NTSB National Transportation Safety Board

Office of Highway Safety

Epoxy Used in the D Street Portal

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Topics Addressed

- Epoxy fundamentals
- Anchor creep testing in the tunnel
- Anchor creep testing in the laboratory
- Standardized testing methods for adhesive anchors

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Epoxy Fundamentals

- *Epoxy* covers a wide range of materials
- Solid epoxy is formed by a chemical reaction between two components
  - Epoxy resin
  - Hardener
- Resin and hardener molecules link to form long chains
- Crosslinks result in a network that limits motion

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Epoxy Fundamentals

- Under constant load, molecular rearrangement allows epoxy to deform continuously in a process called ***creep***
- The rate of creep and the amount of creep depend on molecular structure, crosslink density, and temperature
- Under small loads, deformation is linear and reversible
- With increasing load or longer times, deformation becomes nonlinear and irreversible, leading to fracture and damage accumulation

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Epoxy Fundamentals

- Rate of creep is accelerated at higher temperatures
- Time-temperature superposition: data from short-term tests at increasingly higher temperatures are combined to predict the long-term creep behavior
- Tests applied to Fast Set and Standard Set epoxies from Powers Fasteners

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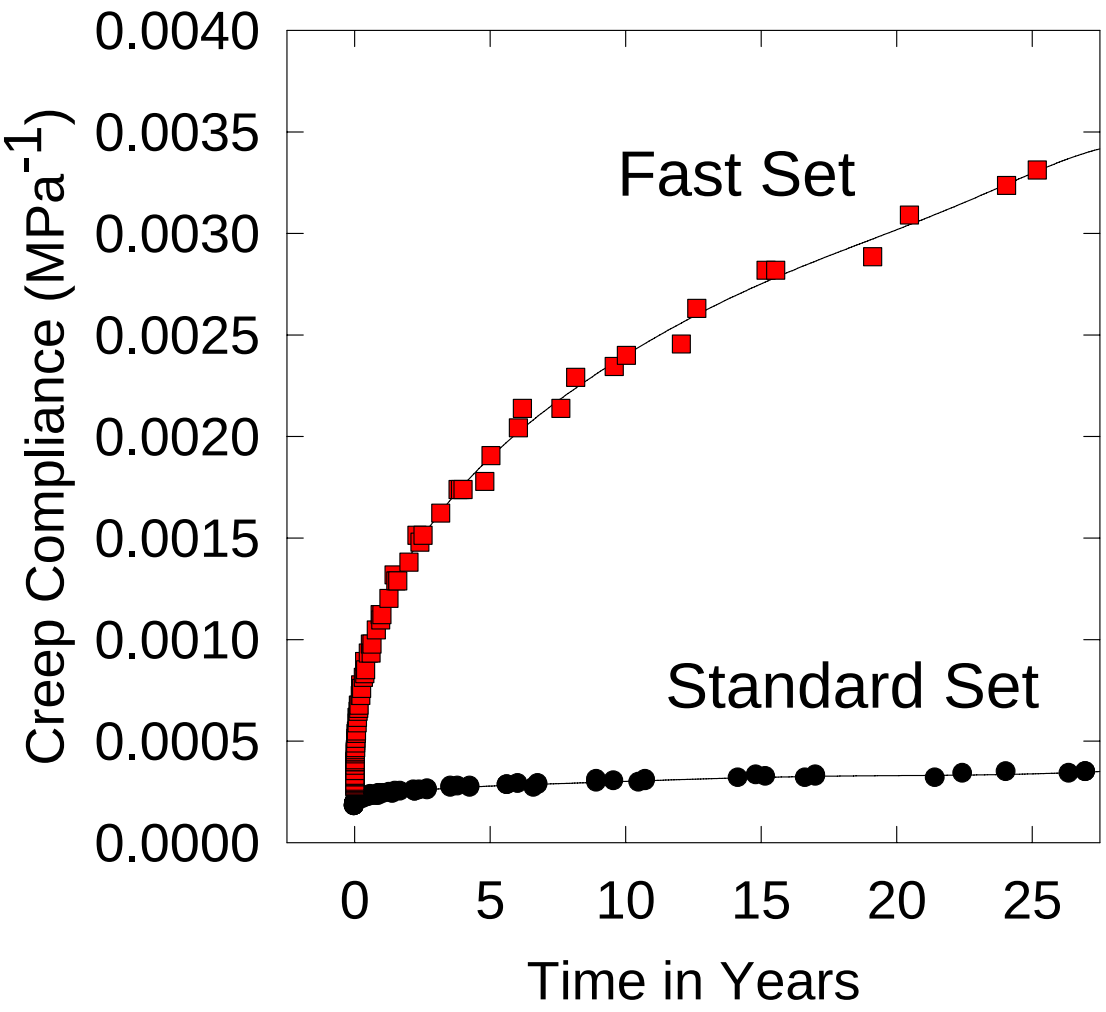

