1. Structural Engineering Research Laboratory

The Structural Engineering Research Laboratory of Empa develops innovative solutions aimed at reducing material and energy consumption, mitigating greenhouse gas (GHG) emissions, and preparing for extreme events. The Lab achieves this by pioneering advanced structural materials and systems, condition assessment and strengthening techniques, digital fabrication, and timber engineering for buildings and infrastructure. The goal is to enhance the safety, serviceability, durability, robustness, and sustainability of structures.

The experienced team of the Lab possesses complementary competences in materials science and engineering, and has excellent infrastructure for experimental research and modelling. The laboratory holds ISO/IEC 17025 accreditation for fatigue and static tests and is equipped with a large testing hall and several testing machines capable of investigating a wide range of specimen sizes and loading capacities.

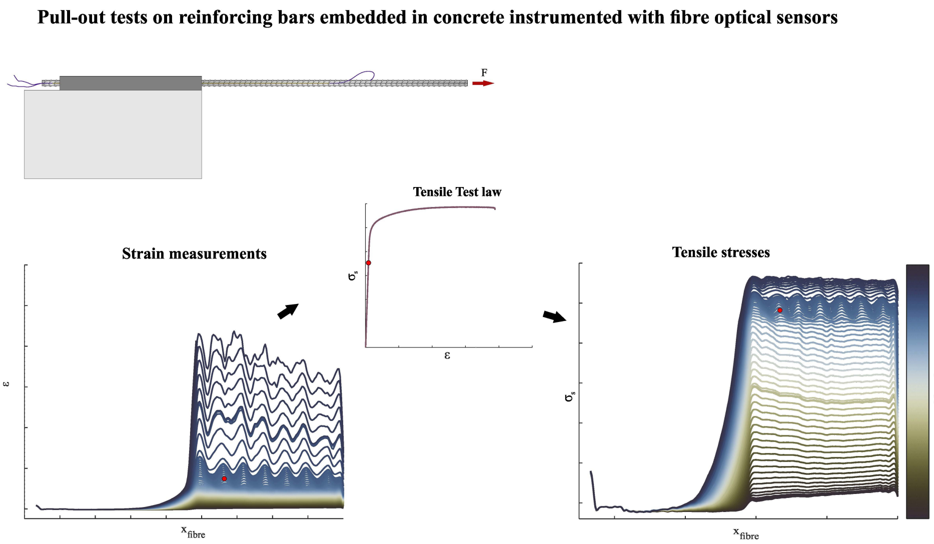
2. Measurement Facilities:

Our laboratory owns state-of-the-art facilities for conducting precise measurements. Specifically for strain field monitoring, we offer a wide range of capabilities suitable for various experimental conditions and the desired domains of measurement. This includes:

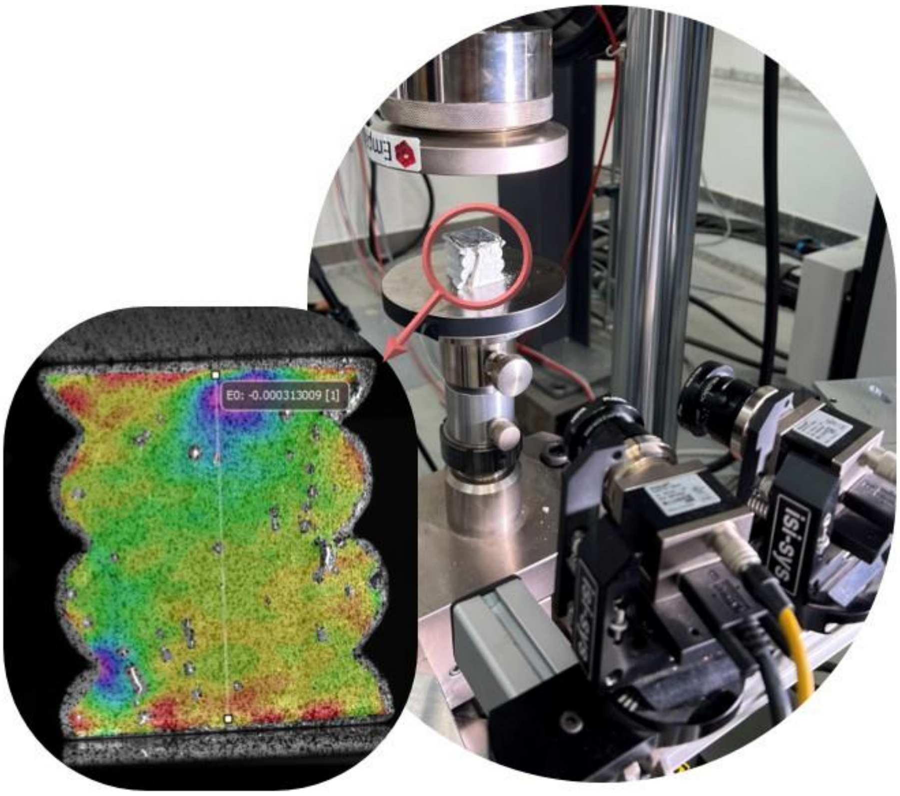
- **Mechanical and Optical Displacement and Strain Measurement Systems:**

