Effects of Creep on Long-Term Performance of Concrete Structures

Discussion for Research Directions and Topics

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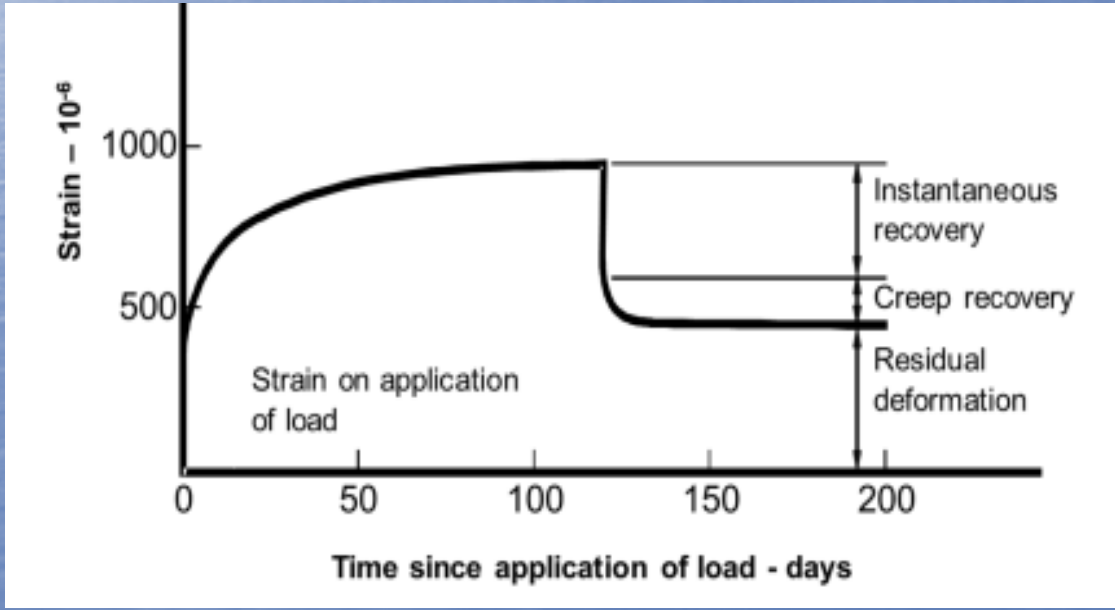
Agenda

- Observations
- Issues
  - Structural related
  - Assessment related
- Knowledge Areas
  - Inelastic creep component
  - Structural performance
  - 3-Dimensional stress states
- Comments and Discussions

Observations

- Creep is time dependent deformation under load
- The creep rate reduces over time as concrete ages
- Primary creep reactivates under a change in loading
- Visco-elastic recovery with irreversible component



Observations

- Considered in design of pre-stressed structures for post-tensioning performance to maintain minimum design specifications
- Not generally considered in assessing thermal / mechanical load combination cases in design basis
- Not generally considered in assessing structural performance for short lived accident conditions since creep changes slowly with time for aged structures
- May be important in assessing long term performance after accident conditions having significant changes in load and temperature
  - Consideration for restarting procedures?
  - Consideration for additional monitoring or maintenance?

Observations

- Creep is more important in designs having elevated compressive stresses
  - Pre-stressed structural components
  - Heavy, thick-walled structures?
- Is Creep Beneficial?
  - Creep reduces stress over time
  - Creep can redistribute load paths
- Is Creep Detrimental?
  - Increase in deformation over time
  - Residual or “locked-in” creep strains under change in loading may contribute to cracking

Creep Related Structural Issues

- Concrete is used in design to carry compressive stress, and compressive creep is ductile response
- Any cracking exacerbated by creep can lead to maintenance or long-term performance issues
- Structural modifications, e.g. steam generator replacements in PCCVs, require significant changes in loading over extended periods, which can affect creep related performance

- Can creep be a primary cause of structural failure?
- Is creep induced cracking a self-limiting mechanism?
- Is creep important in ratcheting under thermal cycles?

Creep Related Assessment Issues

- Creep response is load, time, and temperature dependent => True structural effects are path dependent over the history of the structure
- Tracking creep through elevated temperature gradients or cycles requires “time-shifting” between temperature dependent data
- Creep rate is affected by environmental parameters, such as temperature gradients and cycles, humidity, moisture transport, and thus difficult to establish actual creep characteristics
- True structural effects can be dependent on variations within the structure due to liners, interior vs exterior exposed surfaces, stress state variations

Knowledge Areas

- Data on inelastic component of creep
  - Most creep testing just measures creep rate under load
  - Tests that continue with unloading generally stop before saturation
  - Creep testing generally begins with “early age” specimens (28-90 days)
  - Creep testing generally does not distinguish between drying and basic creep
  - Since inelastic component means a change in material structure, is inelastic component a function of loading rate, magnitude, time at load and/or age at load?
  - What is the nature of the change in material structure leading to irrecoverable deformation due to creep?

Knowledge Areas

- Data for creep effects and structural performance
  - Creep induced specimens are generally not subjected to subsequent structural testing
  - Is concrete tensile strength affected by creep strain
  - Role of differential creep across structural section
  - How does mechanical induced cracking affect creep
- Data for creep in 3-dimensional stress states
  - Is there a creep Poisson's Ratio (CPR) different from elastic Poisson's Ratio
  - Is there a difference in CPR for loading vs unloading
  - In particular, what are creep effects under compressive hoop and axial pre-stress in PCCV

Comments and Discussion

- Pre-stressed containments are important for long term performance
  - Creep due to elevated compressive stresses
  - Last line of defense in accident containment
  - Major structures – hard to replace or upgrade
  - Sometimes require significant modifications

- Creep would seem to be of more concern for changes in loading and load cycling or post-accident conditions

Comments and Discussion

- What is significant?
  - Tendon relaxation and re-tensioning over time
  - Structural integrity pressure tests
  - Local de-tensioning for tendon replacement or maintenance
  - Regional de-tensioning for structural modifications
  - Cracking induced by seismic event
  - Cumulative Re-fueling shutdowns over time
  - Accident condition shutdown and assessment for restart

Comments and Discussion

- Should we also be concerned with other significant nuclear structures?
  - Structural modifications on RCCVs with thick, heavily reinforced concrete walls
  - Thermal cycling, unloading, and load redistribution in Spent Fuel Pools
  - Heavy equipment replacement on containment internal structures

Comments and Discussion

- How do we establish reasonably accurate future structural performance based on current, in-situ creep test data and ignoring past structural history?
- How do we assess if a coupled thermal-stress analysis without considering creep is conservative or un-conservative?
- Due to uncertainties in creep characteristics, assessing effects of creep would seem to be a good candidate for probabilistic methods using confidence bands for creep rates
- What monitoring methods in conjunction with creep studies will bring additional insight for the performance and integrity of the structures?