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Strain ageing effects on the low-cycle fatigue properties of G300E steel reinforcing bars.

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Content

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Introduction

- Buckling of rebars after Kaikoura 2016 earthquake
- Low-cycle fatigue (LCF)
- Strain ageing

LCF experimental testing

- Material and mechanical properties
- Methodology
- Results and discussion

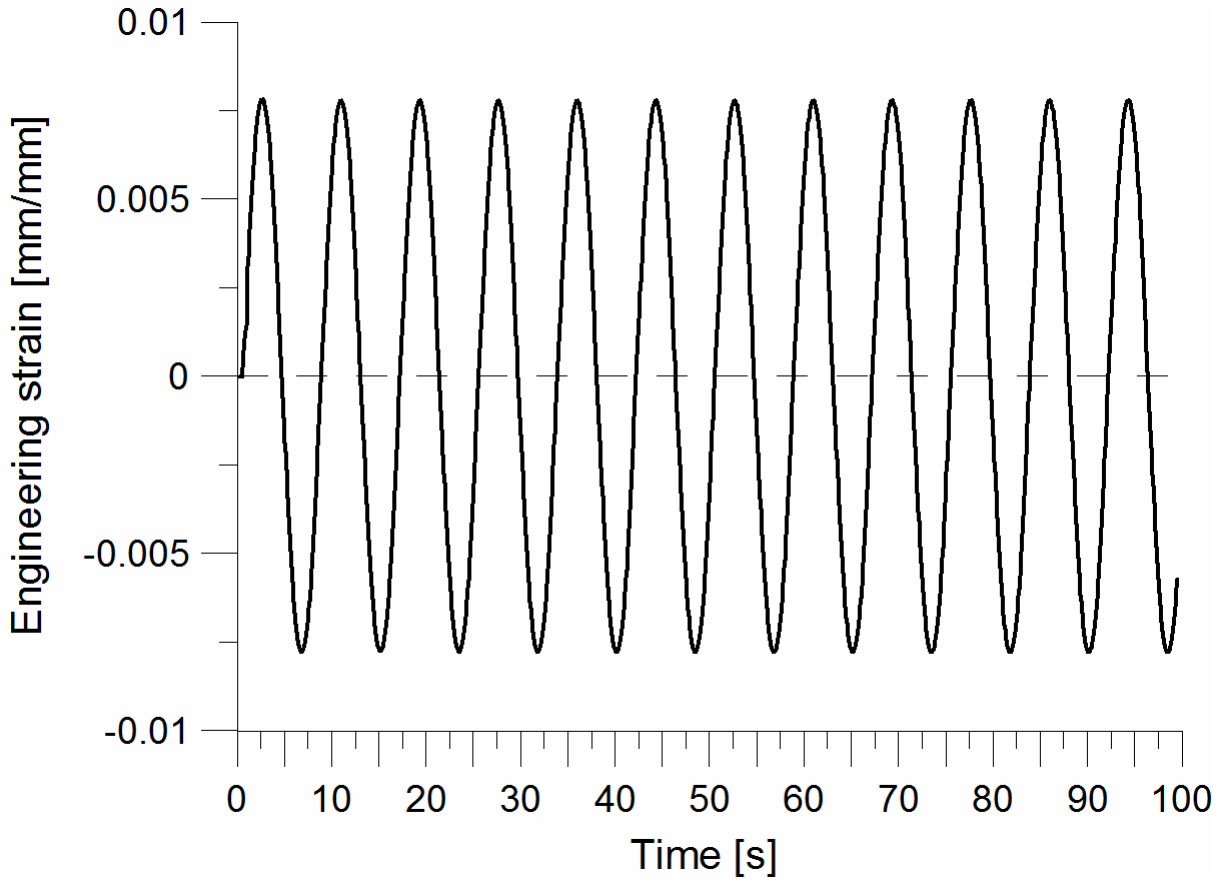
Conclusions

Observed damaged

Kam et al (2011).

