CIVIL-708 **UHPFRC for structures - Fundamentals & Properties**

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Cursus	Sem.	Type
Civil & Environmental Engineering		Opt.

Language of teaching	English
Credits	4
Session	
Exam	Oral
Workload	120h
Hours	**56**
Courses	34
Exercises	16
TP	6
Number of positions	**14**

Frequency

Every year

Remark

Next time: Fall 2022 Minimum number of participants: 6

Summary

This course aims at giving students the fundamental knowledge necessary to design, model, and apply Ultra High Performance Fiber Reinforced Concretes (UHPFRC) in structures, in a sustainable way. It provides an extended and comprehensive insight into engineering and science of these materials.

Content

1. Introduction, motivation: historical perspective, families of materials, strength vs deformability, components and features of UHPFRC, landmark applications, interrelations between composition, processing, structure and properties.

2. =>In situ presentation and discussion of structural UHPFRC applications in Lausanne and Bussigny (Martinet footbridge, roof Olympic museum, Cudrex viaduct).

3. FRC (Fiber Reinforced Concrete): bases of mechanical behavior, discontinuous fibers, bond, effects of orientation - anisotropy, characterization of mechanical performance.

4. Hydration and structure: binders and mineral additions (SCM), reactions, degree of hydration, hydration kinetics and influence factors, maturity, effects of high and low temperatures, microstructure, porosity, advanced measurement methods.

5. Rheology at fresh state, superplasticizers: bases, measurement methods, effect of packing density and liquid film thickness, effect of granular inclusions and discontinuous fibers. => Application: batch test in the lab, thixotropic UHPFRC.

6. Mix-design, optimization of packing density and liquid film thickness, dry and wet packing measurements, fibrous mix.

7. Mechanical properties (quasi-static): resistance, deformability, fracture energy, tension, compression, bending, shear, aging, heat-curing, orientation effects of fibers, combination with reinforcement bars, effect of SCM.

8. Modeling the mechanical response of tensile strain hardening/softening composites: bases, cohesive crack models for materials with bulk dissipation, scale effects, meso-scale models, analytical models, inverse analysis methods.

9. =>Application: inverse analysis of bending test results with FEM - ATENA.

10. Time dependent mechanical response: low strain rates, creep, shrinkage, early age, long term, heat curing,

thermo-mechanical response under restraint, fatigue, high strain rates.

11. Modeling of viscoelastic response: continuous models, discrete aging models, transformation algorithms (creep to relaxation and vice-versa).

12. => Application: thermo-mechanical effects - structural response: case study of tunnel reinforcement with UHPFRC - FEM - DIANA.

13. Durability - transport properties: moisture, liquids and ions, self healing effects, gases, carbonation, chlorides, corrosion, effects of cracking and self healing, sulfates, freeze-thaw, AAR.

14. Design of structures with UHPFRC: bases, prestressing (pre or post tensionning), fire resistance, recycling, LCA (CO_2 emissions, embodied energy), next generation UHPFRC with synthetic fibers, examples of applications, synthesis. => Mini projects (SNSF funding request basics) - group presentations and discussion.

Keywords

Cementitious Composites, Discontinuous Fibers, UHPFRC, Tensile Hardening, Creep, Shrinkage, Mix-Design, Packing, Rheology, Durability, LCA, Numerical Modeling

Learning Prerequisites

Required courses

Basic courses on Building Materials, Continuum Mechanics, Structural Mechanics, Physics and Chemistry

Learning Outcomes

By the end of the course, the student must be able to:

- to design UHPFRC mixes, characterize and model their physical, chemical and mechanical properties; to use UHPFRC to create new structures or maintain existing ones in a sustainable way.

Resources

Websites

- https://people.epfl.ch/emmanuel.denarie?lang=en; http://phd.epfl.ch/page84375.html