Lessons Learned from Recent Earthquakes in Japan from the view of Lifeline Earthquake Engineering

Masakatsu Miyajima

Kanazawa University, Japan

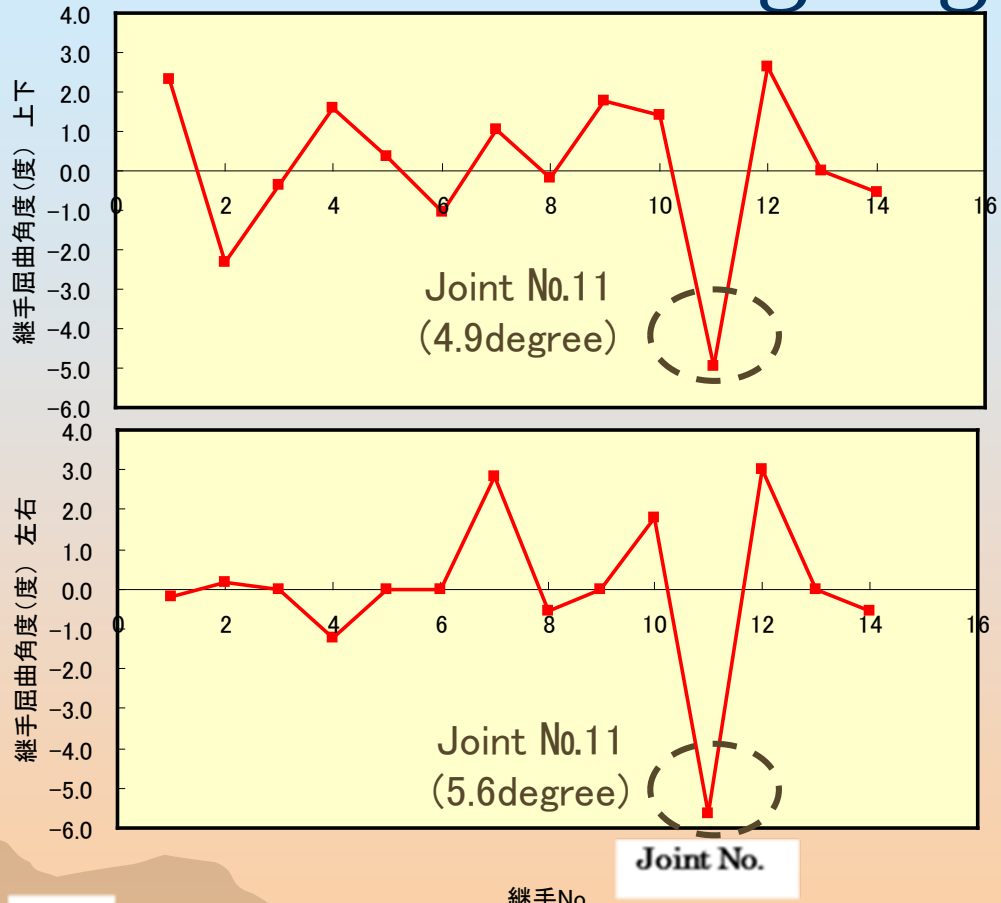
Recent Damaging Earthquakes in Japan

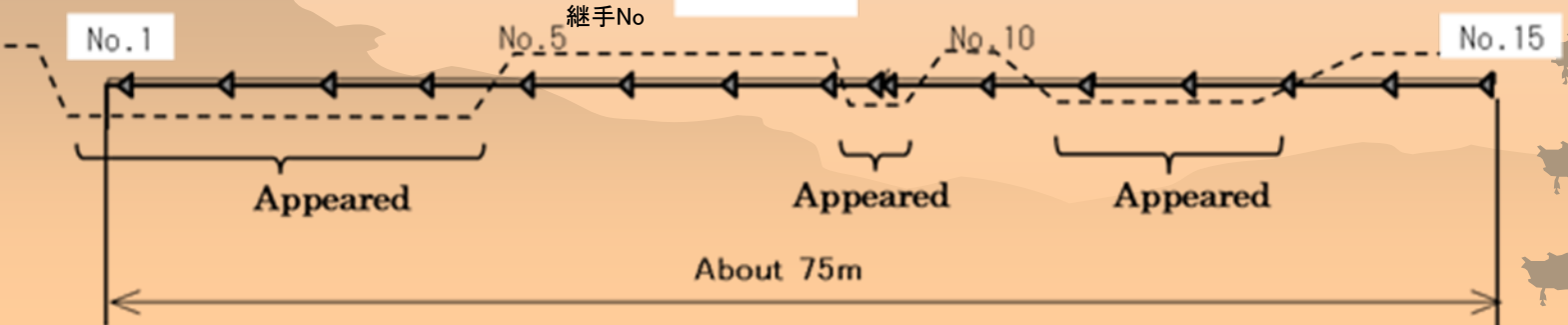
- 2011 Tohoku Earthquake (*Mw*=9.0)
  - *Tsunami
  - *Liquefaction
- 2016 Kumamoto Earthquake (*Mw*=7.0)
  - *Surface Faulting
  - *Liquefaction