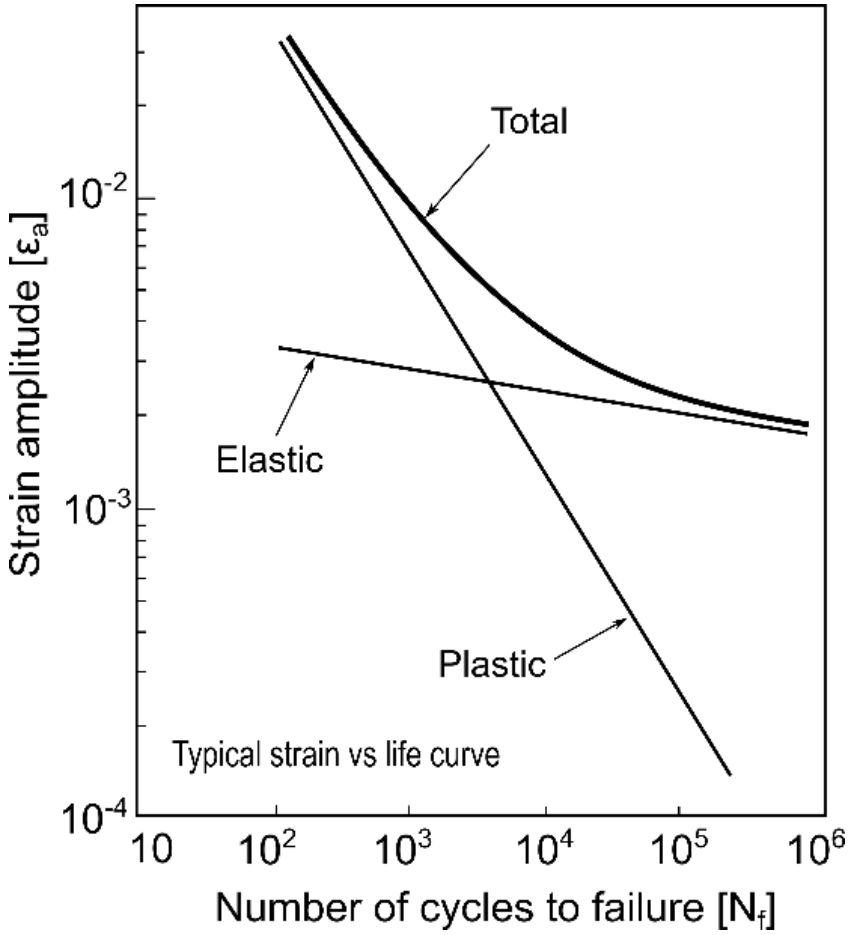
Low-cycle fatigue (LCF) test

Strain history



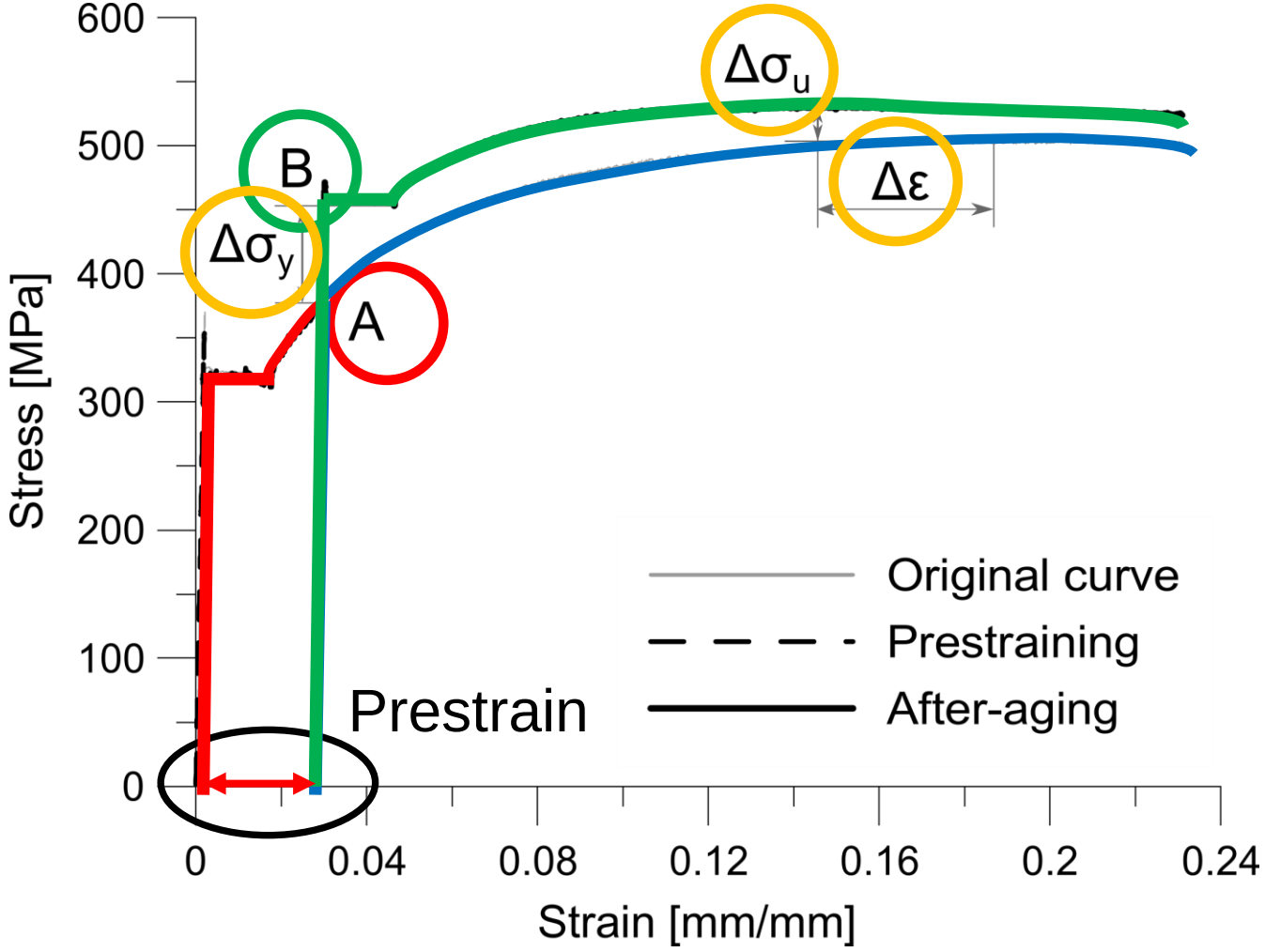
Coffin-Mason model (1954)