Increasing anchor displacement

Data courtesy of NIST

Epoxy Fundamentals

- Compared to Standard Set epoxy, Fast Set epoxy forms a poor network with a much lower crosslink density
- Fast Set epoxy is therefore expected to creep at a higher rate and by a larger amount

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Anchor Creep Testing in the Tunnel

- 11 tests total, for up to 3 months
- Loads of 1000, 2000, and 3000 pounds
- 3 failures
- All anchors showed continuous displacement throughout the test (up to 0.14 inch)

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Anchor Creep Testing in the Laboratory

- Eliminate unknown installation and load histories
- 1000, 2000, 3000, and 4000 pounds
- 82 days, 2 replicates
- Fast Set and Standard Set epoxies

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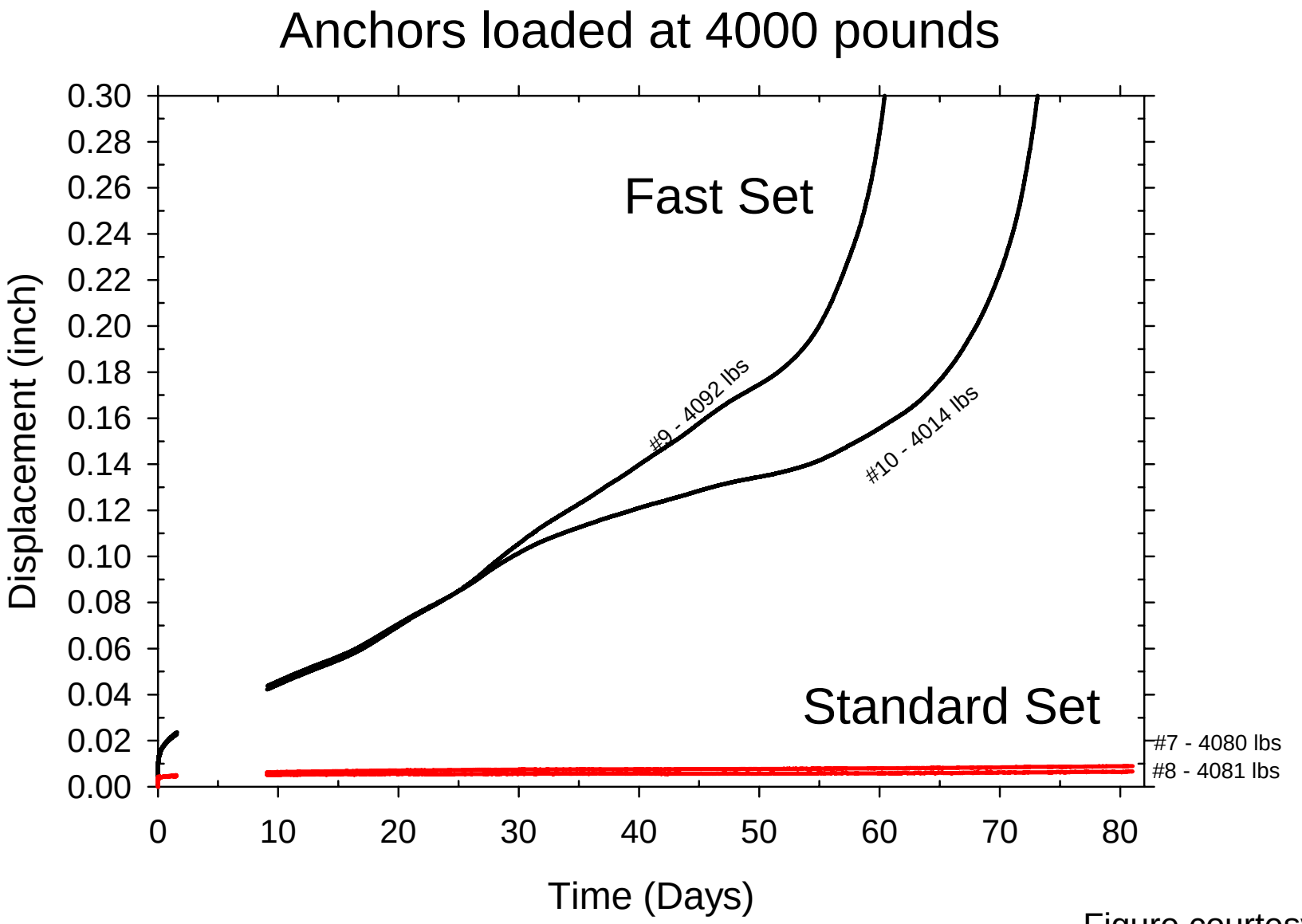

