Experimental investigation of strain behavior and concrete properties of thermally-loaded structures

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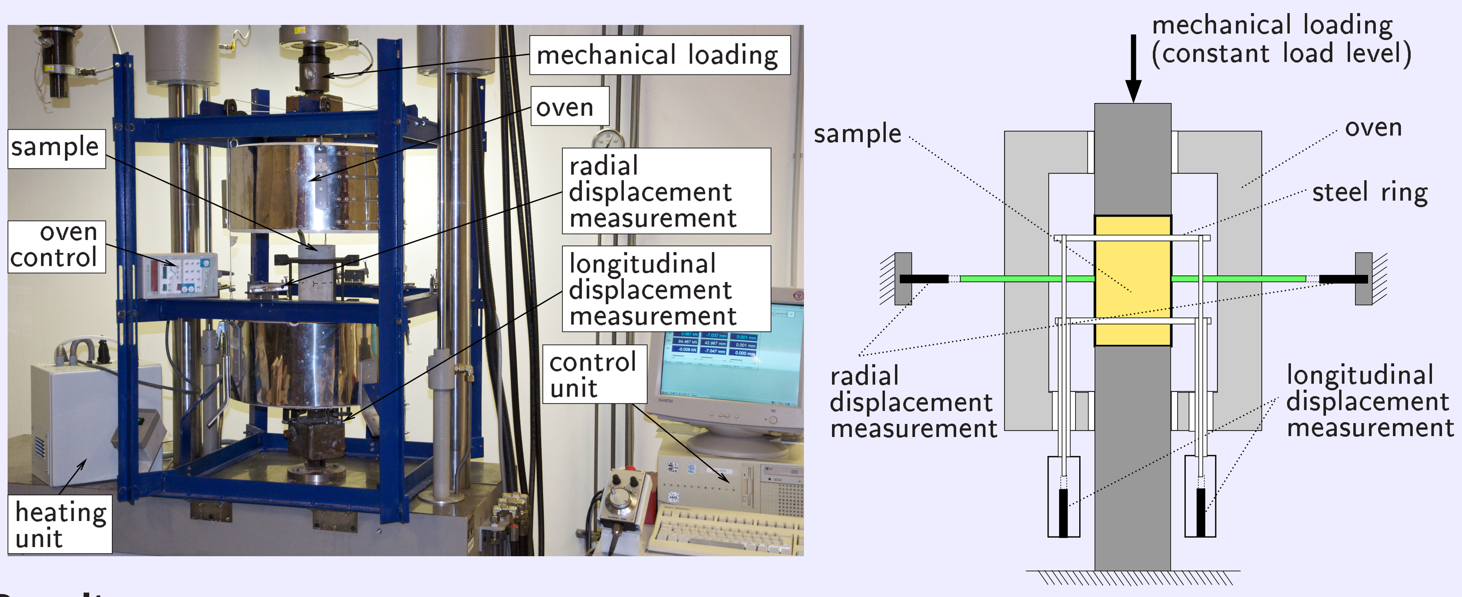
Within experimental research activities at the IMWS (TU-Vienna), following material properties of concrete subjected to high temperature are investigated: (i) the strain behavior of concrete under combined thermal and mechanical loading and (ii) the permeability increase of temperature-loaded concrete and cement paste.