$$\varepsilon_a = \frac{\sigma'_f}{E}(2N_f)^b + \varepsilon_f(2N_f)^c$$



Strain ageing

The mechanical properties of (some) strained low-carbon steel are subject to a “strain ageing” phenomenon.



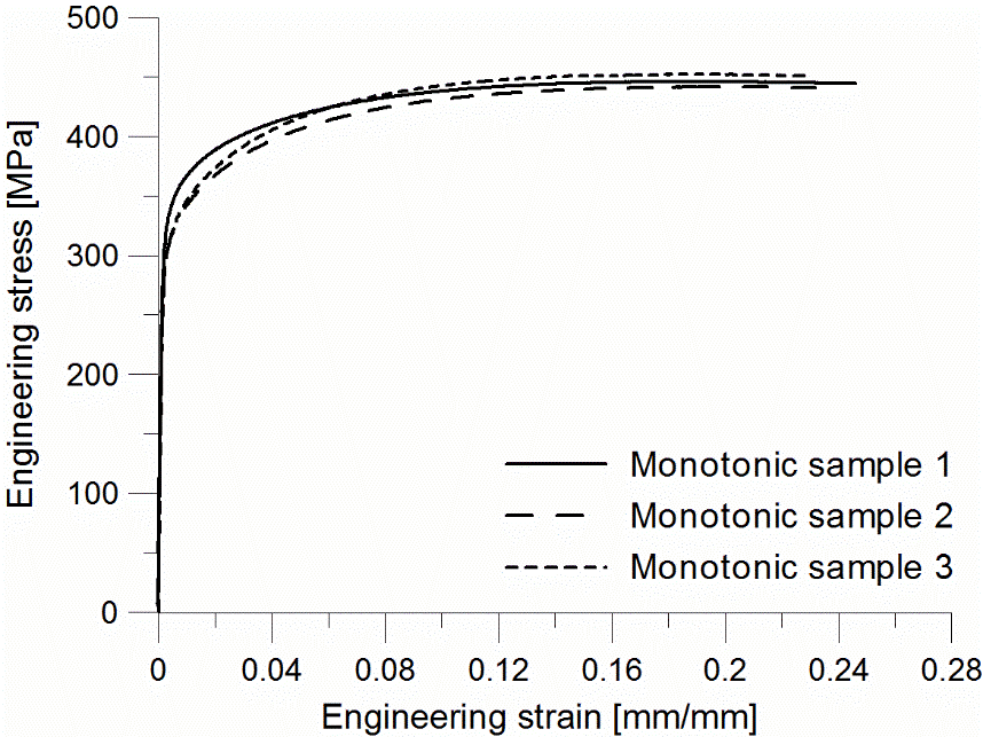
Monotonic test:
Grade 300E
Prestrain amount:
3%
Ageing time: 1year

