

ISIS@MACH and Composite Materials: Construction Materials

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- Structural Health Monitoring
- **The neutron experiment *via* ISIS@MACH**
- Results
- Other opportunities using neutrons
- Outlook and conclusions

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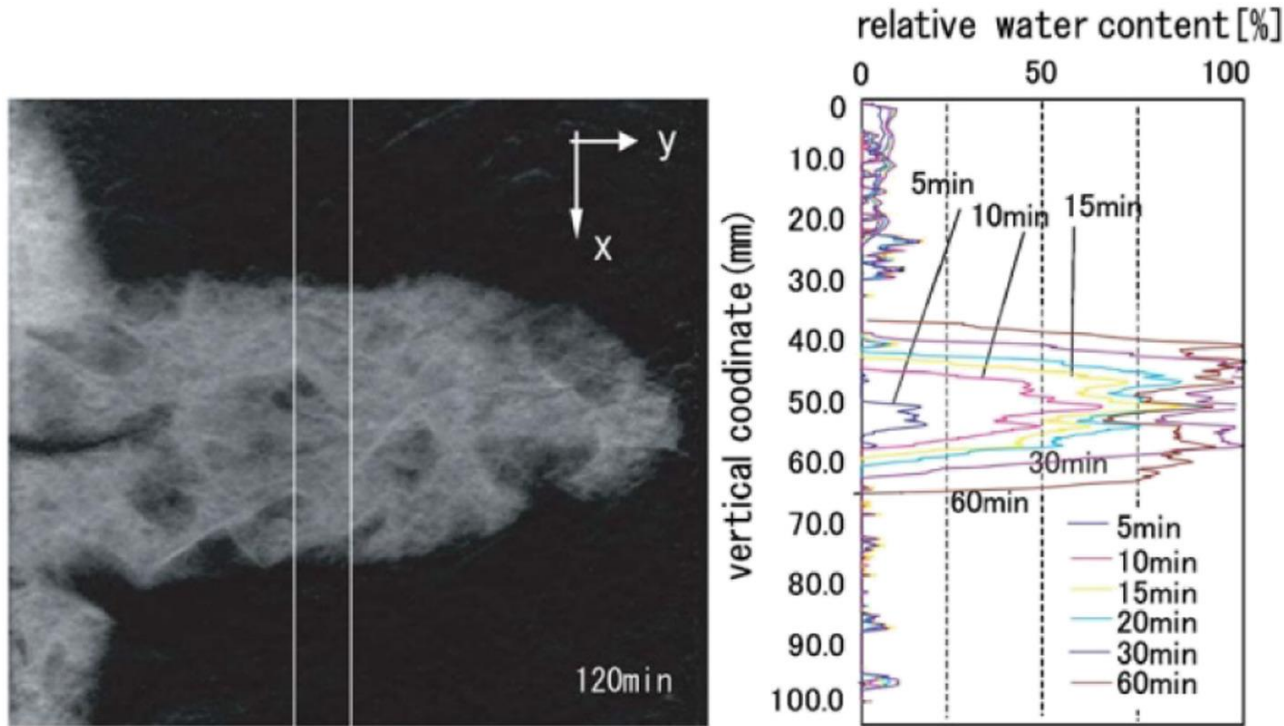


Latex-modified CNT/rGO-reinforced mortar with piezoelectric strain-sensing capabilities

STFC ISIS Neutron and Muon Source, <https://doi.org/10.5286/ISIS.E.RB1920214>

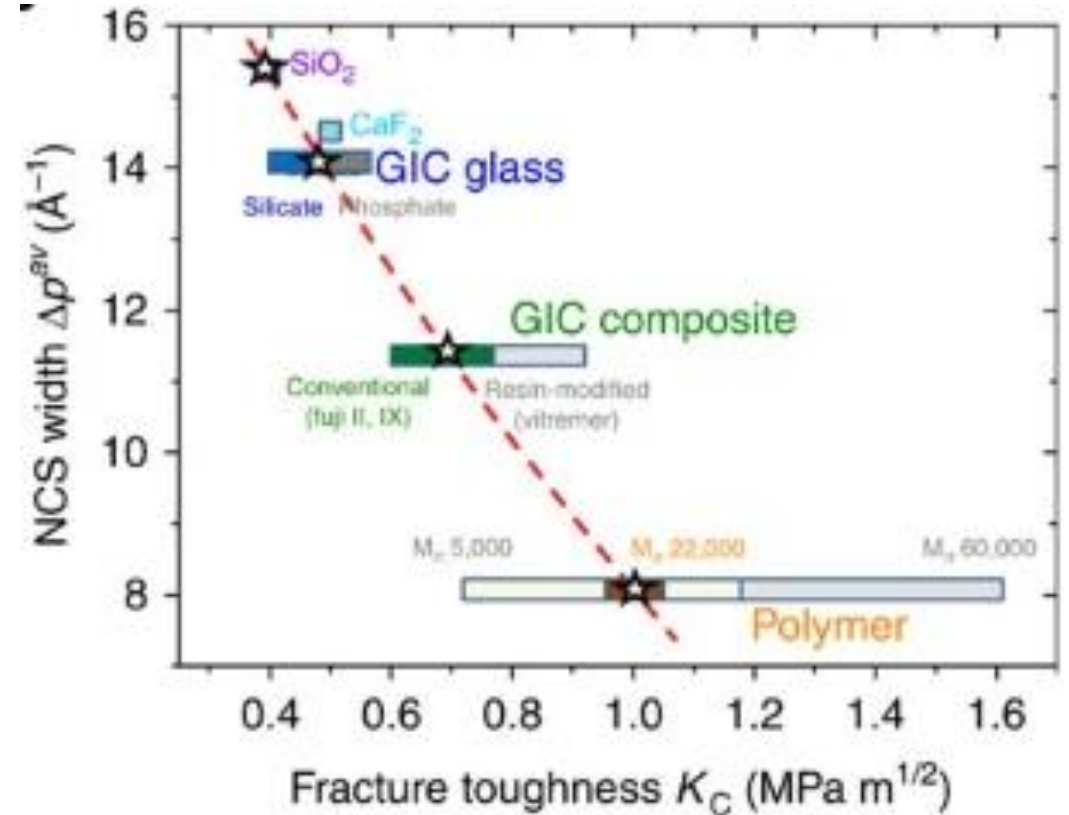
Neutrons and cement: penetrating and precise

