Influence of Curing Temperature on Strength Development of Concrete

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Influence of Curing Temperature on Strength Development of Concrete

Background:

- Minimize the risk of thermal cracking in large concrete structures using temperature and stress analysis.

Problem – risk of cracking in Large Concrete Structures:

Thermal cracks in top of restrained wall

Thermal cracks in wall cast on existing structure

Using Temperature and Stress analysis in the planning phase can significantly minimize the risk of thermal cracking in large concrete structures

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Is the result of a temperature and stress analysis reliable?

- If the input parameters are right – yes!

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Questions have been raised regarding:

- The applicability of the maturity concept to modern concretes.
- The effect of the curing history on compressive strength of laboratory samples cured at elevated temperatures.

Development of strength - a decisive input parameter for the Temperature and Stress analysis

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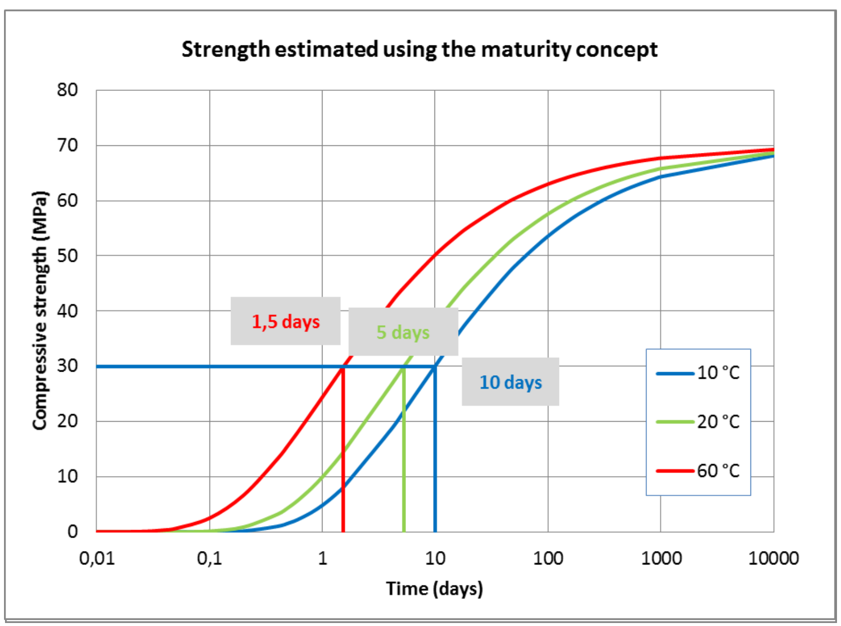
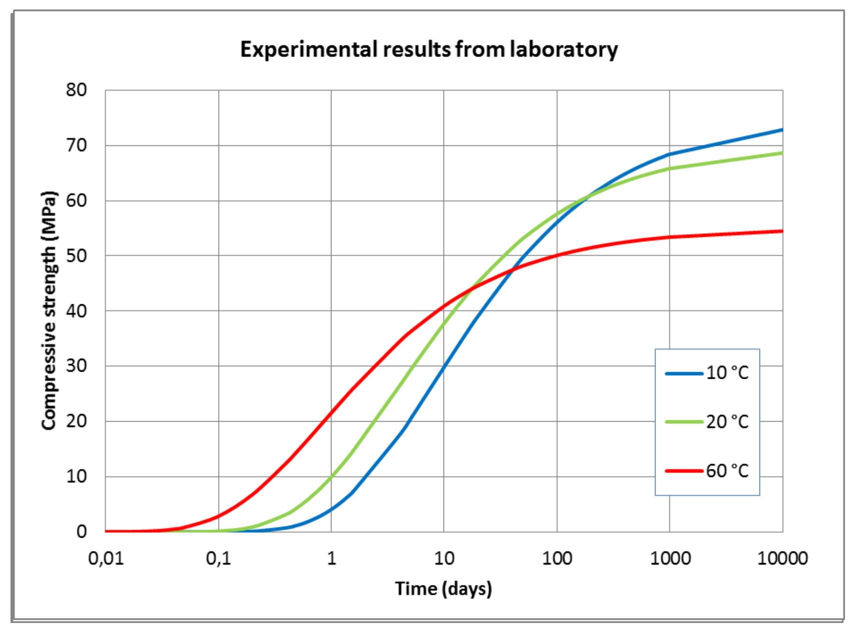
1. The applicability of the maturity concept to modern concretes.
2. Validity of experimentally determined strength values for samples exposed to high curing temperatures.