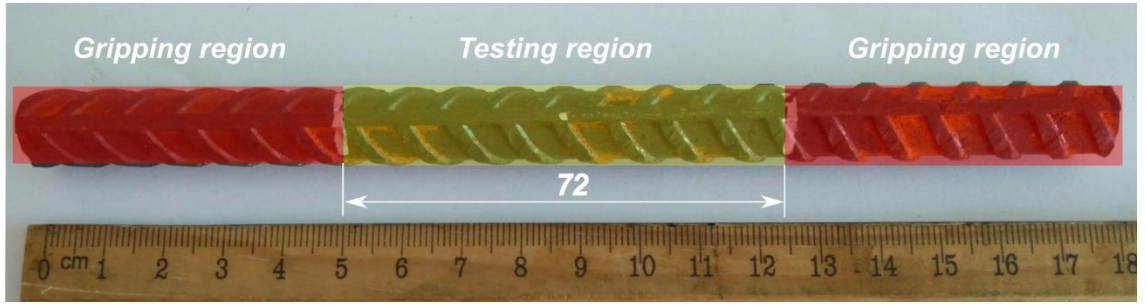
$\Delta\sigma_y$ = ~ 70 MPa
$\Delta\sigma_u$ = ~ 30 MPa
$\Delta\varepsilon$ = ~ 0.05 mm/mm