From multi-cm in depth investigation to sub-Angstrom motion detection



Neutron screening of water penetration in a concrete crack

Zhang et al., *Cem. Concr. Res.* (2018)

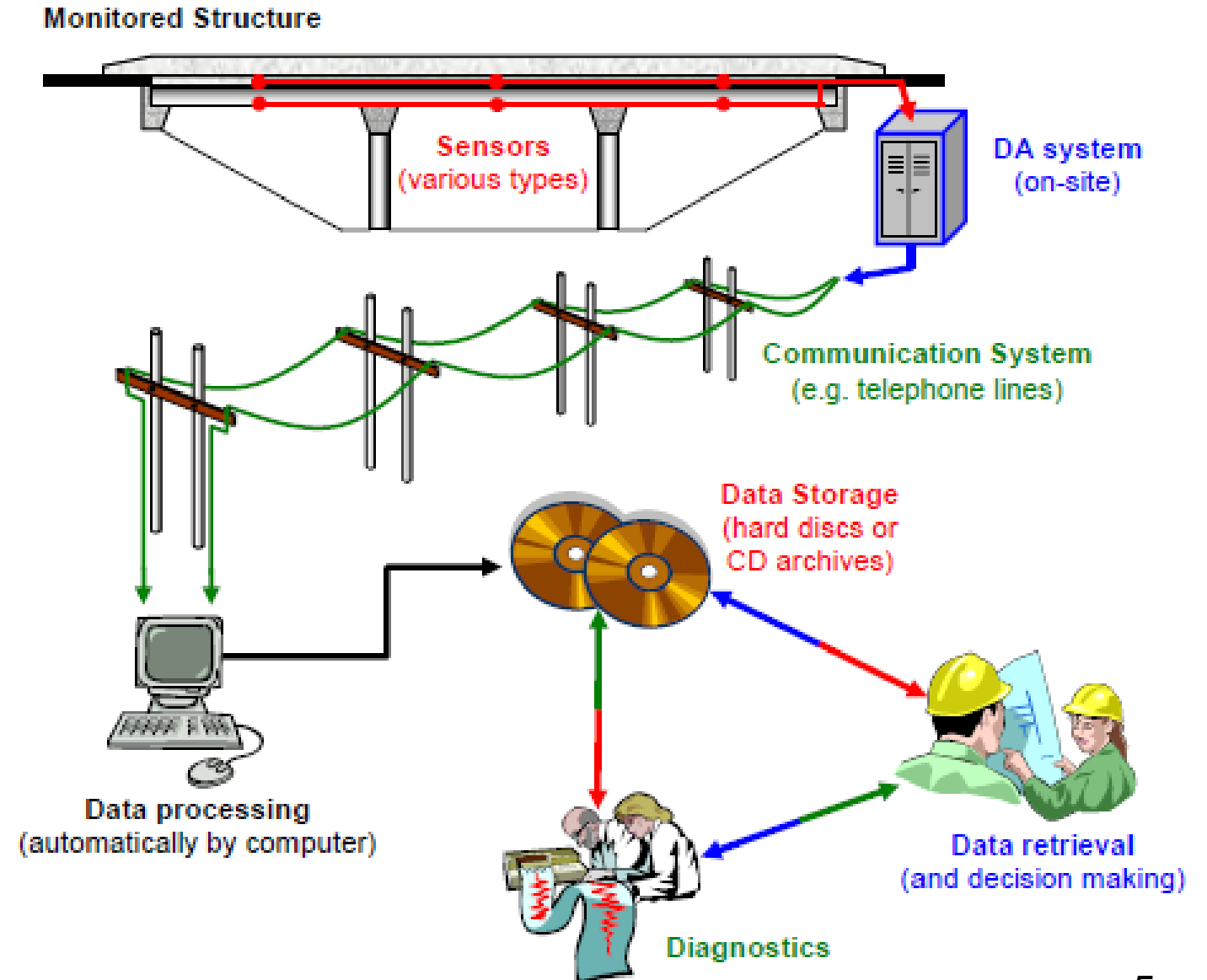


Neutron probing of atomic motion to infer mechanical toughness

Tian et al., *Nature Comm.* (2015)

