Influence of gamma irradiation on the expansion of concrete with different aggregates

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Motivation and objective of investigation

Due to gamma irradiation the mechanical properties of concrete are changed provided that the gamma dose is above certain threshold level:

- reduction of strength, elastic modulus – the dose > ca. 200 MGy,
- volumetric changes (shrinkage) due to drying of cement paste, related to water radiolysis and gamma heating.

Volume changes of concrete may also occur as a result of „internal swelling reactions” in wet concrete; high moisture saturation of the pore system favors the occurrence of expansive reactions, such as alkali-aggregate reaction, delayed ettringite formation.

Objective of investigation: to reveal the influence of gamma irradiation on the volume stability of wet concrete at conditions favoring the detrimental internal swelling reactions.

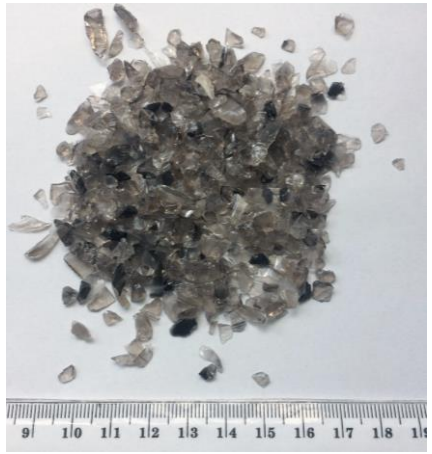
Experiments: main constituents of concrete

- **Cement CEM I 52.5 R**

- fineness: 525 m^2/kg (PN-EN 196-6)
  - soundness: < 1 mm (Le Chatelier method)
  - chemical composition determined using XRF method

Constituent	Quantity [%]
SiO_2	19,42
Al_2O_3	5,45
Fe_2O_3	2,94
CaO	64,10
MgO	1,75
SO_3	3,50
Na_2O	0,24
K_2O	0,97
Na_2O_{eq}	0,88

- **Rock aggregates prone to alkali-silica reaction**



Obsidian

Sandstone

Flint

Greywacke

Aggregate	Bulk density [g/cm^3]
Greywacke	2,60
Obsidian	2,38
Flint	2,74
Sandstone	2,60

Experiments: mortar specimens

- **Mortar composition:**
- water-cement ratio 0.47
- content of cement: 600 kg/m^3
- volume of aggregate: 52.4%
- aggregate gradation: 0-4 mm

- **Number of specimens:** 46
  (10 or 13 of each mortar)

- **Size of specimens:** 25x25x140 mm

Specimens after demoulding

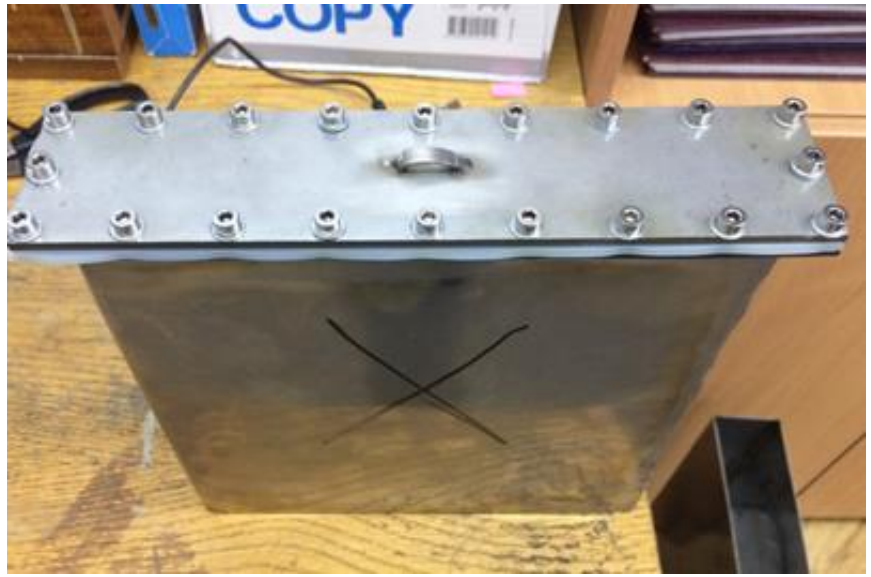
Experiments: exposure conditions

- **Storage:** specimens immersed in 1 M NaOH solution
- **Exposure condidions**:

- **38, 60** and **80°C** (IPPT PAN laboratory)
- gamma irradiation,
  total dose: **10.9±0.6 MGy** (JIPNR Sosny)

- **Exposure time:** approx. 3 months

^{60}Co Irradiation chamber UGU-420 of the Joint Institute for Power and Nuclear Research – Sosny, Belarus



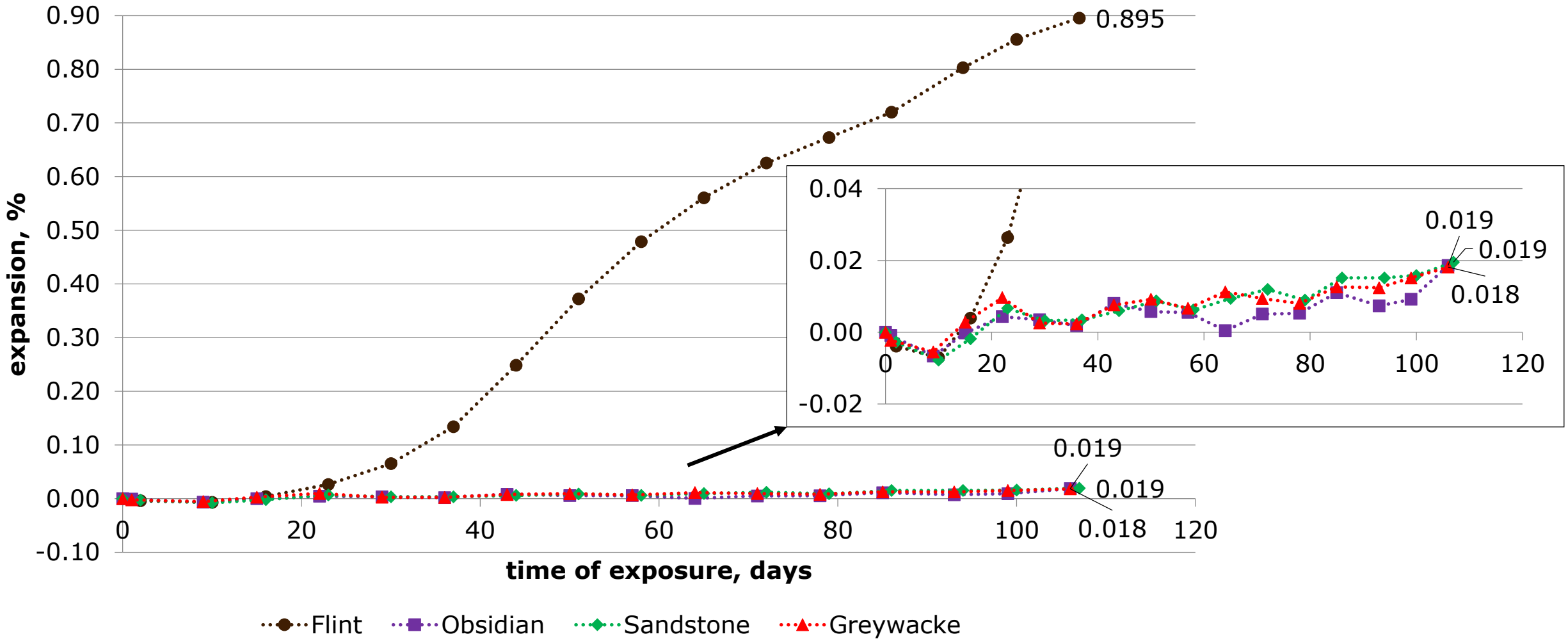
Stainless steel container for specimens

Experiments: test methods

- **Characterization of constituent materials:**
  - Petrographical examination on thin sections
  - Chemical composition (XRF method)
  - Phase composition (XRD method)
- **Physical and microstructural tests on irradiated and reference specimens:**
  - Linear expansion vs. time of exposure
  - Flexural and compressive strength
  - Coefficient of thermal expansion
  - Porosity size distribution (MIP)
  - Identification of reaction products (SEM/EDS)