Figure courtesy
of FHWA TFHRC

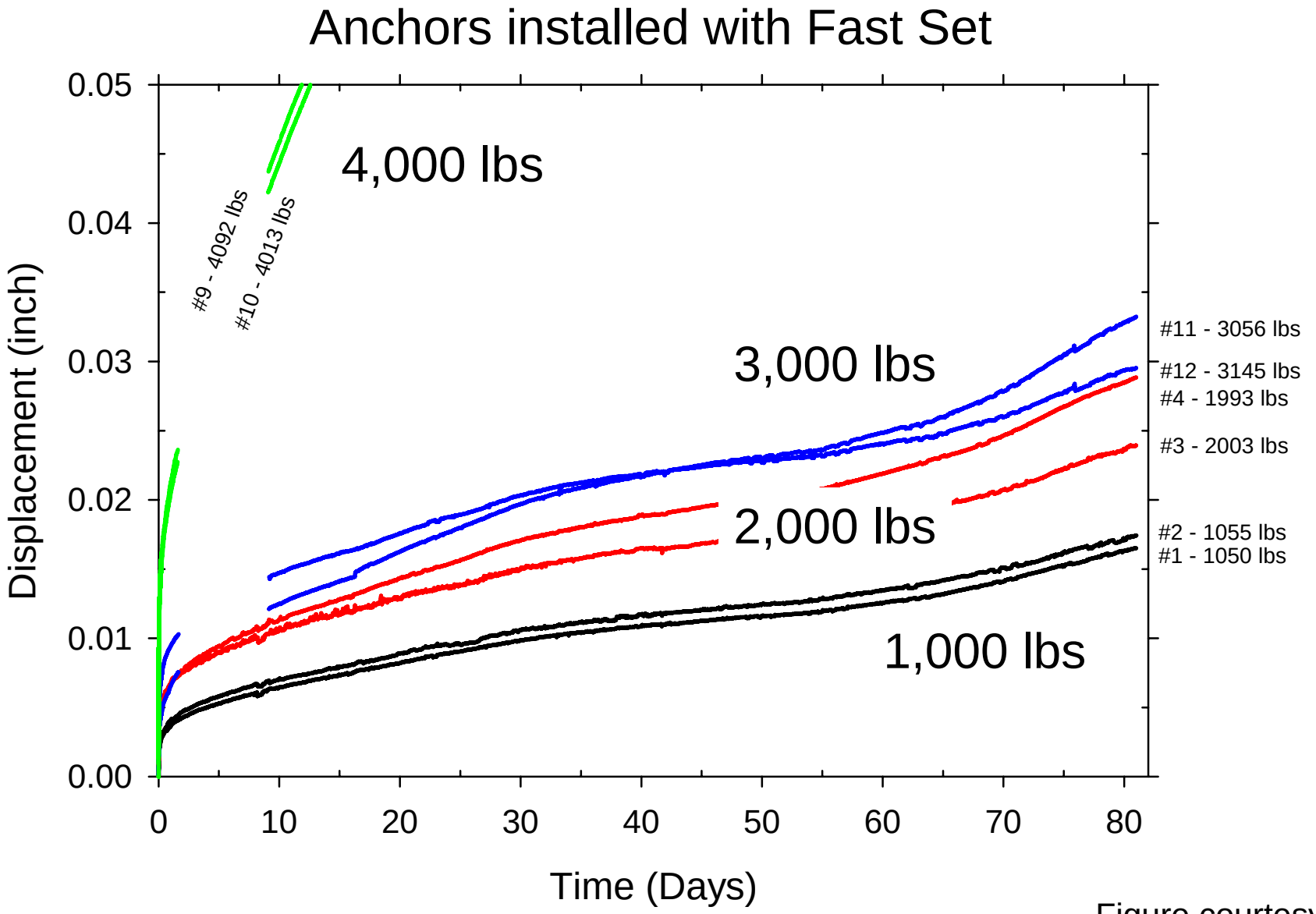

Figure courtesy
of FHWA TFHRC

Anchor Creep Testing in the Laboratory

- Fast Set epoxy showed significant displacement at all load levels
- Standard Set epoxy showed minimal displacement throughout the test
- Fast Set anchors loaded at 4000 pounds pulled out completely
- The ceiling collapse was primarily the result of the poor creep resistance of the Fast Set epoxy

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Standardized Testing Methods

- No FHWA or AASHTO standards for adhesive anchors
- Adhesive anchor standards (including creep) in International Code Council - Evaluation Service (ICC ES) Acceptance Criteria AC 58
- Without the creep test, adhesive is limited to short-term loading only
- AC 58 creep test is ***optional***

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Standardized Testing Methods

- ICC-ES AC 58 creep test is relatively rigorous – useful as a screening tool
- 1995-96 - Standard Set and Fast Set tested for creep per AC 58
  - Standard Set epoxy passed
  - Fast Set epoxy failed
- Fast Set failing the creep test should have precluded its use in 1999 to support the ceiling

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