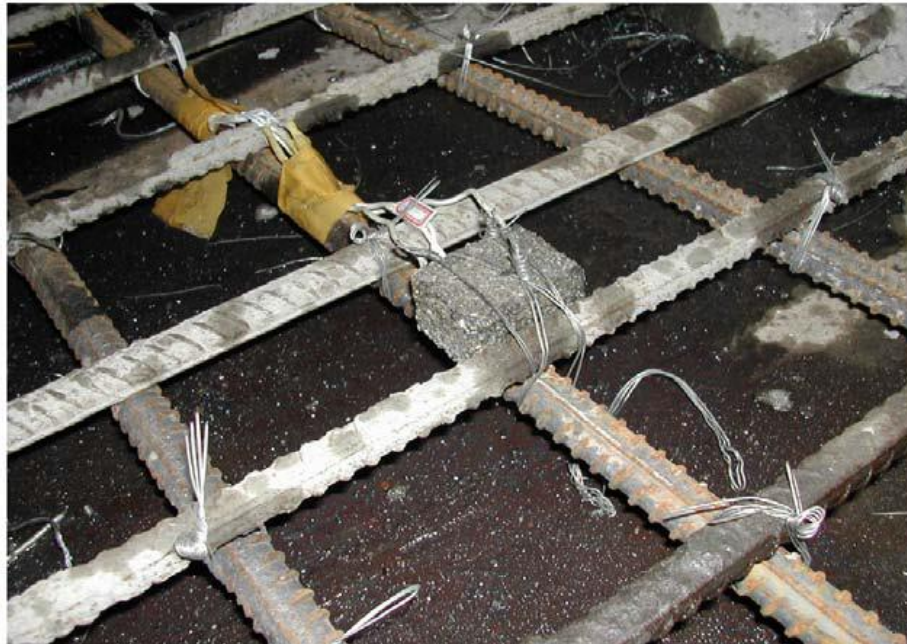
“The process of implementing a damage identification strategy for aerospace, civil and mechanical engineering infrastructure is referred to as structural health monitoring.”

Farrar and Worden, Phil. Trans. R. Soc. A (2007) 365, 303–315



Structural health monitoring

Cement-based sensors embedded in the Chongqing Guangyang Island Bridge in China (Ou 2006)

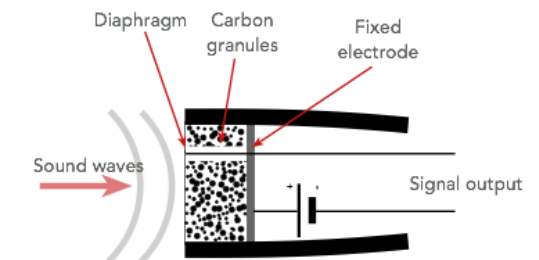
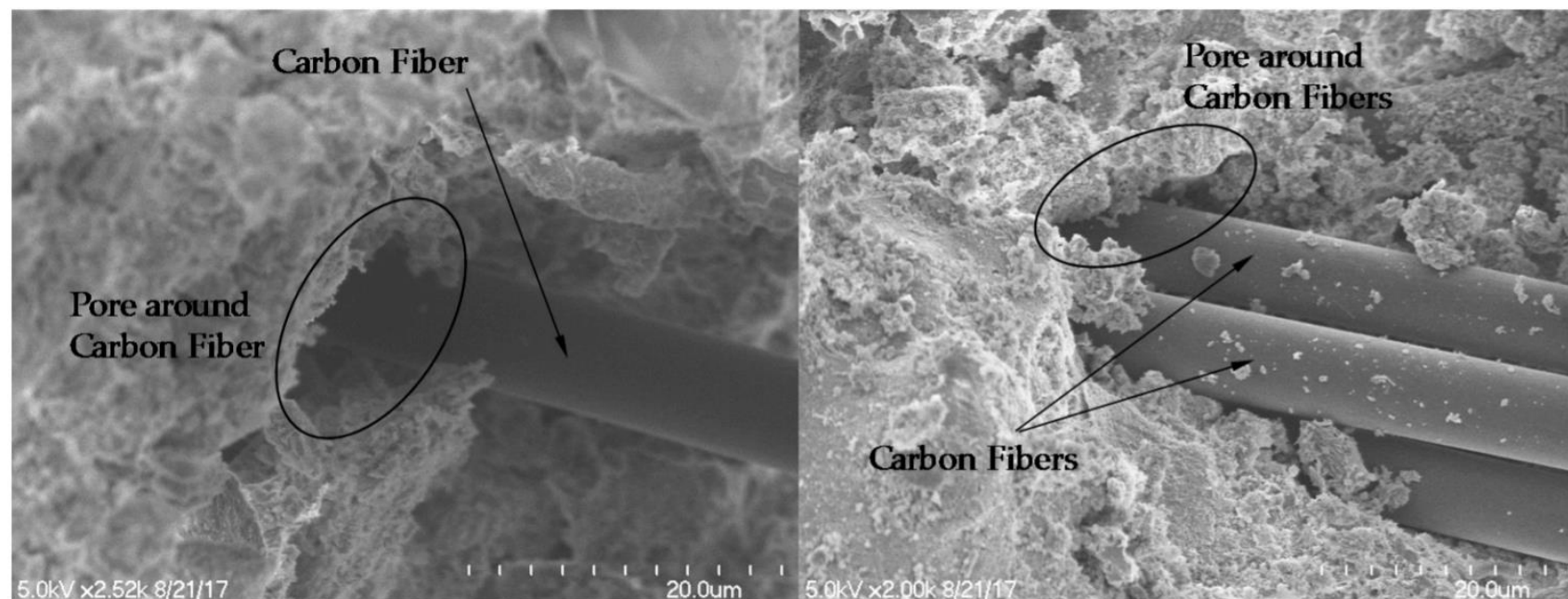