Damaged pipelines by tsunami in the 2011 Tohoku EQ （Scouring and washing away）

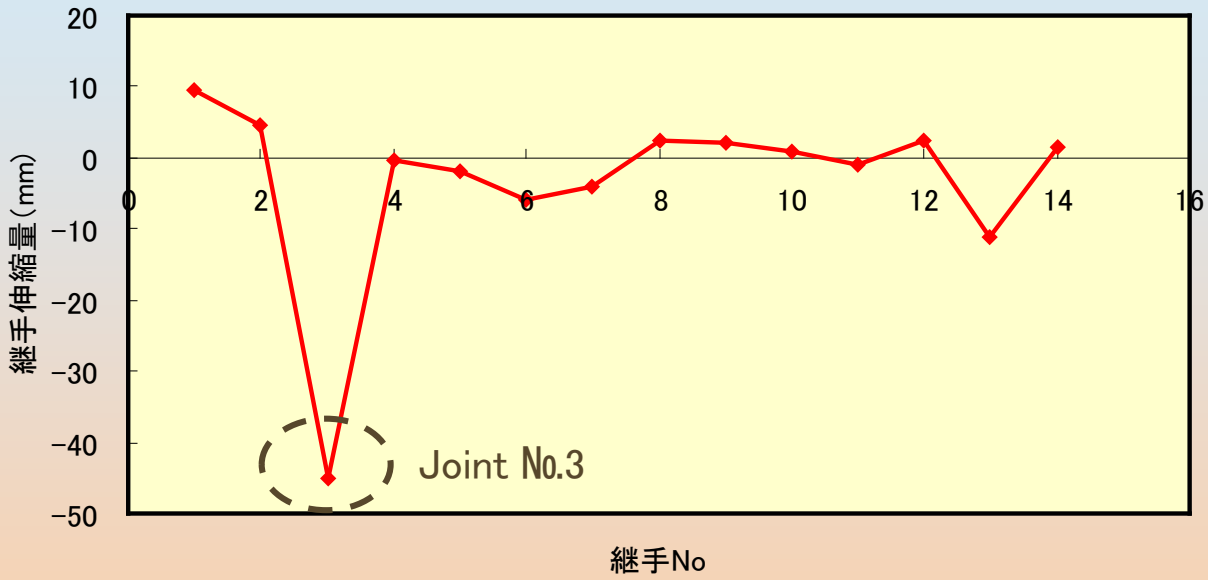
福島県新地町

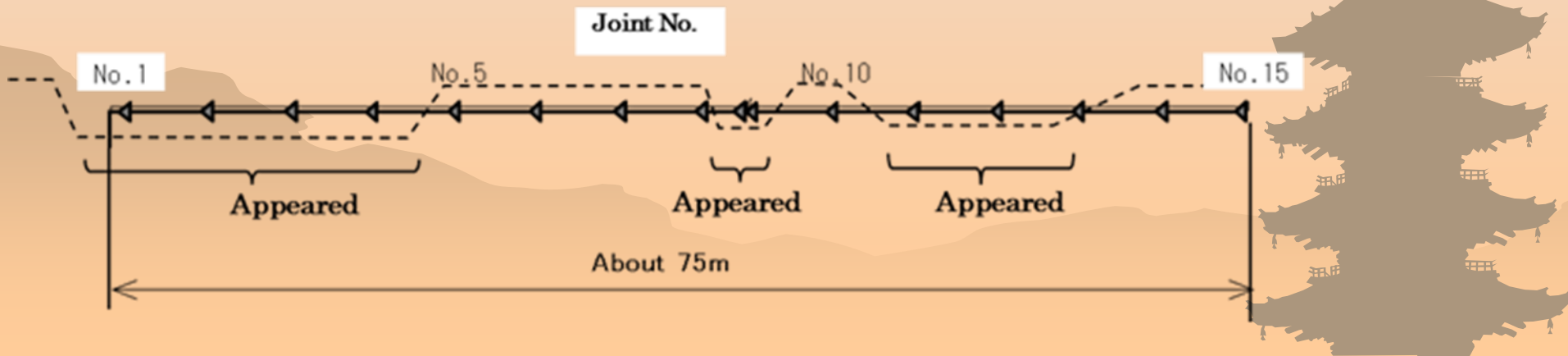