Material and methodology

Grade 300E

σ_y = 314 MPa
σ_u = 447 MPa
ε_u = 19.3 %

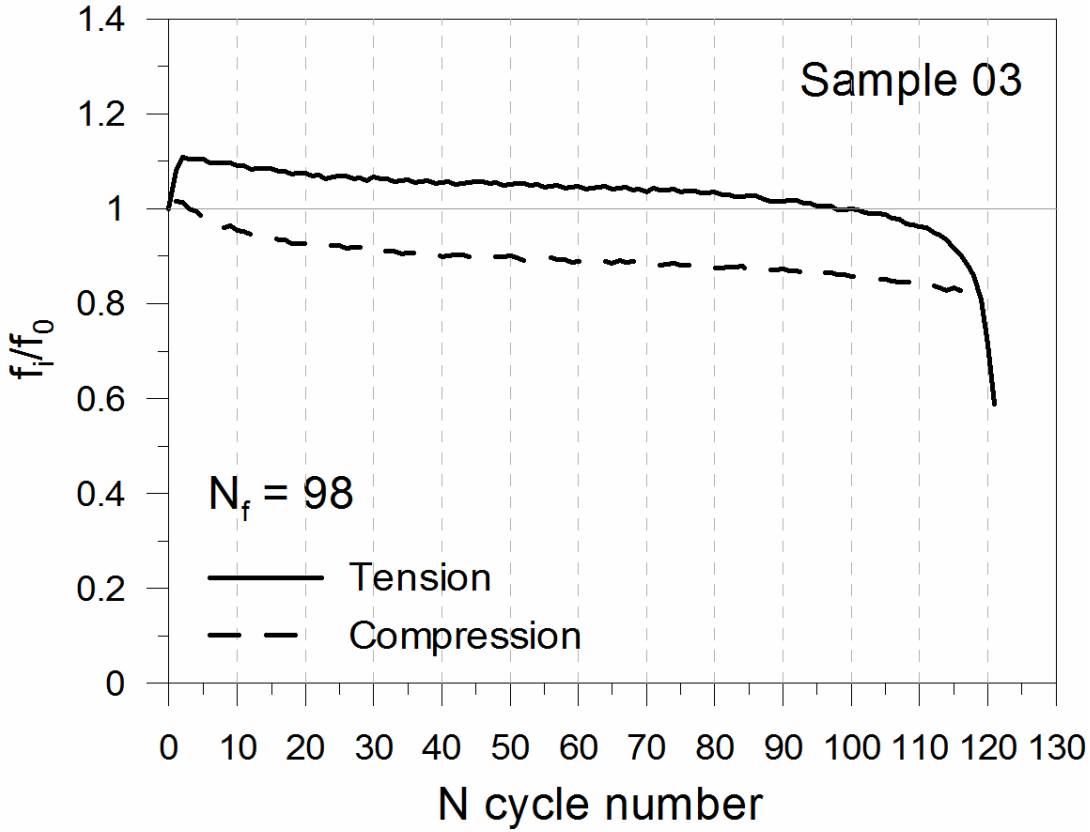




Methodology

Determination of the number of cycle to failure

$\varepsilon_a < 0.02$ mm/mm



$\varepsilon_a > 0.02$ mm/mm

Methodology

Strain amplitude	Frequency (Hz)	Number of cycles to failure
0.0078	0.12	125
0.0078	0.12	130
0.0083	0.12	98
0.0107	0.11	61
0.0140	0.09	34
0.0140	0.09	32
0.0178	0.06	14
0.0179	0.06	16
0.0179	0.06	13
0.0271	0.04	6
0.0272	0.04	6
0.0275	0.04	7