  The Structural Engineering Research Laboratory has a wide range of "classical" displacement and strain measurement systems available, including strain gauges, extensometers, LVDTs and point- and line-laser sensors, among others. Several of these sensors can be applied from low temperatures (-80°C) up to high temperatures (+300°C).

- **Fiber Optic Strain Sensing System Luna**: The Luna *ODiSi 6000 Series* is an advanced system to measure 2D and 3D strain fields as well as the in-situ temperature profiles of complex structures and new materials. It can be embedded within structures and bonded to curved surfaces to detect minute cracks and defects, while being corrosion-resistant. This system is a real-time, multichannel system monitoring over distances up to 100 m, with thousands of data points with a sub-millimeter gage pitch (ranging between 0.65 - 5.2 mm). Such advanced system can offer a strain resolution of 0.1 $\mu\epsilon$ and a temperature resolution of $0.1^{\circ}C$ with uncertainties of $\pm 5\ \mu\epsilon$ and $\pm 2.2^{\circ}C$ for the shortest gage pitch.



Digital Image Correlations (DIC) System VIC 3D: The VIC-3D system is an advanced non-contact method for capturing real-time 3D displacements and strain fields on a specimen's surface under both high loading rate static and dynamic conditions. The system offers nanometer-level resolution for displacement measurement, and strain measurements with a resolution of 50$\mu\epsilon$.



DIC VIC 3D setup and axial strain field measured in a 30 mm 3D-printed concrete cube under compressive loading

3. Universal Testing Machines:

The Structural Engineering Research Laboratory possesses a comprehensive range of universal testing machines designed for conducting **static**, **dynamic**, and **fatigue** tests under various loading conditions, including tension, compression, shear, bending, and combined loads. With the integration of temperature chambers, many of these tests can also be performed under controlled temperature gradients, enabling more precise and versatile material characterization. The following table provides an overview of the universal testing machines of the laboratory for static tests.

* E= electric, H = Hydraulic, S = Servo hydraulic, T =Tension, C = Compression, B =Bending, X =available, (X) = conditionally available

Manufacturer	Capacity [kN]	T	C	B	Maximum specimen length [mm]	Clear width [mm]	loading rate [mm/s]	Stroke [mm]	Temperature chamber range: -40 to 250°C
Zwick (**E**)	20	X	X	**(X)**	1'500	440	16	1500	X
Amsler (**H**)	200	X	X		1'600	980	6.28	200	
Amsler (**H**)	1'000	X	X		1'600	450	2.35	200	
Amsler (**H**)	5'000		X		5'800	800	0.85	150	
Amsler (**H**)	20'000	**(X)**	X		7'800	1'650	0.1	400	
W&B (**S**)	500	X	X	**(X)**	1'400	650	> 10	250	X
m. Adapter (**S**)	100	X	X		300	650	> 10	250	X
ELS (**H**)	30'000	X			6'500/2'660	690	0.3	120	
Schenck (**S**)	160	X			700	500	> 10	100	

To perform various tests such as determination of cable elongation, anchor head deflection and wire/wedge draw-in, the Structural Engineering Research Laboratory has a tensile testing machine, ELS 1043. The system can reach the maximum load of 30 MN and is able to test samples with length of 5.5 m to 7 m. The maximum dimension of the anchorage is 600 mm x 600 mm, or 600 mm in diameter.

In accordance with the ETAG 013 guideline and the client's specifications, load transfer tests can be performed using large compression machine, Amsler 20MN, to assess load transfer mechanism from anchorages of tendons or stay cables to the structure. As required by the guideline, both the deformation of the concrete and the surface crack widths can be measured during the test. The maximum stroke of this machine can reach to 400mm.

The available devices at the Structural Engineering Research Laboratory suitable to assess fatigue performance of large pre-stressing and stay cables are listed in the following table. The tests are performed according to test procedures specified by the customers, following PTI, fib or ETAG013 guidelines.