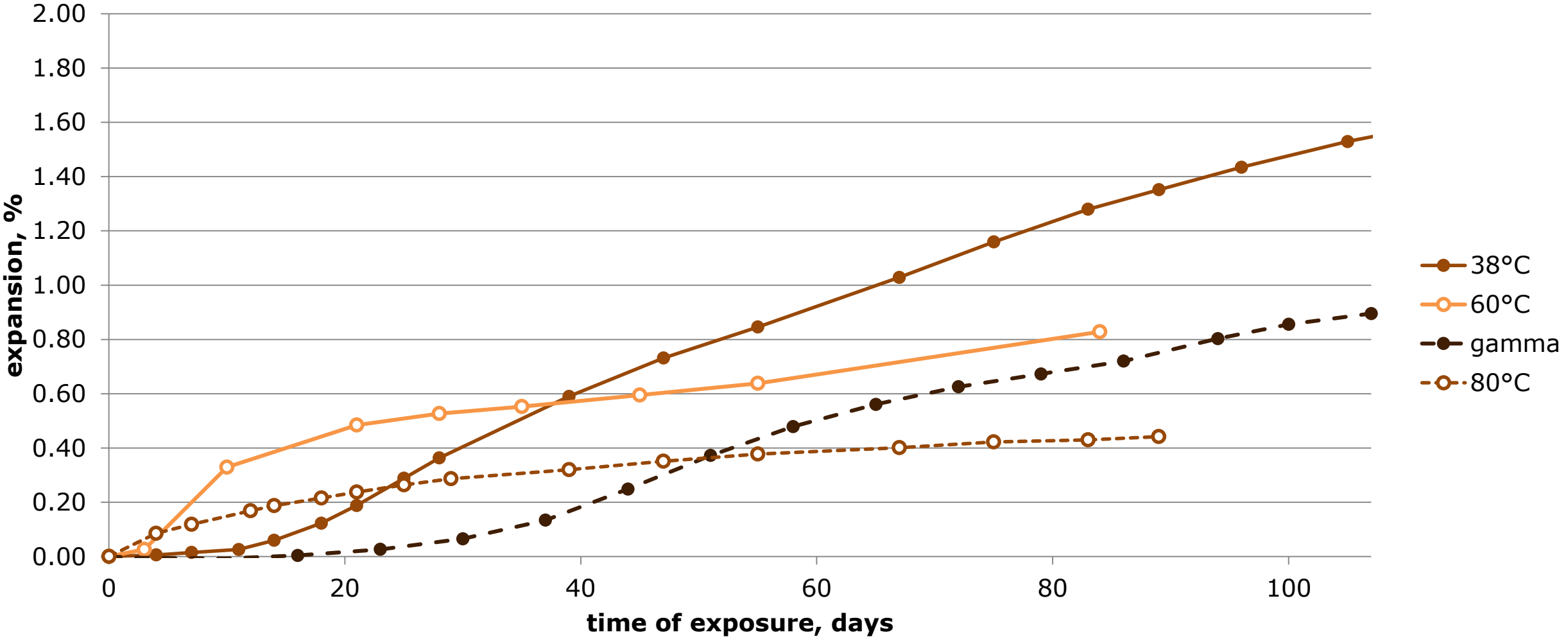
Linear expansion due to gamma irradiation