Cement-based sensors using piezoresistivity

Cement-based sensors using **piezoresistivity** contain three main microscopic phases:

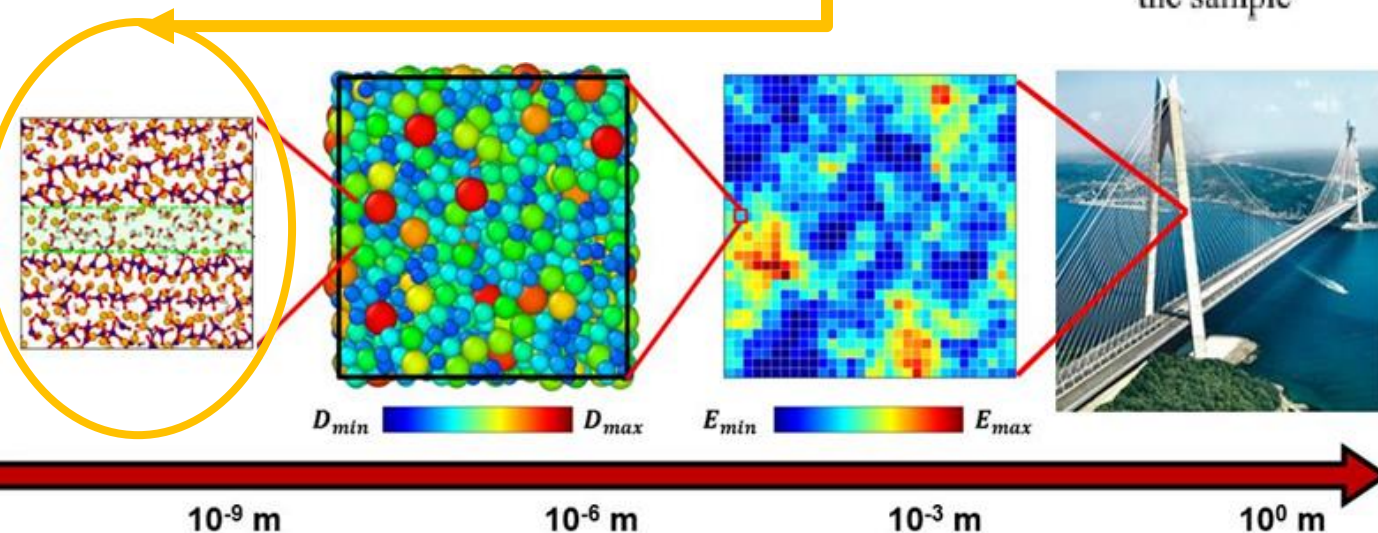
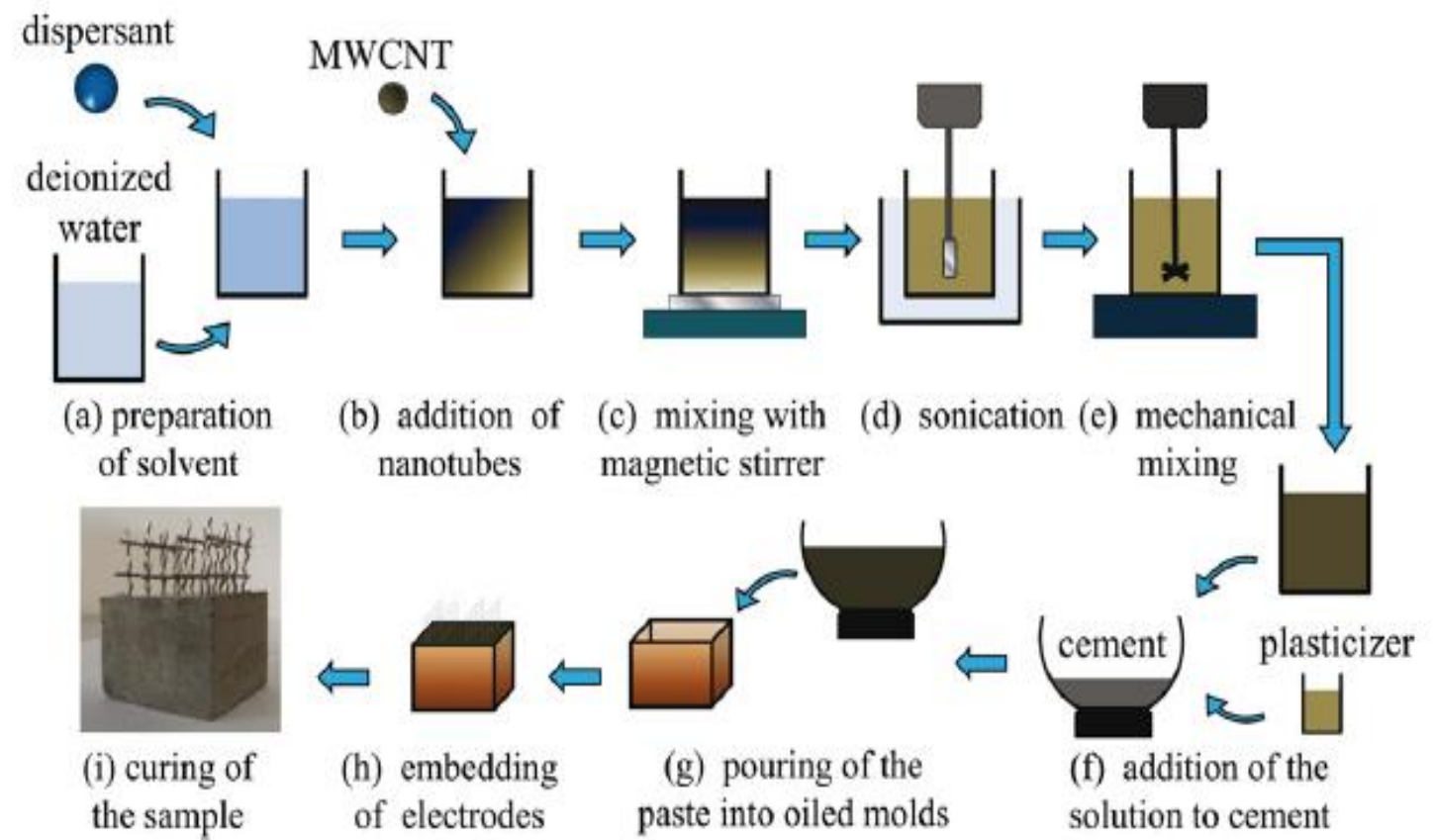
- 1) interfaces between fillers;
- 2) cementitious matrix;
- 3) fillers.