$$M = \sum_{i=1}^{n} H\,(\theta_i)\,\Delta t_i$$





The applicability of the maturity concept to modern concretes

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Activation Energy

Freiesleben, 1977:

$$M = \sum_{i=1}^{n} H\left(\theta_i\right) \Delta t_i \qquad H(\theta) = \ exp\left[\frac{E(\theta)}{R}\left(\frac{1}{293} - \frac{1}{273+\theta}\right)\right]$$

Since 1977, we have used:

$E(\theta) = \text{B}$ $= 33{,}500$ J/mol for $\theta \geq 20$ °C

$E(\theta) = \text{B} + \text{C}\ (20-\theta)$ $= 33.500 + 1.470\ (20 - \theta)$ J/mol for $\theta < 20$ °C

- Introduction of new cements
- Increased use of fillers and pozzolans (limestone powder, fly ash, micro silica ect.)
- How has this effected the Activation Energy ***E(θ)*** ?

The maturity concept – experimental investigation

Four concretes:

Concrete	**A (LA)**	**B (LA+FA)**	**D (Rapid+FA)**	**E (Slag)**
Low alkali cement, CEM I 42.5 N	100	75		
Rapid cement, CEM I 52.5 N			75	
Slag cement, CEM III/B				100
Fly ash		25	25	

Six curing temperatures: 5, 10, 20, 30, 45 and 60 °C.

Five ages (from 24 m-hours to 28 m-days)

Compressive strength: 3 Ø100 x 200 mm cylinders for each combination of concrete, temperature and age.

The maturity concept

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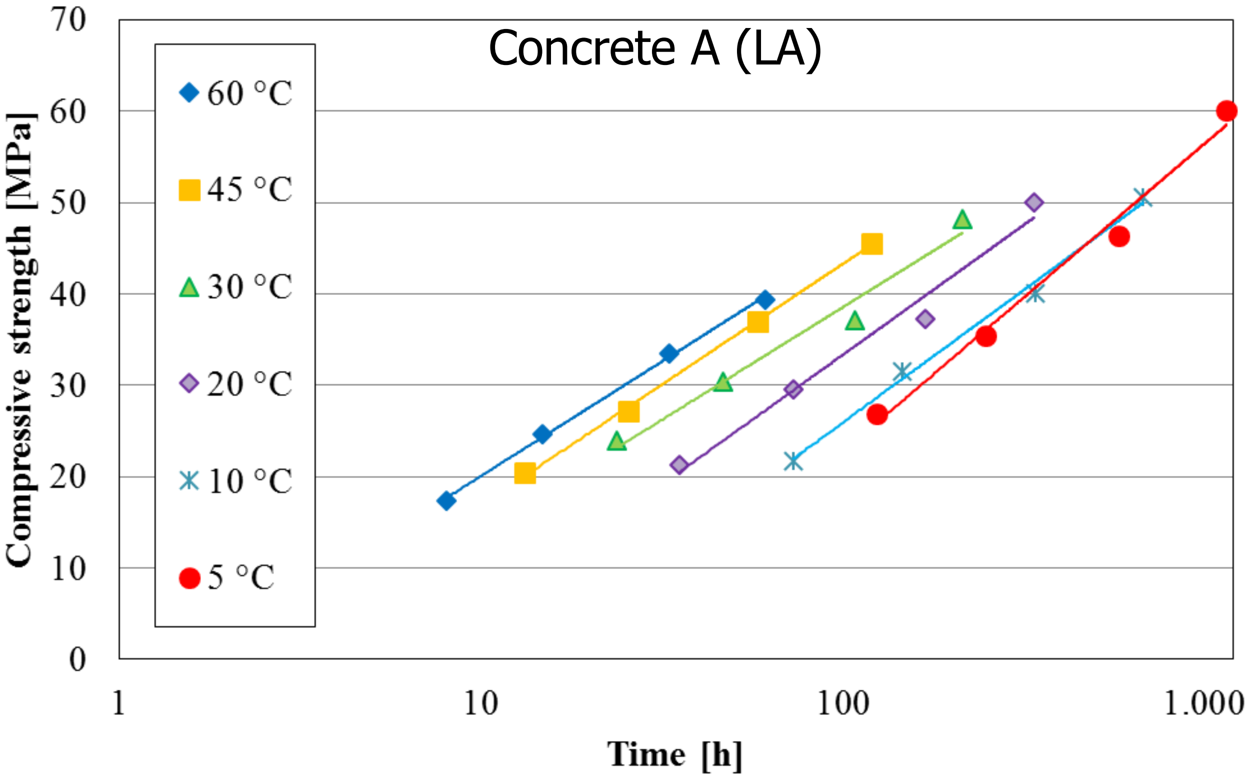
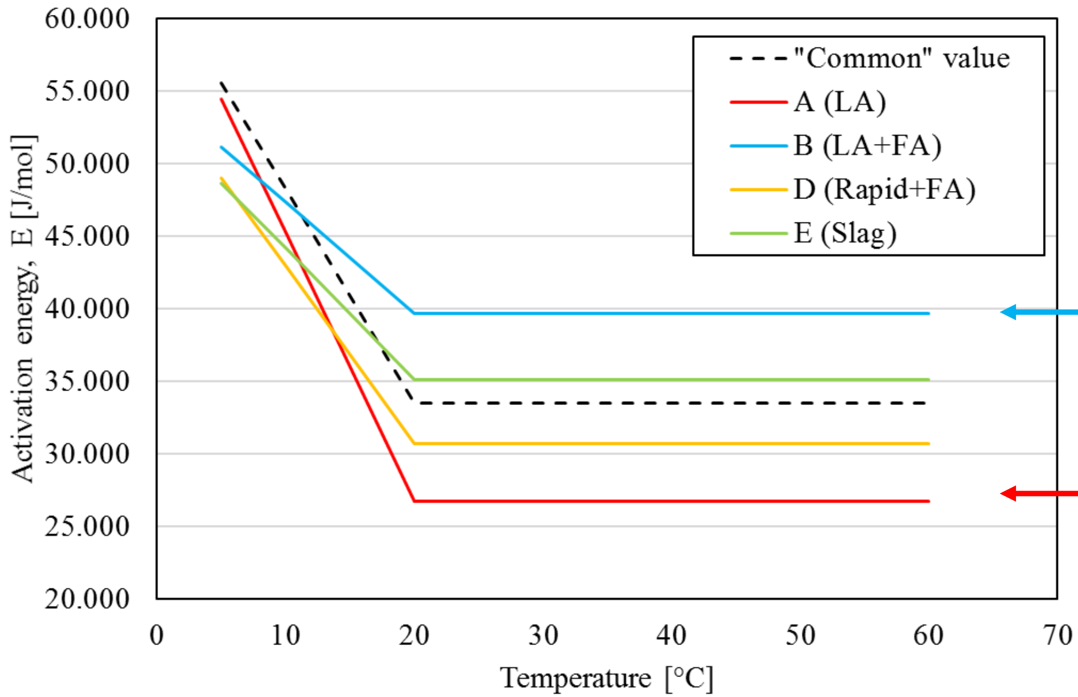
The activation energies calculated using the principles of the test method TI-B 103:

$$E(\theta_n) = (\ln k_{\theta n} - \ln k_{20}) \frac{R}{\left(\frac{1}{T_{20}} - \frac{1}{T_{\theta n}}\right)}\,, \qquad \theta_n \neq 20\,°C$$



The maturity concept

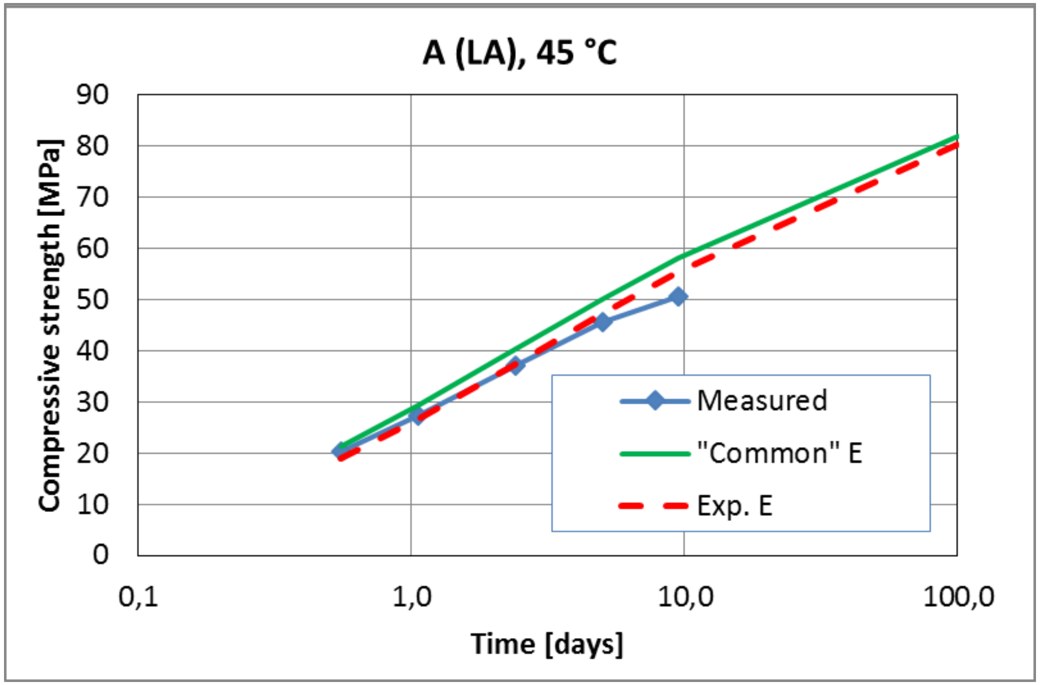
Mix design	Activation energy		
	E(≥20) [J/mol]	C [J/mol/°C]	E(<20) [J/mol]
A (LA)	26.690	1.851	26,690 + 1,851 (20–θ)
B (LA+FA)	39.682	765	39,682 + 765 (20–θ)
D (Rapid+FA)	30.651	1.225	30,651 + 1,225 (20–θ)
E (Slag)	35.098	903	35,098 + 903 (20–θ)
"Common" value	33.500	1.470	33,500 + 1,470 (20–θ)



