of the Ground Settlement experiment

Real scale simulated test

Center of pipeline
Real scale simulated test

Longitudinal strain distribution

Settlement side
Fixed side

Distance from center of pipeline (m)

Settlement = 50cm
Settlement = 30cm
Settlement = 10cm
Hydrostatic strength of straind pipe

Pull the pipe

Water pressure

PE Pipe

PE pipe

Fixing rod

2.5% ~ 10%

Real scale simulated test
Hydrostatic strength of straind pipe

![Graph showing hoop stress vs. time to failure for different strains. The graph includes data points for no strain (LPL), strain=2.5%, strain=5.0%, strain=7.5%, and strain=10.0%. The x-axis represents time to failure in hours, ranging from 10 to 1,000,000. The y-axis represents hoop stress in MPa, ranging from 10 to 20.](image)
4. Investigation of PE pipeline after earthquake
# Investigation of PE pipeline after earthquake

<table>
<thead>
<tr>
<th>Name of earthquake</th>
<th>Magnitude</th>
<th>Total length of PE</th>
<th>Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003 Miyagiken Hokubu Earthquake</td>
<td>6.4</td>
<td>10km</td>
<td>None</td>
</tr>
<tr>
<td>2003 Tokachi-oki Earthquake</td>
<td>8.0</td>
<td>2.6km</td>
<td>None</td>
</tr>
<tr>
<td>2004 Mid Niigata Prefecture Earthquake</td>
<td>6.8</td>
<td>11.4km</td>
<td>None</td>
</tr>
<tr>
<td>2004 Noto Hanto Earthquake</td>
<td>6.9</td>
<td>2km</td>
<td>None</td>
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<tr>
<td>2007 Niigataken Chuetsu-oki Earthquake</td>
<td>6.8</td>
<td>13km</td>
<td>None</td>
</tr>
<tr>
<td>2008 Iwate-Miyagi Nairiku Earthquake</td>
<td>7.2</td>
<td>47.4km</td>
<td>None</td>
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<tr>
<td>2011 The Great East Japan Earthquake</td>
<td>9.0</td>
<td>996km</td>
<td>None</td>
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<tr>
<td>2016 Kumamoto Earthquake</td>
<td>7.3</td>
<td>147.7km</td>
<td>None</td>
</tr>
</tbody>
</table>

※ Except for extreme cases like tsunami and ground collapse
“Tsunami” of 2011: The Great East Japan Earthquake

The earthquake occurred in Japan

Investigation of PE pipeline after earthquake

Shinchi-machi, Fukushima Prefecture

Web: Japan Meteorological Agency
“Tsunami” of 2011 The Great East Japan Earthquake

Before “Tsunami”  
After “Tsunami”

PE Pipeline
D=180mm  
t=16.4mm  
(SDR11)

Investigation of PE pipeline after earthquake
“Tsunami” of 2011 The Great East Japan Earthquake

Investigation of PE pipeline after earthquake

PE Pipe was not broken where the seawall is not destroyed.

Destroyed seawall

Northside Breakpoint

Southside Breakpoint
### Test result of PE pipe scoured by “Tsunami”

<table>
<thead>
<tr>
<th>No.</th>
<th>Characteristic</th>
<th>Requirement</th>
<th>Result</th>
<th>standard</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Elongation at break</td>
<td>$\geq 350%$</td>
<td>613%</td>
<td>ISO 4427-2</td>
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<tr>
<td>2</td>
<td>Yield stress</td>
<td>$\geq 20\text{MPa}$</td>
<td>28\text{MPa}</td>
<td>JWWA K 144※</td>
</tr>
<tr>
<td>3</td>
<td>Hydrostatic strength at 20°C</td>
<td>No failure</td>
<td>No failure</td>
<td>ISO 4427-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.4\text{MPa} 100h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Hydrostatic strength at 80°C</td>
<td>No failure</td>
<td>No failure</td>
<td>ISO 4427-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.4\text{MPa} 165h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Destroying water pressure</td>
<td>$\geq 4.0\text{MPa}$</td>
<td>5.5\text{MPa}</td>
<td>JWWA K 144※</td>
</tr>
</tbody>
</table>

※ Japan Waterworks Association (JWWA) Standard
2014 Nagano prefecture Kamishiro fault Earthquake

Investigation of PE pipeline after earthquake

Hakuba village
Nagano Prefecture
Reverse Fault

Before earthquake

After earthquake

Investigation of PE pipeline after earthquake

2014 Nagano prefecture Kamishiro fault Earthquake

80cm
2014 Nagano prefecture Kamishihiro fault Earthquake

Investigation of PE pipeline after earthquake
2014 Nagano prefecture Kamishiro fault Earthquake

Investigation of PE pipeline after earthquake

69.8cm
2014 Nagano prefecture Kamishiro fault Earthquake

Destroyed sewer pipeline (Reinforced concrete pipe : 450mm)

Investigation of PE pipeline after earthquake
5. Conclusions
Conclusions

1. The yield strain of the PE pipe for both longitudinal tensile and compressive was about 8%, and, until reaching the yield point, the pipe deformed evenly.

2. The maximum pipe strain obtained by the 50cm fissure and uneven ground settlement experiments was about 3%.

3. We investigated PE pipeline damages after actual earthquakes. There was no damage by ground deformation, seismic motions and liquefaction, except for extreme cases like tsunami and ground collapse.
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