Expansion - time curves for mortars with 4 different aggregates



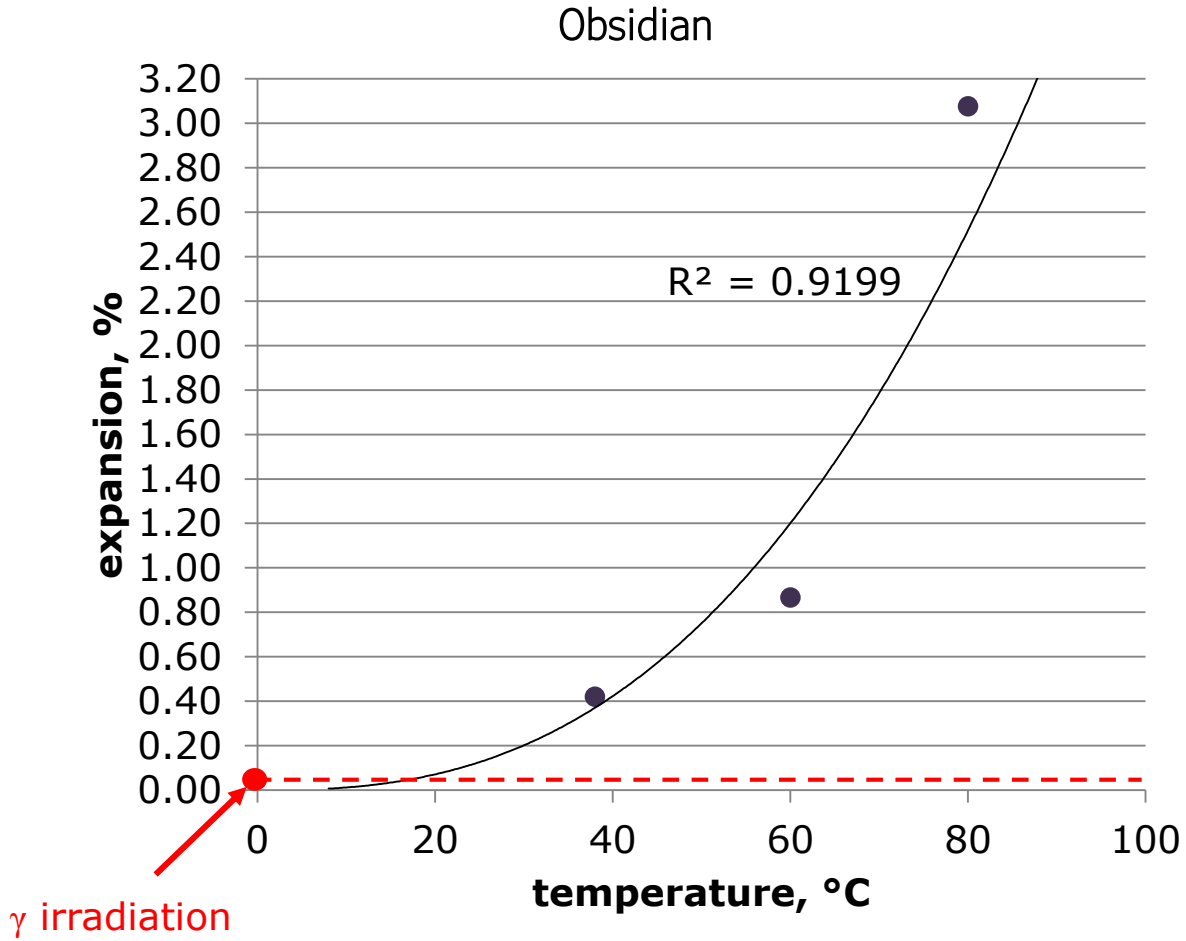
Linear expansion in time

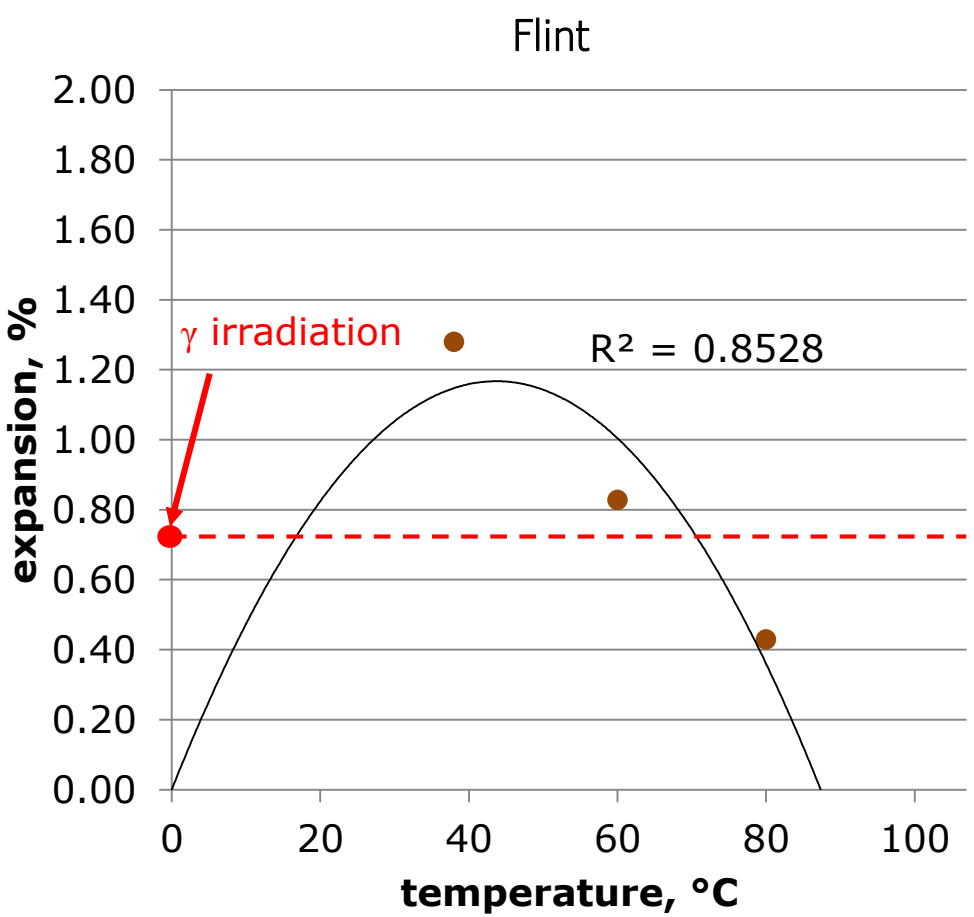
Flint aggregate: mortar bars exposed to 1 M solution of NaOH and