B (LA+FA): + 18%

A(LA): – 20%

The maturity concept



Conclusion:

- The activation energy does vary with the binder composition (± 20%).
- Only a slight improvement of the estimated compressive strengths is obtained using the experimentally determined value of E(θ).
- Determination of E(θ) requires a comprehensive testing program – thus the common value of E(θ) is still "best practice" for most modern concretes.

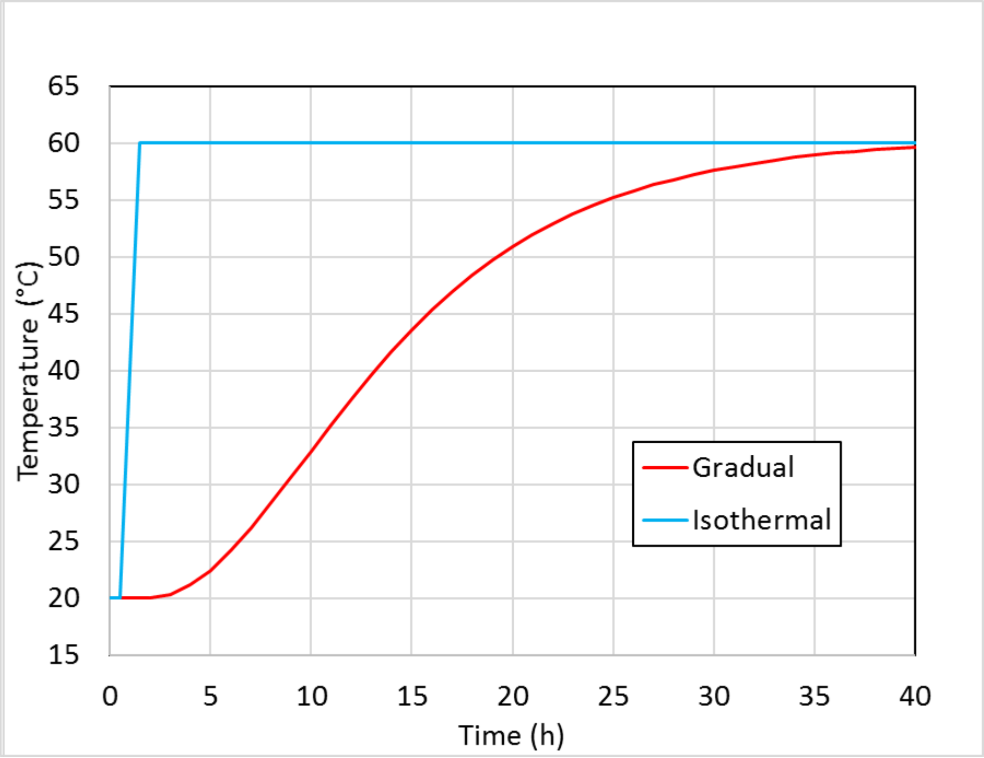
Impact of curing history on strength of laboratory samples cured at high temperatures

Four concretes: A (LA), B (LA+FA), D (Rapid+FA), E (Slagg)

Two different curing scenarios were applied for samples cured at 60 °C:

1. Isothermal curing at 60 °C.

2. Gradually increased temperature from 20 to 60 °C.



Impact of curing history on strength of laboratory samples cured at high temperatures