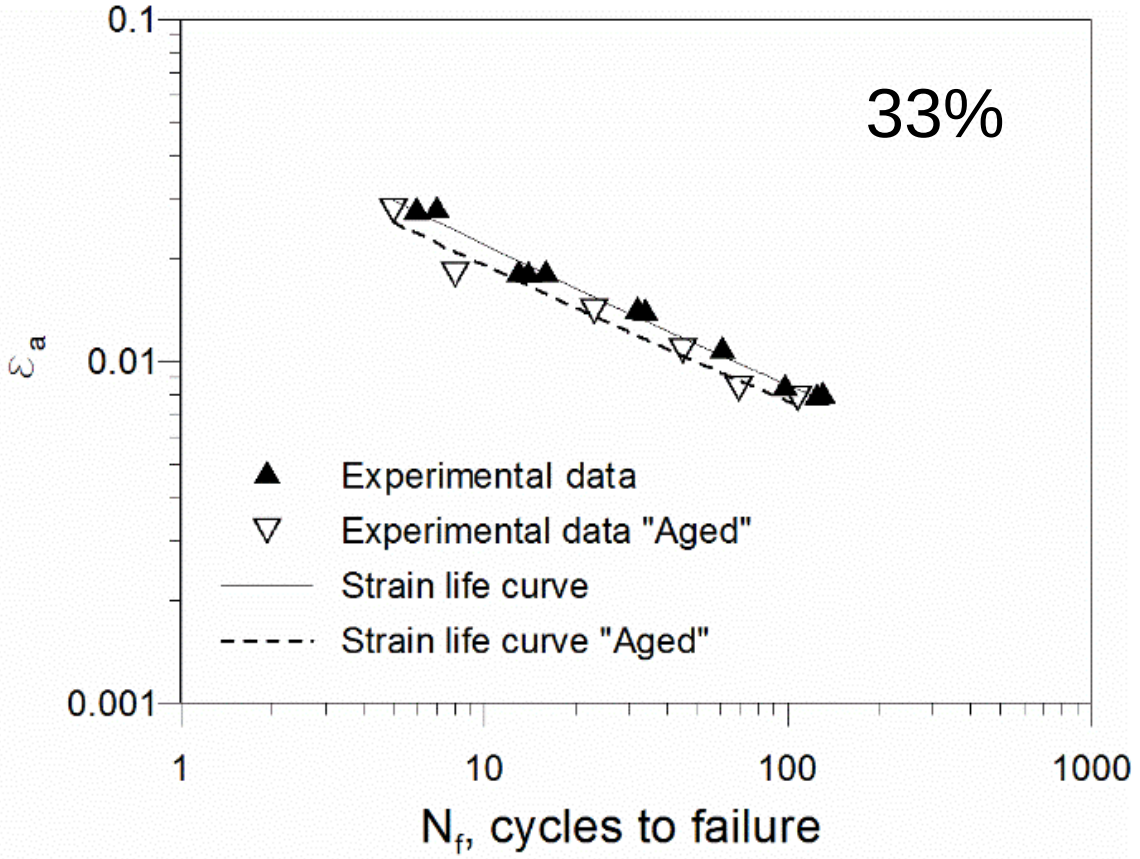
Precycling to 33%N_f and 66%N_f

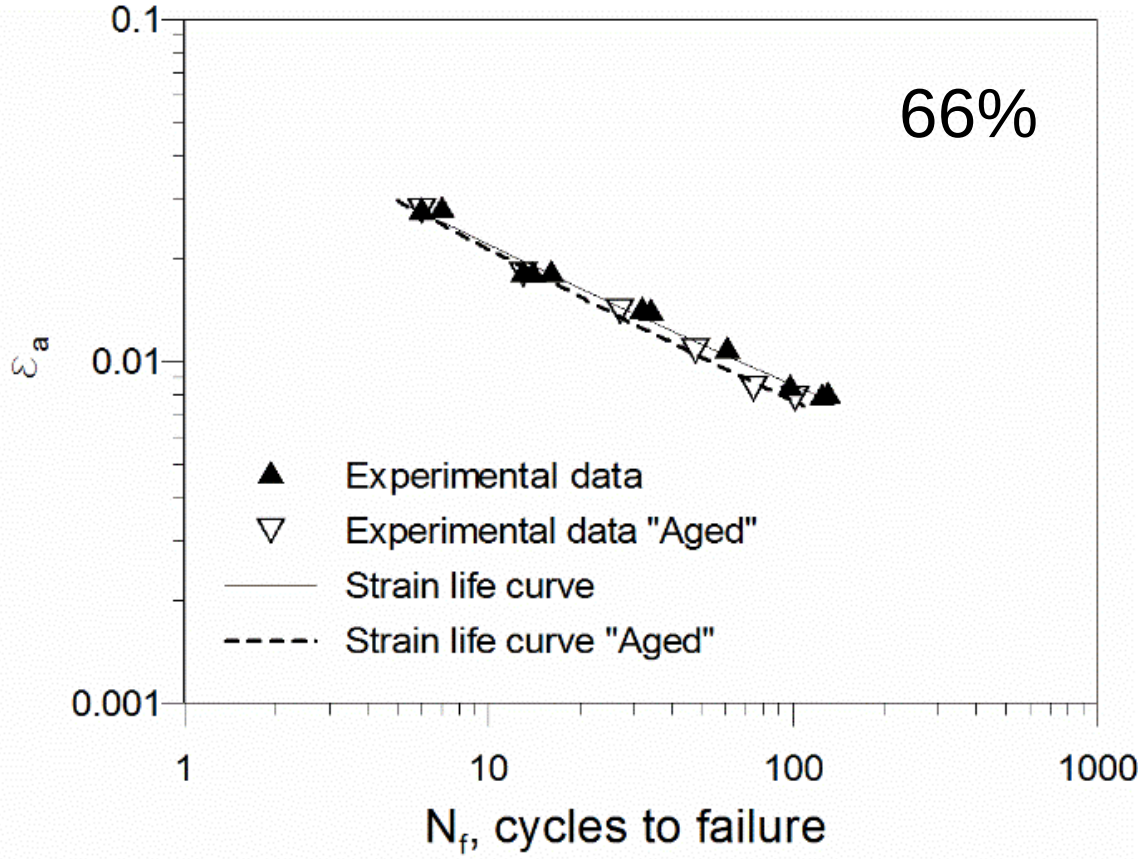
"Accelerated" Ageing phase

Cycling tests to failure

Results and discussion

Original model: $\varepsilon_a = 0.0025\left(2N_f\right)^{-0.076} + 0.080\left(2N_f\right)^{-0.464}$





$\varepsilon_a = 0.0025\left(2N_f\right)^{-0.076} + 0.067\left(2N_f\right)^{-0.456}$

$\varepsilon_a = 0.0025\left(2N_f\right)^{-0.076} + 0.088\left(2N_f\right)^{-0.507}$

Results and discussion

Loss due to strain ageing = (Expected – Actual) Remaining Fatigue Life

Strain amplitude	Loss due to strain ageing for samples precycled to 33% [%]	Loss due to strain ageing for samples precycled to 66% [%]
0.0078	20.5	56.1
0.0083	43.9	72.7
0.0107	39.0	61.9
0.0140	42.9	45.5
0.0179	72.7	50.0
0.0275	40.0	33.3

Conclusions

- Strain ageing not only causes a reduction in ductility but also a reduction in the fatigue life
- Steel manufactured with the addition of vanadium (e.g. NZ-Grade 500E) are not prone to strain ageing
- The developed fatigue models could be used to estimate the remaining fatigue life of earthquake-damaged structures
- No technique is able to quantify the remaining number of cycle to failure

Thanks, any questions?

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