Strain Behavior

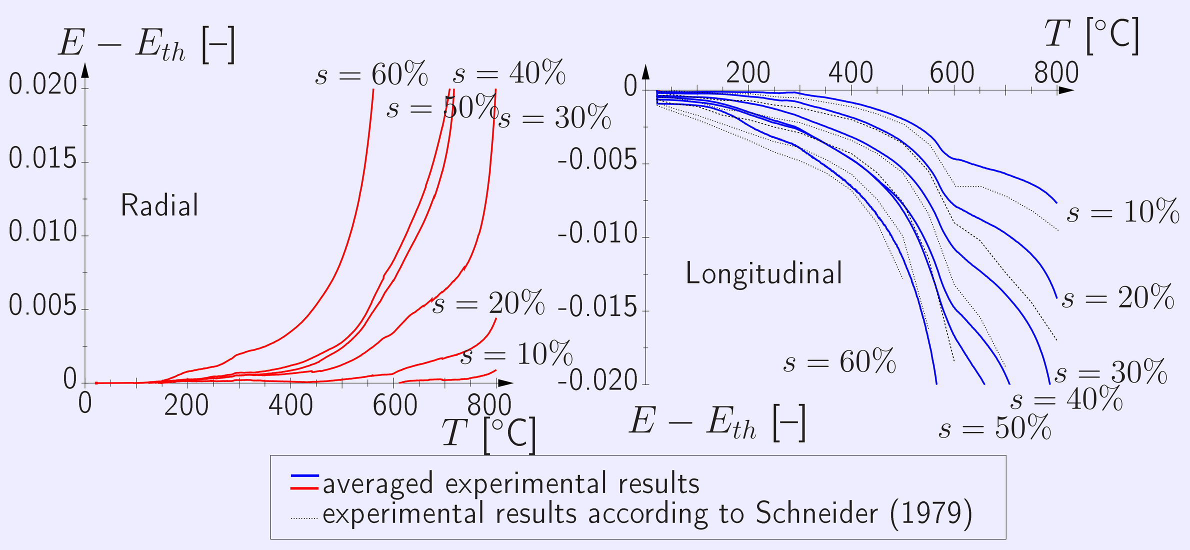
Testing Device:
Concrete specimen and steel pistons used for mechanical loading are surrounded by a radiant oven, enabling for simultaneous mechanical and thermal loading. Therefore, the testig device can be used for a wide range of testing under temperature (creep, compressive strength, Young's modulus,...).
Longitudinal and radial displacements are monitored by displacement sensors connected to the specimen via temperature-resistant steel rods. In longitudinal direction, the relative displacement between two steel rings mounted to the specimen is recorded.



Results:
In order to identify the described path dependence in the strain behavior, concrete cylinders (with polypropylen fibers, 100 mm in diameter and 200 mm long) were subjected to combined thermal (radiant) and mechanical (compressive) loading (see [1] for more details). The experiments were conducted at different load levels $s = \Sigma/f_{c,0}$ [–] (i.e., the ratio between stress and compressive strength at room temperature).

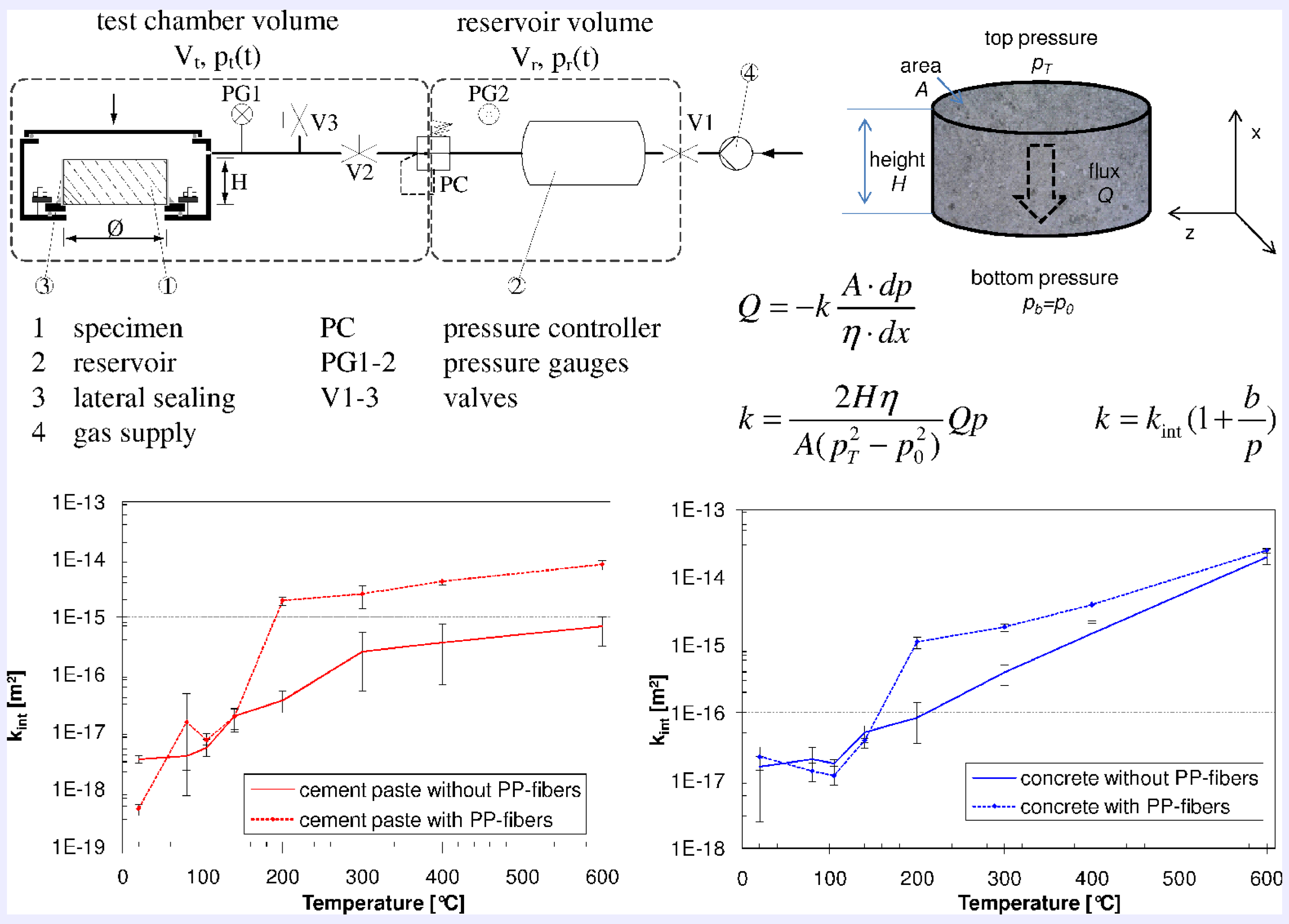
$$E = E^{el}(\Sigma) + E^{pl}(\Sigma) + E^{th}(T) + E^{LITS}(T,\Sigma)$$