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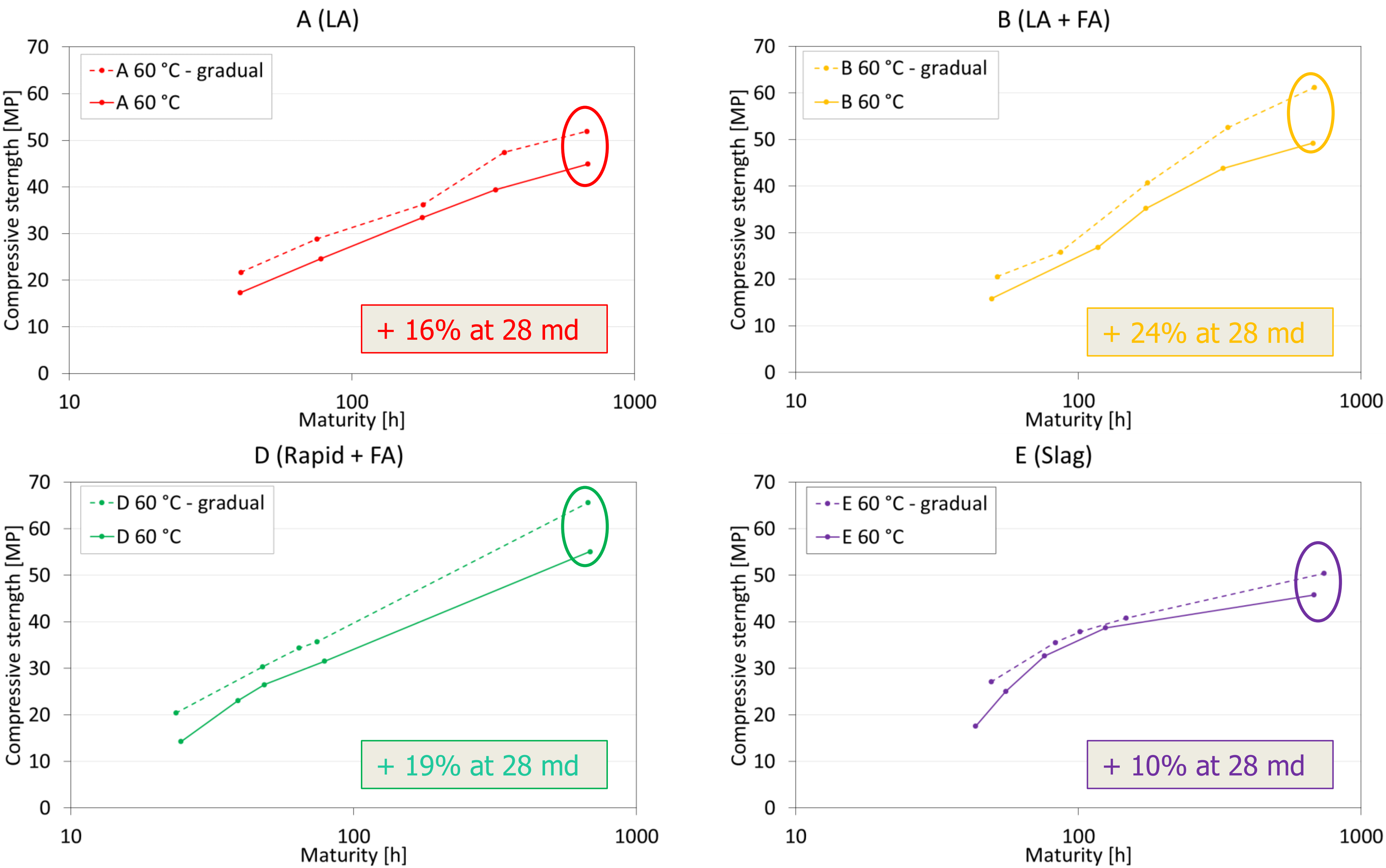

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Impact of curing history on strength of laboratory samples cured at high temperatures

Conclusion:

- The temperature history of concrete samples cured at elevated temperatures has a significant impact on the compressive strength.
- Gradual heating of the concrete, results in a significantly higher strength than when curing takes place at a constant high temperature.
- The above shall be taken into consideration in the planning of laboratory experiments that shall estimate the strength in a structure that will be exposed to high temperatures during the curing process.

4C-Temp&Stress for concrete - Demo

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A demo version of 4C-Temp&Stress is curently unavailable for downloading. The new demo version will be available by the end of May 2015.

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