S-J Lee et al, Sensors 2017, 17, 2516

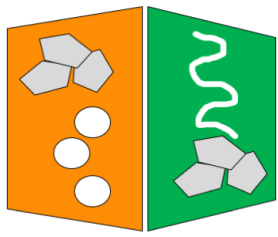


A microscopic description of the final product is needed so as to tailor the best composition of cement and fillers.

Experimental insight is extremely valuable, for molecular dynamics simulations can require months.



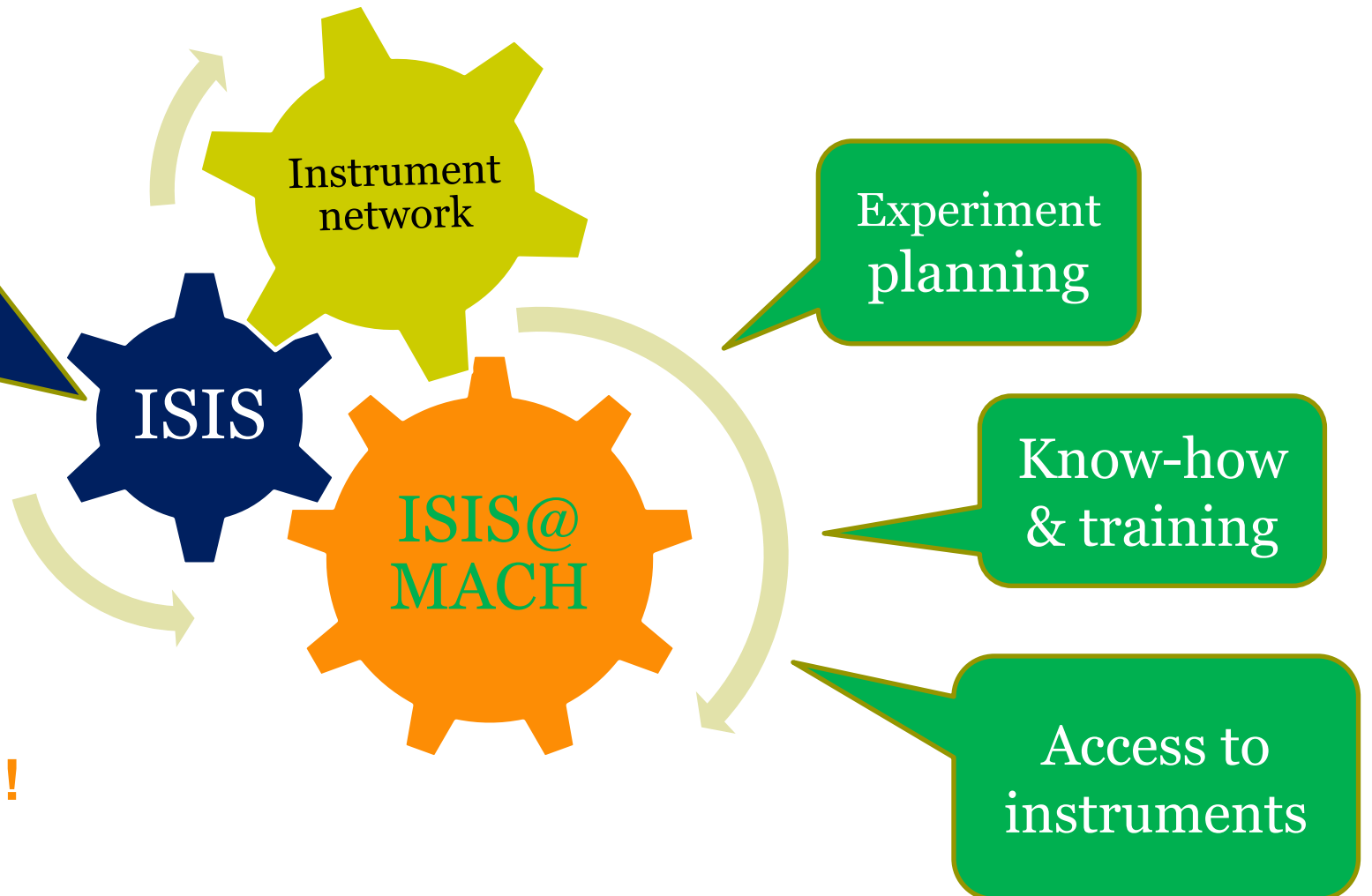
Ubertini et al.,
Engineering Structures,
60, 2014, 265-275