The influence of combined mechanical and thermal loading is directly visible and the obtained results are in good agreement with experimental results from literature. The results are reduced by the free thermal expansion ($E - E_{th}$) in order to show the additional strain component with occures under combined mechanical and thermal loading. The the mechanically-unloaded case ($s = 0$) produces the same deformition in longitudinal (loaded) and radial direction. For load levels s>30 % the specimen fails before the maximum testing temperature of 800°C is reached.



Permeability

Permeability Testing Device:
The permeability of concrete governs the ability of concrete to advect water vapor originating from vaporization of pore water in consequence of heating of concrete during fire loading. Hereby, the magnitude of pore-pressure built up is directly related to the permeability of concrete and its evolution during temperature loading. In this section, experimental investigations of the effect of thermal loading as well as the influence of addition of PP-fibers on the permeability of concrete and cement paste are presented. In order to cover the wide range of the permeability of concrete and cement-paste specimens subjected to temperature loading, the volume of the air reservoir can be varied. Within the experiment, the permeability was determined from the gas flux through the specimen which was determined either from the pressure decrease in the test-chamber volume, $p_t(t)$ (see [3] for details) or from the pressure decrease in the reservoir, $p_r(t)$ (with constant pressure p_t in the test chamber, i.e., at the top of the specimen (see [2]):



Results:

- At low pre-heating temperatures, no fiber effect is observed, neither for concrete nor for cement paste.
- The permeability of cement paste is smaller than the respective values of concrete. This can be attributed to the existence of interfacial transition zones (ITZ) between cement-paste matrix and aggregates.
- The fiber effect can be observed between pre-heating temperatures of 140 and 200 °C, for both concrete and cement paste. This effect is stronger for cement paste (leading to a larger jump in k_{int}). In case of concrete, also the (non-permeable) aggregates as well as ITZ contribute to the macroscopic permeability, therefore the fiber effect is smaller for the composite.
- With further increase in pre-heating temperature, the fiber effect is reduced.
- Temperature-induced damage is higher in case of concrete where strain incompatibilities between cement paste and aggregate contribute to damage of the composite. In case of cement paste, dehydration (leading to an increase in pore space as well as cracking) is the only source of damage, therefore the fiber effect persists to a larger extent.

References

[1] A. Galek, H. Moser, T. Ring, M. Zeiml, J. Eberhardsteiner, and R. Lackner. Mechanical and transport properties of concrete at high temperatures. In *Applied Mechanics and Materials*, volume 24-25, pages 1–11. Trans Tech Publications, Switzerland, 2010.

[2] P. Paulini and F. Nasution. Air permeability of near surface concrete. In F. et al. Toutelemonde, editor, *Proceedings of the 5th International Conference on Concrete Under Severe Conditions: Environment and Loading (CONSEC'07)*, pages 241–248, Paris, 2007. Laboratoire central des ponts et chaussees (LCPC).

[3] M. Zeiml, R. Lackner, D. Leithner, and J. Eberhardsteiner. Identification of residual gas-transport properties of concrete subjected to high temperatures. *Cement and Concrete Research*, 38(5):699–716, 2008.

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