ASTM E05 Workshop on Advancements in Evaluating the Fire Resistance of Structures – Dec 6-7, 2018 – Washington, DC

Probabilistic strength retention factors for steel and concrete and effect on structural reliability of columns in fire

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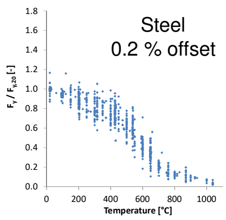
ABSTRACT: Evaluating reliability of structures requires consideration of the uncertainties in demand and capacity. While material strengths exhibit a significant scatter at high temperature, no probabilistic model is available to quantify these uncertainties. To fill this gap, this work has **compiled a database of test data on strength retention factors for steel and concrete**, **formulated a set of temperature-dependent probabilistic models** based on these data, and **applied the models in FE analyses of columns in fire**. The proposed material models yield an average response similar to well-established deterministic models (Eurocode), but allow an explicit evaluation of the variability in structural fire response due to experimentally observed variability in material strength.

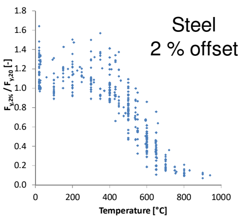
OBJECTIVES

- Compile test data on steel and concrete retention factors
- Formulate probabilistic models to capture the observed variability
- Implement the models in a finite element software
- Run analyses on columns subjected to ASTM fire to assess the effect of uncertainties in material strengths on the fire resistance

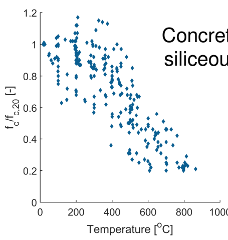
1. DATA ON MATERIAL RETENTION FACTORS



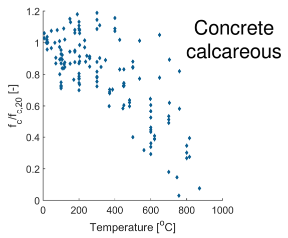
764 datapoints



387 datapoints



242 datapoints

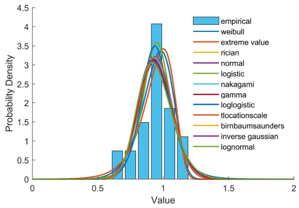


162 datapoints

2. METHODOLOGY

Two methods are tested to establish the probabilistic models

1. Looking at temperature by temperature
   - Divide dataset over temperature groups with increment of 50°C
   - Construct the experimental histograms for each temperature
   - **Identify the type of PDF** (e.g. LN Beta, Weibull, etc.) fitting best for each temperature (AICc criterion)
   - For the selected PDF, **calibrate temperature-dependent functions for the parameters characterizing the PDF**

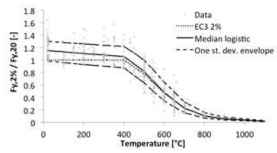


2. Looking at the continuous evolution
   - Use a **temperature-dependent logistic function**
   - Calibrate the function parameters using **Bayesian updating**

3. PROBABILISTIC MODELS FOR RETENTION FACTORS

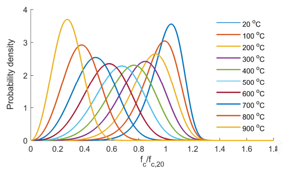
STEEL

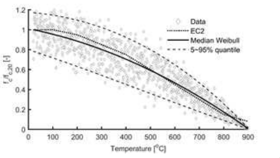
1. Lognormal and a Beta distributions
2. **Logistic** function build on EC3 model
   - Data-based (Bayesian) correction
   - Based on 2% offset yield strength
   - Normalized against 20°C 0.2% offset



CONCRETE

1. **Weibull**
2. Logistic

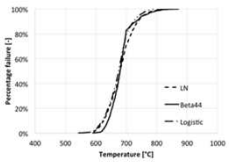




4. ANALYSES OF COLUMNS IN FIRE

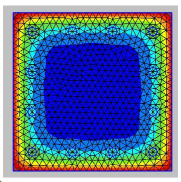
STEEL

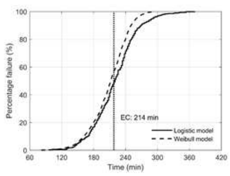
- Column from One Meridian Plaza
- 3.56 m height, W14x311
- Loaded at 25% plastic capacity
- Temperature at failure under uniform heating
- Difference ~20°C at 1-10% quantiles between the models

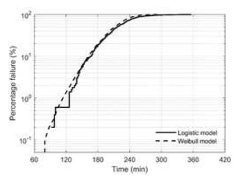


CONCRETE

- Column from a 5-story office building, 3.87 m height
- RC section 450 mm x 450 mm, 16 M25 rebars
- Loaded at 50% of failure load
- ASTM fire on 4 sides, computes the standard fire resistance time







CONCLUSIONS

- Material strengths at high temperature exhibit variability
- This can be quantified by analytical models calibrated on test data
- The adoption of such probabilistic material model leads to a full range of possible fire resistance times for a given column, allowing the explicit evaluation of the structural fire reliability
- Different modeling assumptions lead to close results, for the specific assumptions and structural fire cases tested

➢ Data-informed probabilistic models are given for retention factors of steel and concrete
➢ The models can be used in reliability assessments of structures in fire