elevated temperature or gamma irradiation



Linear expansion – temperature/gamma irradiation

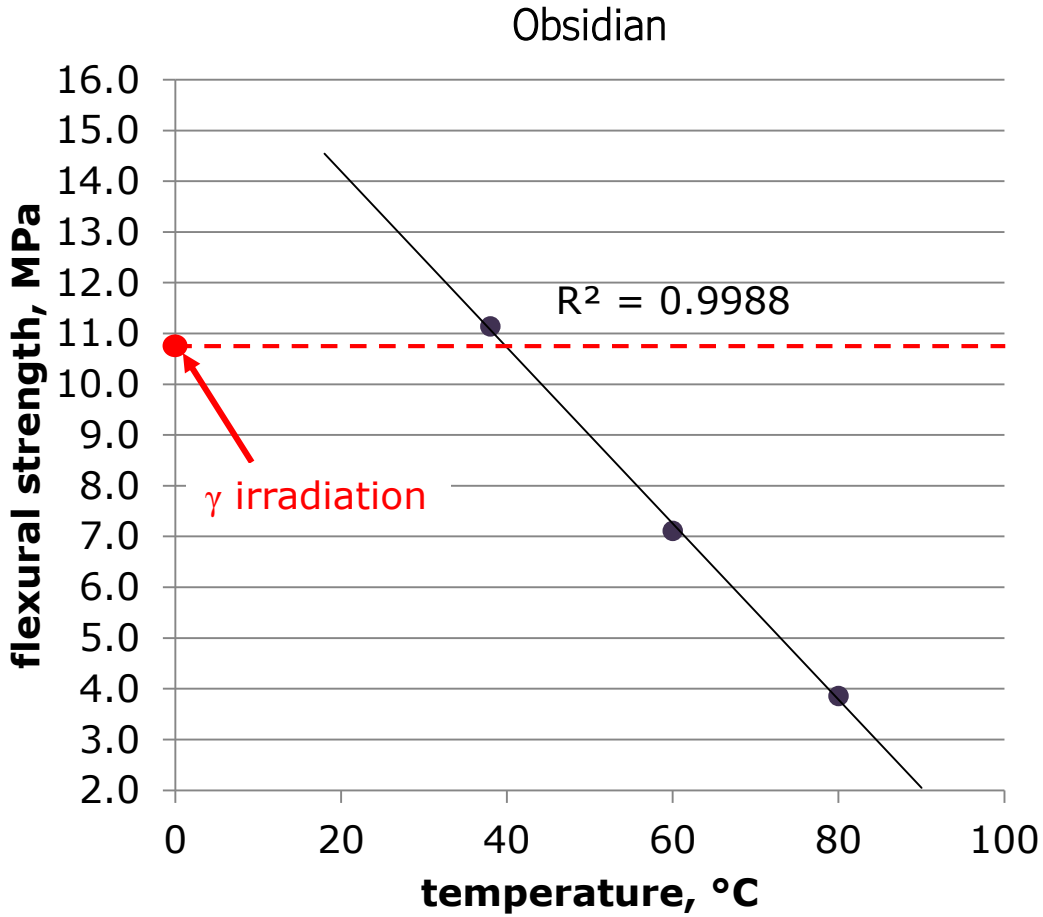
Relationship between expansion of mortar bars exposed to 1 M solution of NaOH and exposure temperature