Maximum upper load [MN]	Maximum Load range [MN]	Maximum displacement range [mm]	Sample Length [m]	Frequency [Hz]
2.5	2	5	3 to 4	1 to 8
6.7	1.6	8	5.5 to 7	4.4

4. Strong-floor

The Structural Engineering Research Laboratory is equipped with a strong-floor and corresponding steel profiles. This makes it possible to create big and complex test setups. The relevant technical data for the strong-floor are:

Length: 40 m

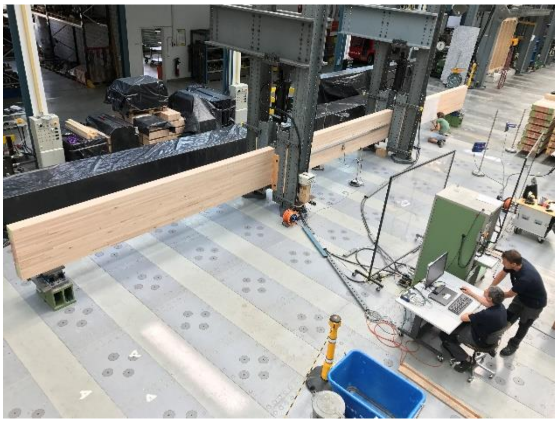
Width: 12 m

Depth: 1.20 m

Clear room height: 13 m

Grid of anchor points: 1.20 m x 1.20 m

Maximal force per anchor point: 2 MN



There are a big number of different hydraulic and servo-hydraulic actuators available with capacities between 20 kN and 2'000 kN and strokes up to 1'000 mm. Single and multi-channel controllers enable multi-axial loading of specimens and operation of complex loading protocols.

5. Additive Manufacturing Technologies:

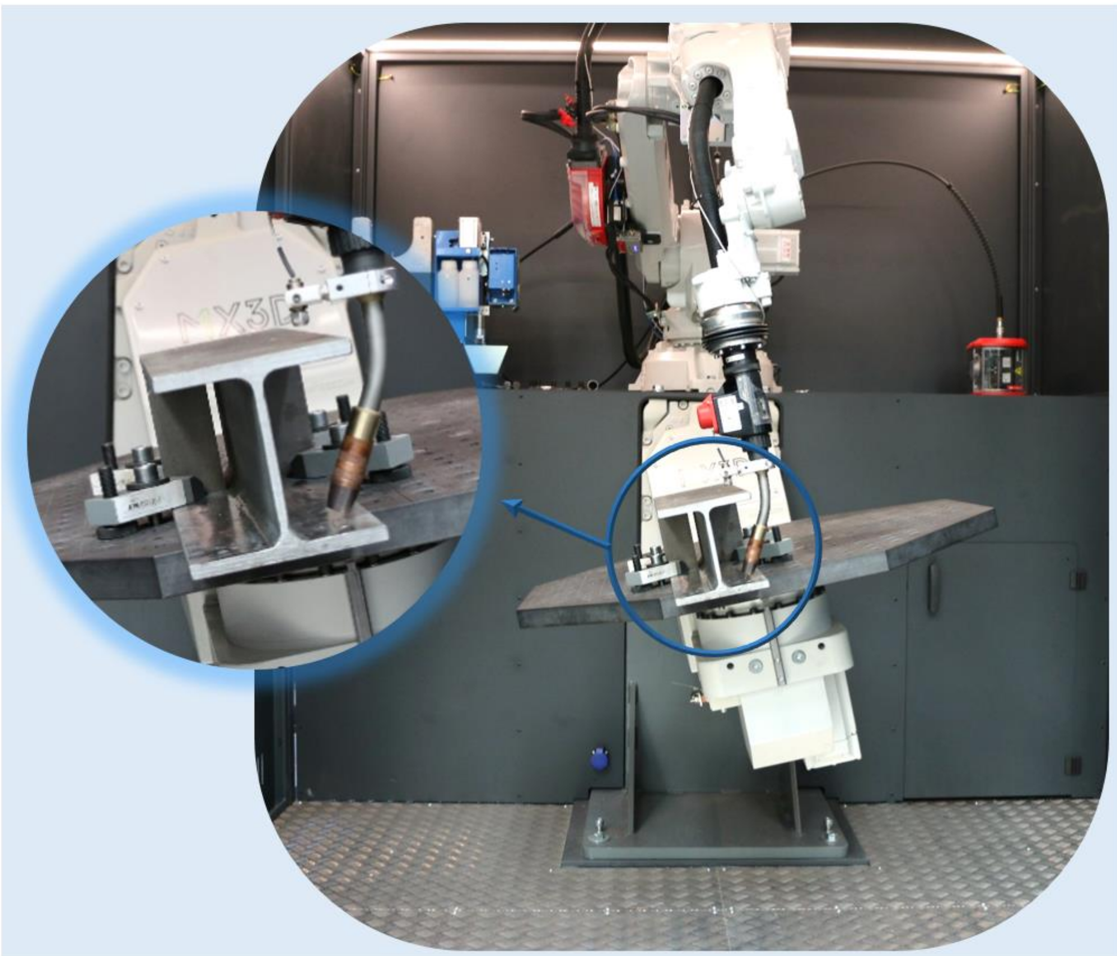
3D Printing Metallic Components:

Wire-Arc Additive Manufacturing (WAAM) represents an Additive Manufacturing (AM) method, specifically designed for the manufacturing of optimized large metallic components. It employs an electric arc as a heat source and metal wire as feed material, layering welds to construct complex shapes and geometries. This technique is versatile, supporting all weldable metals existing in the form of wires. The MX3D-M1 WAAM system at the Structural Engineering Research Laboratory provides unique capabilities for manufacturing optimized structural and mechanical components on an industrial scale. The unique features of our WAAM system include:

- An ABB robot with a positioner providing 8 degrees of freedom robotic WAAM set-up, enabling 3D-printing of complex geometries.
- Fronius welding system providing quality welding using advanced welding technologies such as Cold Metal Transfer (CMT).

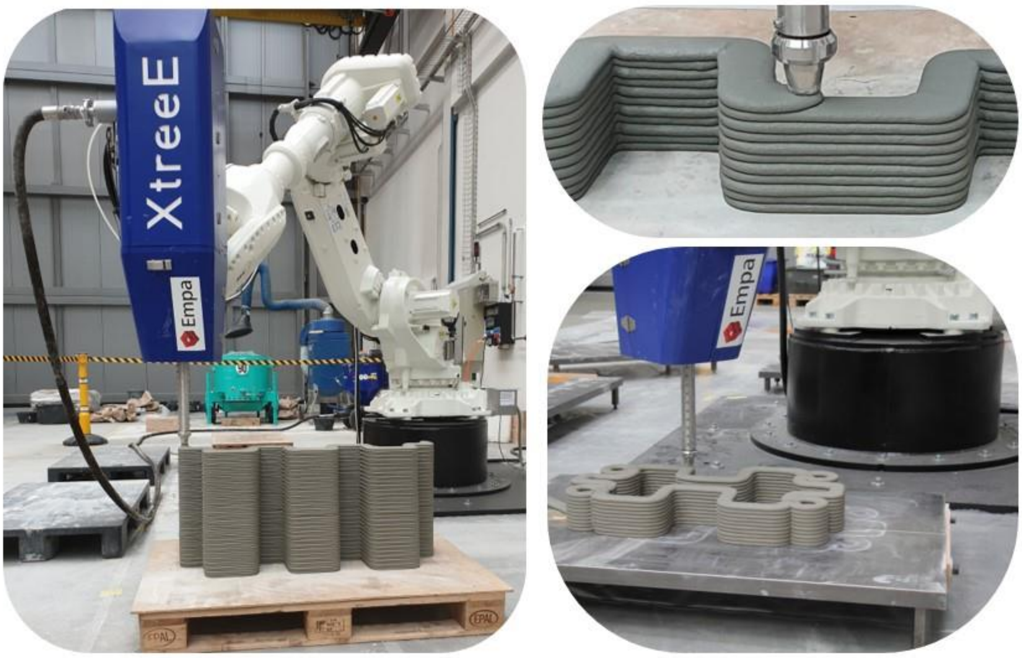
- Control system providing robot control, process simulation, print monitoring, high-resolution data logging, and real-time communication to the robot operator.
- Temperature sensoring to control the heat input during the fabrication process to achieve high quality WAAM specimens and components.
- Capability for manufacturing of large parts, up to 2.2 m x 1.4 m x 1.7 m and 500 kg.
- High deposition rate: ≥ 3 kg/hr.
- Application of optimized fabrication parameters using its own library for a wide range of welding wires with different diameters.

The Structural Engineering Research Laboratory is ready to provide these distinct features of its WAAM system to industry and research institutes, supporting the development of optimized, large-scale structural and mechanical components through service or R&D projects.



3D Printing of Concrete Components:

Owing to advancements in additive manufacturing, the automation in construction of concrete structures has been significantly transformed in recent times. These systems not only enable the printing of newly developed materials which can reduce the carbon footprint, but also allow for creation of highly complex topology-optimized designs aimed at reducing mass while enhancing structural performance. The XtreeE printing system at the Structural Engineering Research Laboratory offers large-scale 3D printing concrete capabilities, with a printing capacity of up to 4 - 5 m and a material capacity of 245 kg. The system is comprised of five key components: supervision, control, feeding, head, and robot. The robot is capable of printing at a speed of 3 liters per minute and can produce layers with widths ranging from 18 to 40 mm.



XtreeE 3D-printer robot and digital fabrication of concrete formworks with various shapes.