Deformation of pipeline by Tsunami (Bending angle at joint)





Deformation of pipeline by Tsunami (Pull out of joint)





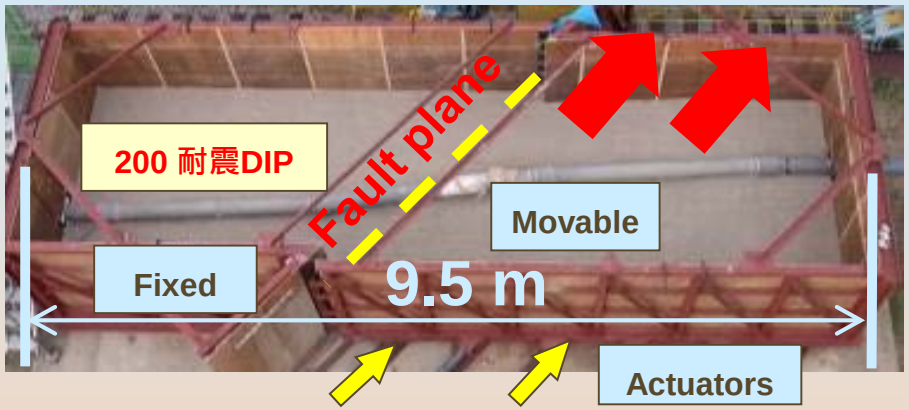
Surface faulting in the 2016 Kumamoto EQ