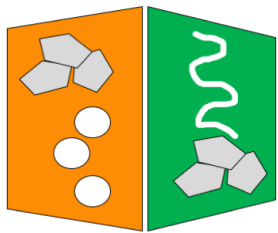


Why neutrons?

- 1) Penetration depth;
- 2) Particularly sensitive to hydrogen and water
- 3) Allow a description of the system at the atomic scale.

Complementary information!

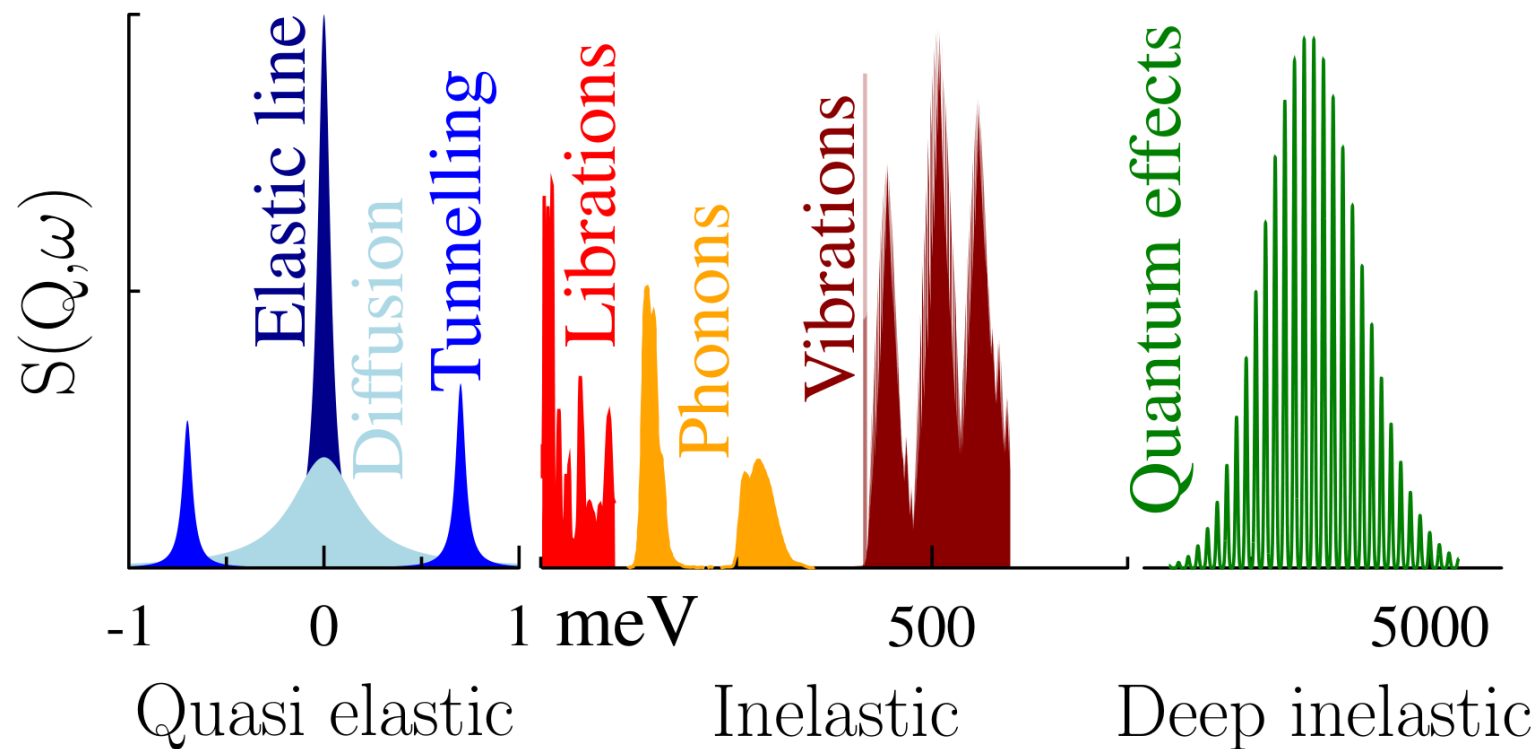




The neutron experiment *via* ISIS@MACH

Molecular spectroscopy with neutrons can help understanding, **amongst other things:**