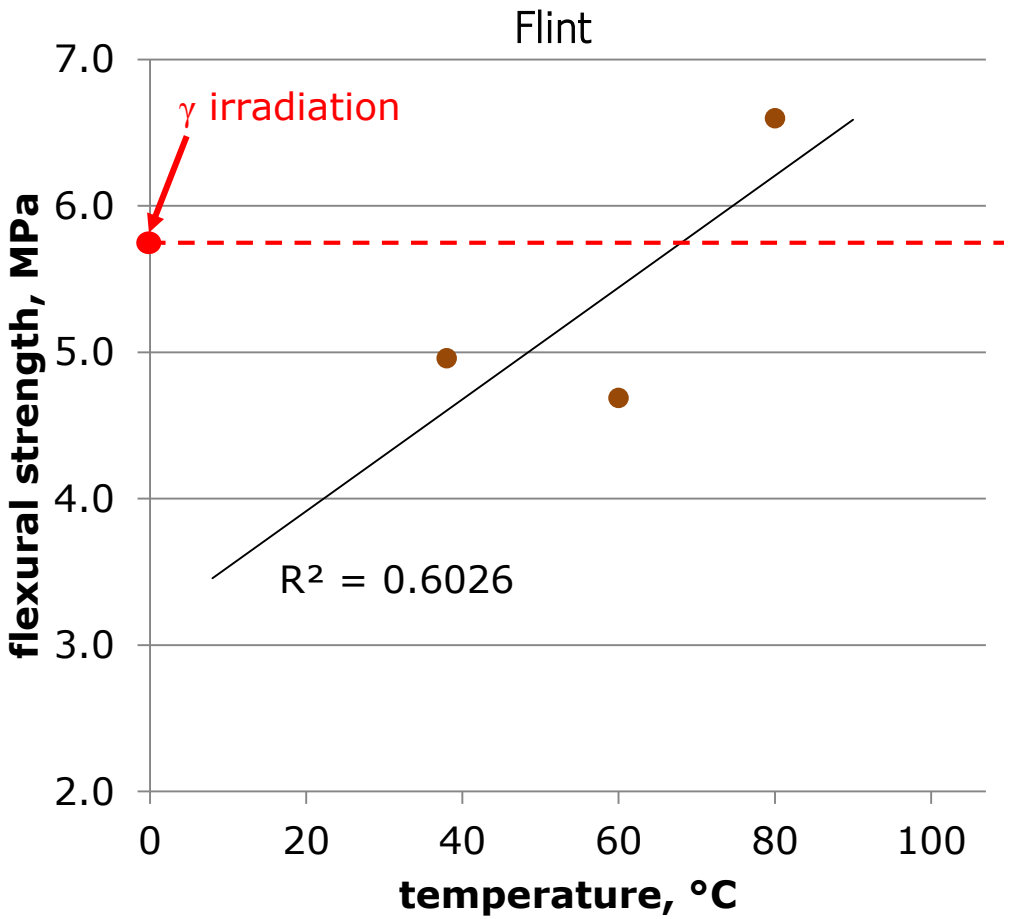




Flexural strength – effect of elevated temperature or gamma irradiation

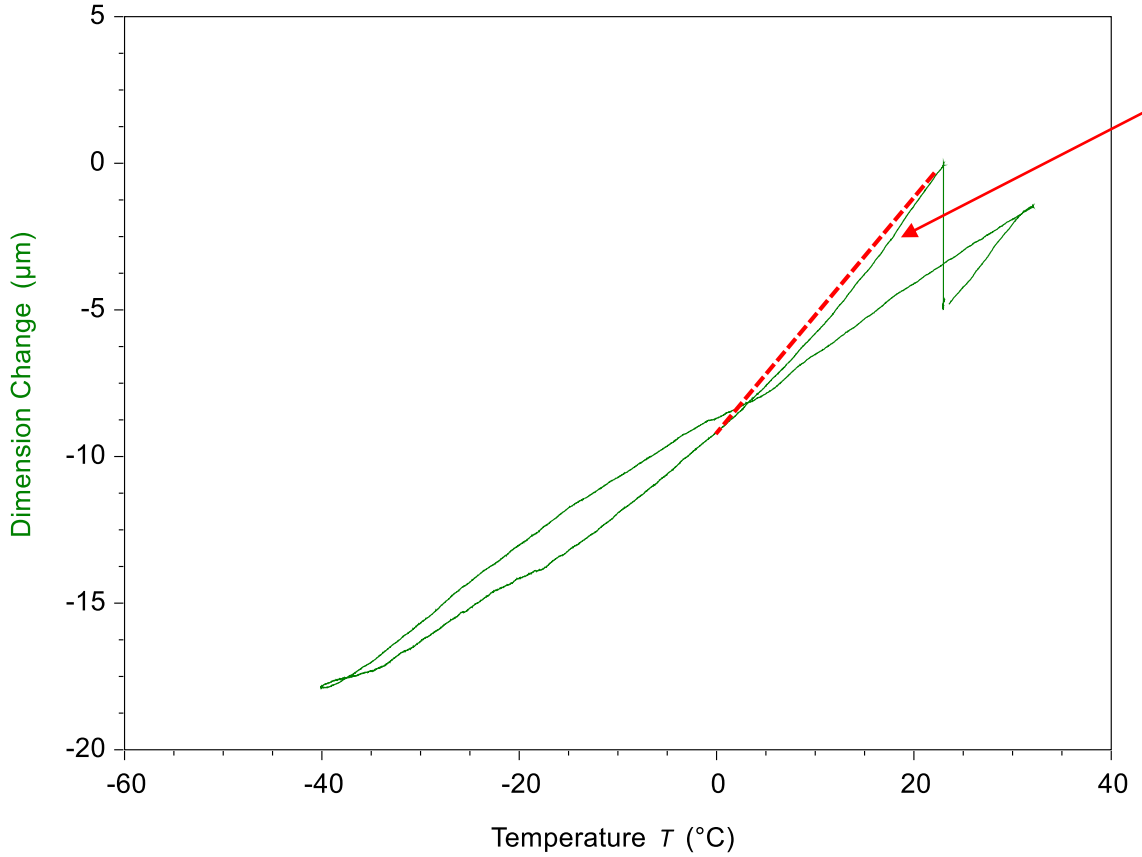
Mortar bars exposed to 1 M solution of NaOH and elevated temperature /gamma





Coefficient of linear thermal expansion

Dimension change – temperature curve: mortar with flint exposed to eleveted temperature of 38°C



CLTE for mortars exposed to eleveted temperature of 38°C:

Aggregate	CLTE $\left[\frac{\mu m}{m \cdot °C}\right]$	Expansion [%]
Flint	18,0	1,435
Obsidian	11,1	0,045
Sandstone	15,8	0,024

Final remarks

- Significant linear expansion of mortar bars due to gamma irradiation was observed only for flint aggregates (up to 0.9% at absorbed gamma dose 10.9 MGy).
- The shape of expansion - time curve was similar to these obtained at elevated temperature of 38°C.
- In spite of identified susccesibility of obsydiane, greywacke and sandstone aggregate to expansive alkali-silica reaction, the expansion due to gamma irradiation was not observed.
- Effects of elevated temperature on the linear expansion of mortar specimens were dependent on the mineral composition of rock aggregate.
- No significant change of flexural or compressive strength due to gamma irradiation was observed.
- Coefficient of thermal expansion was related to the mineral composition of rock aggregate and effects of the gamma irradiation/temperature exposure are under investigation.

THANK YOU FOR ATTENTION!

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