Pipe damage across surface faulting in the 2016 Kumamoto EQ

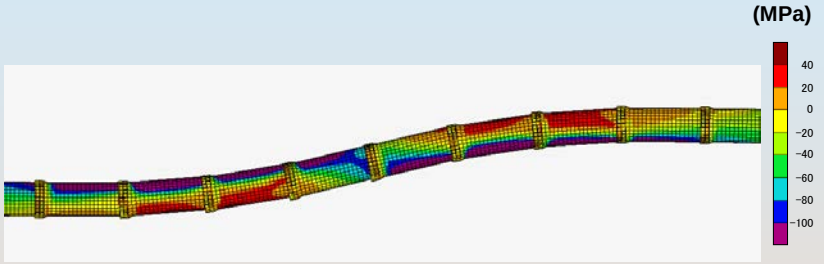
写真：益城町水道センター水道課提供

Earthquake resistant DIP across surface faulting

Large size tests



FEM Analysis



Non-linear FEM analysis

Criteria for evaluation

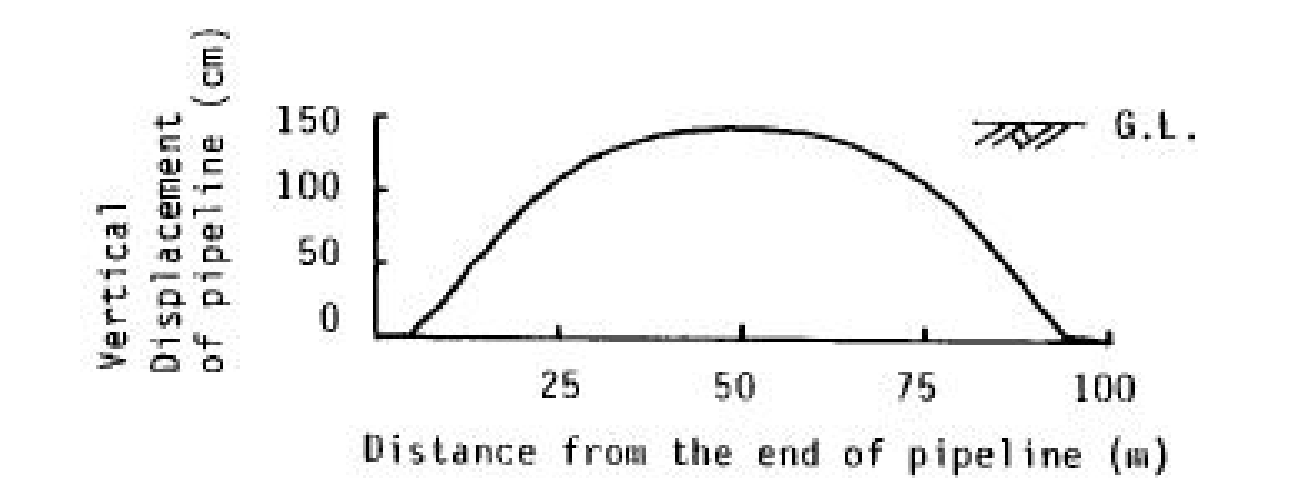
Tensile Stress	≦ 270 MPa (Proof-Stress)
Axial Force	≦ 3D kN (D : Nominal diameter)
Deflection Angle	≦ 4°