- Diffusion mechanisms (QENS)
- Intermolecular interactions (INS)
- Hydrogen amounts on an absolute scale (DINS)

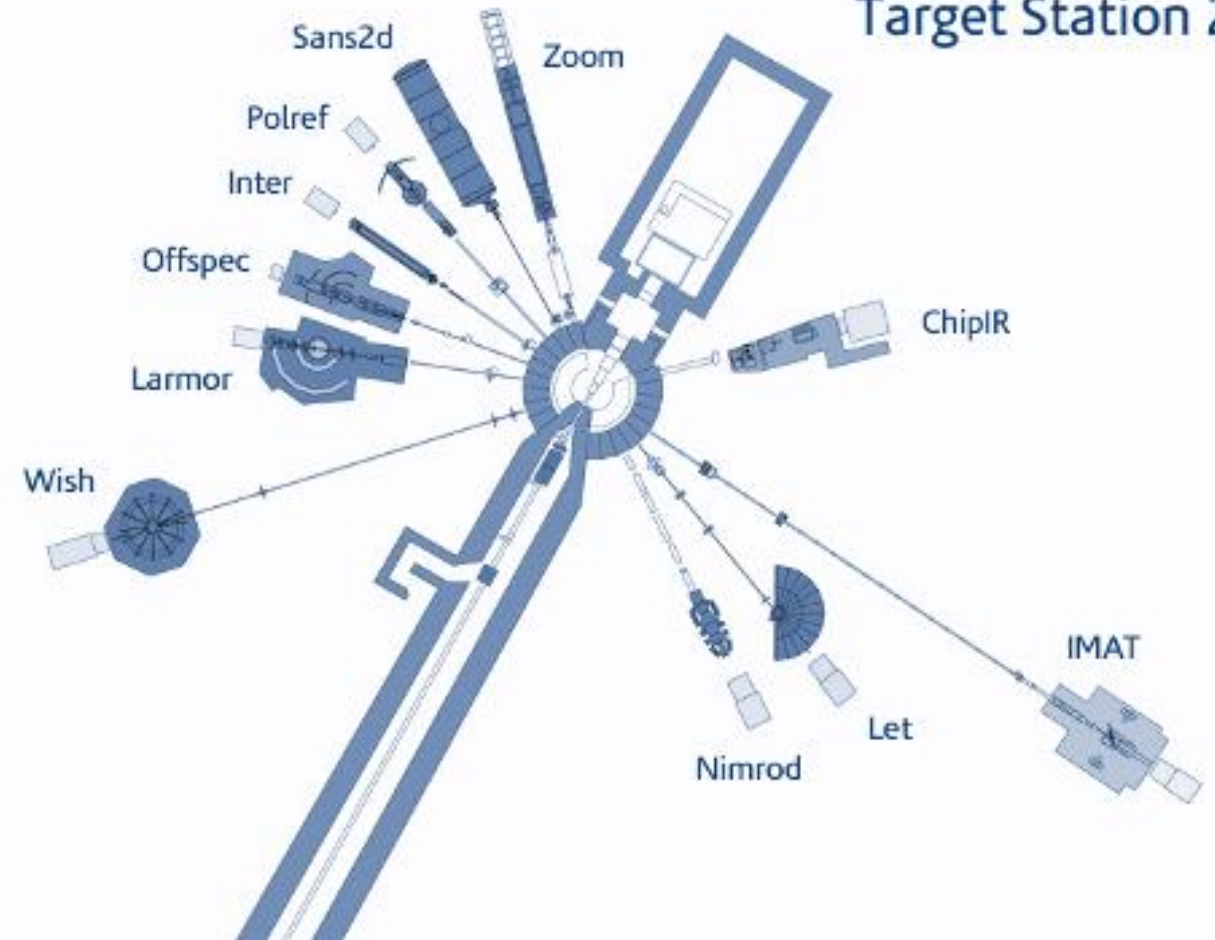


Discussion with the ISIS@MACH and ISIS local contacts to understand what techniques and instruments to use, and how to plan the experiment.

Target Station 1



Target Station 2



Inelastic Neutron Scattering experiments on TOSCA – Dr. S. Rudic (ISIS local contact)

Analysis/service at ISIS@MACH and ISIS through NEUTRON GATE

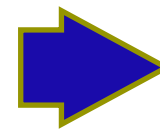
... in a nutshell...

- **USERS** Contact
ISIS@MACH Scientists
- **USERS** apply for Access to
ISIS@MACH and ISIS