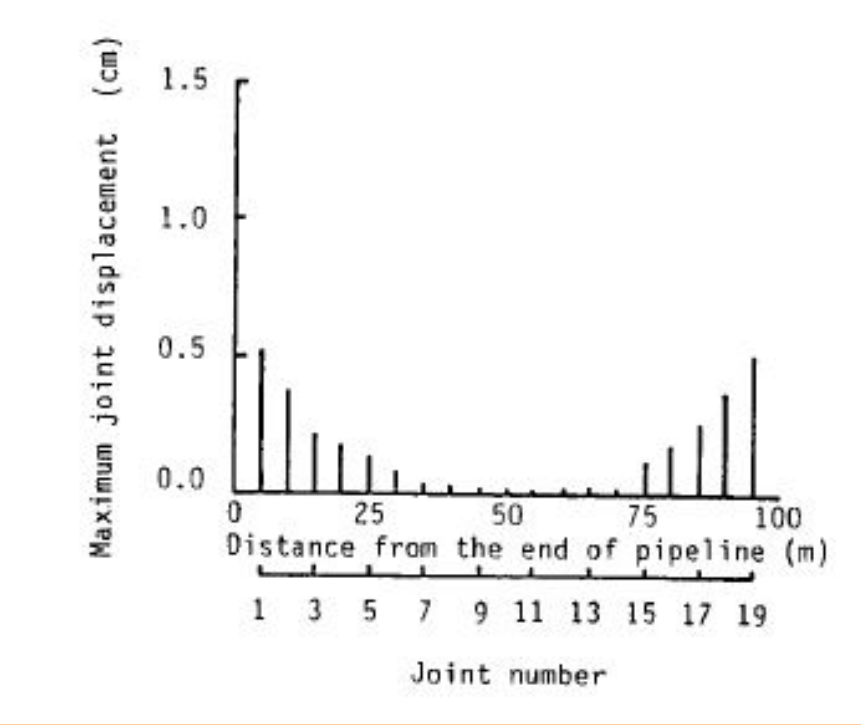
Liquefaction in the 2016 Kumamoto EQ

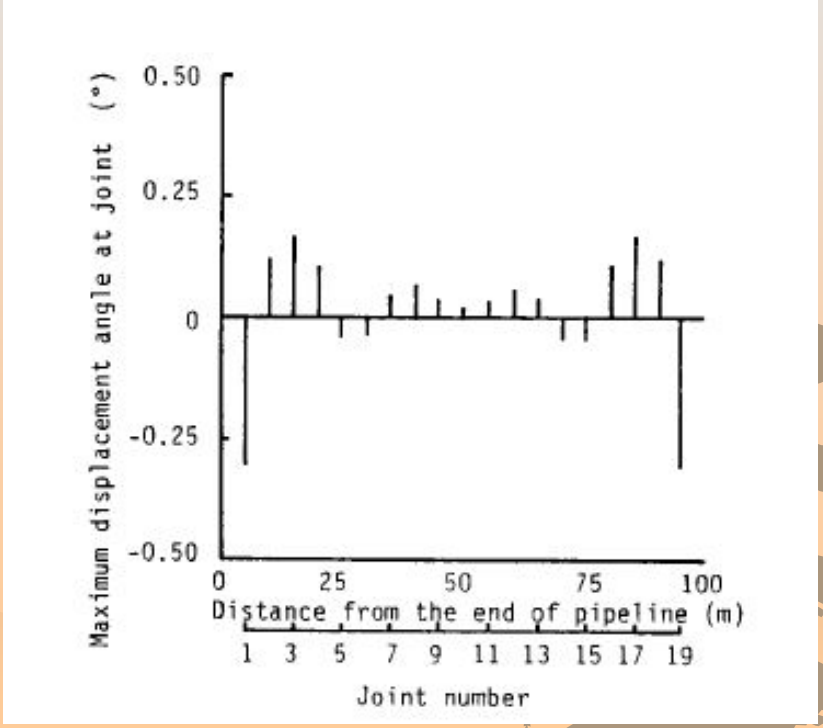
Pipeline damage prediction equation

Pipeline damage prediction equations	
If there is no information available on liquefaction or if there is no possibility of liquefaction	If there is information available on liquefaction and if ther is the possibility of liquefaction
$R_m = C_p \times C_d \times C_g \times R(v)$ R_m : Predicted damage rate (locations/km) C_p : Correction factor for pipe and joint type C_d : Correction factor for pipe diameter C_g : Correction factor for microtopograpy $R(v)$: Reference damage rate (locations/km) $R(v)=9.92\times10^{-3}\times(v-15)^{1.14}$ v: Peak ground velocity(cm/s) ($15 \leqq v < 120$)	$R_m = C_p \times C_d \times R_L$ R_m : Predicted damage rate (locations/km) C_p : Correction factor for pipe and joint type C_d : Correction factor for pipe diameter R_L : Average damage rate of liquefaction area (locations/km), $R_L = 5.5$

Behavior of pipeline in uniform liquefied ground







Un-uniform behavior of liquefied ground
(2011 Tohoku EQ)

Concluding remarks

- Field investigation just after an earthquake is very important not only for damaged structures but also survived structures.
- Countermeasures for fault crossing pipeline must be studied.
- Behavior of pipeline in un-uniform liquefied ground should be clarified.

Thank You for Your Kind Attention