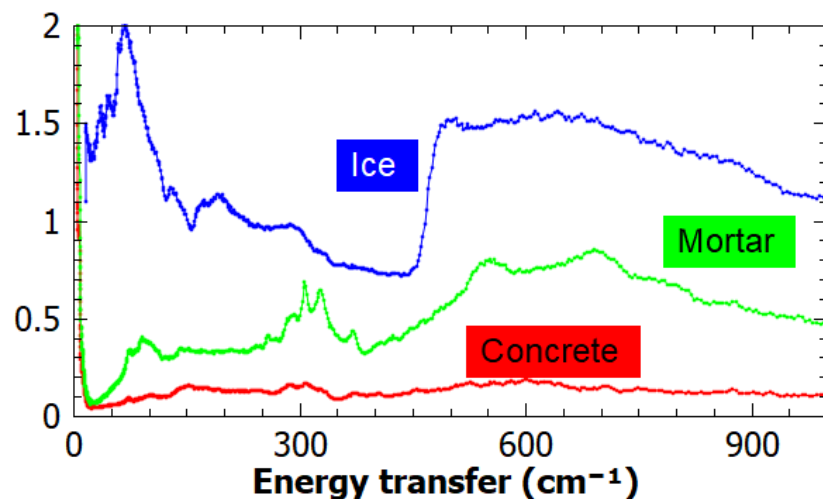
ACCESS approved



Bring the samples to ISIS@MACH

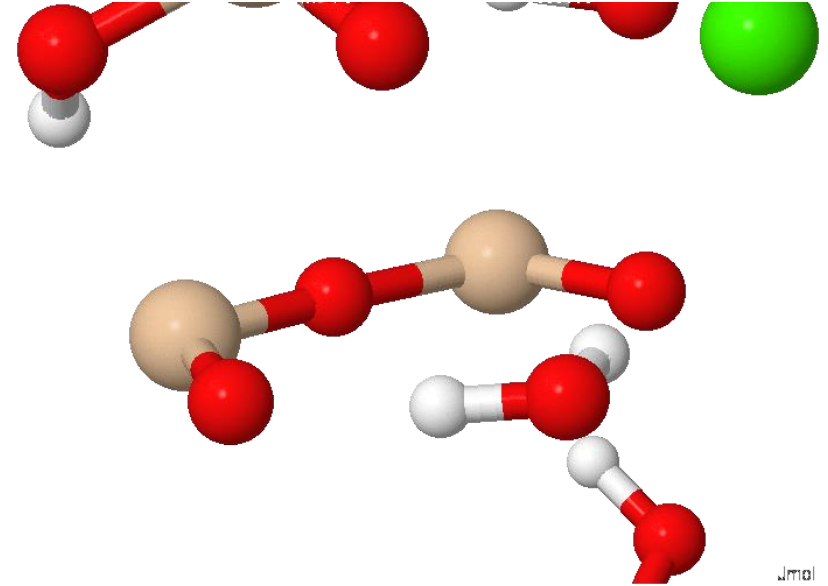


NEUTRON
GATE



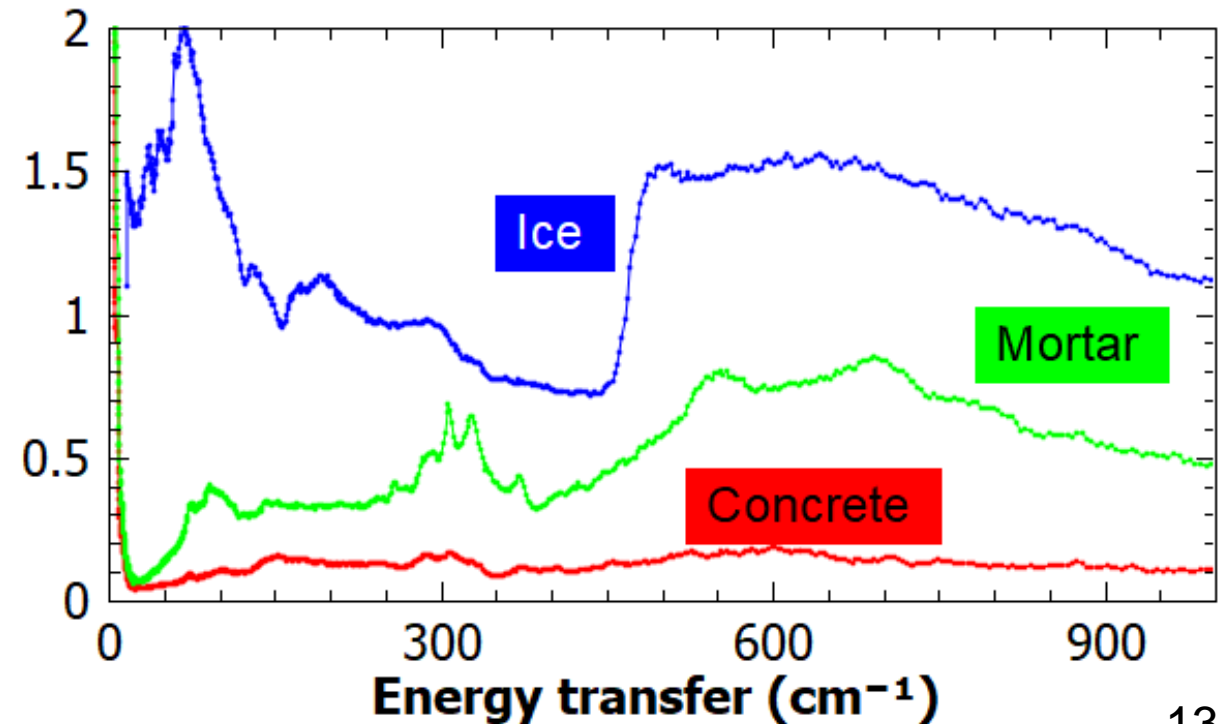
Get
your
data





The preliminary results

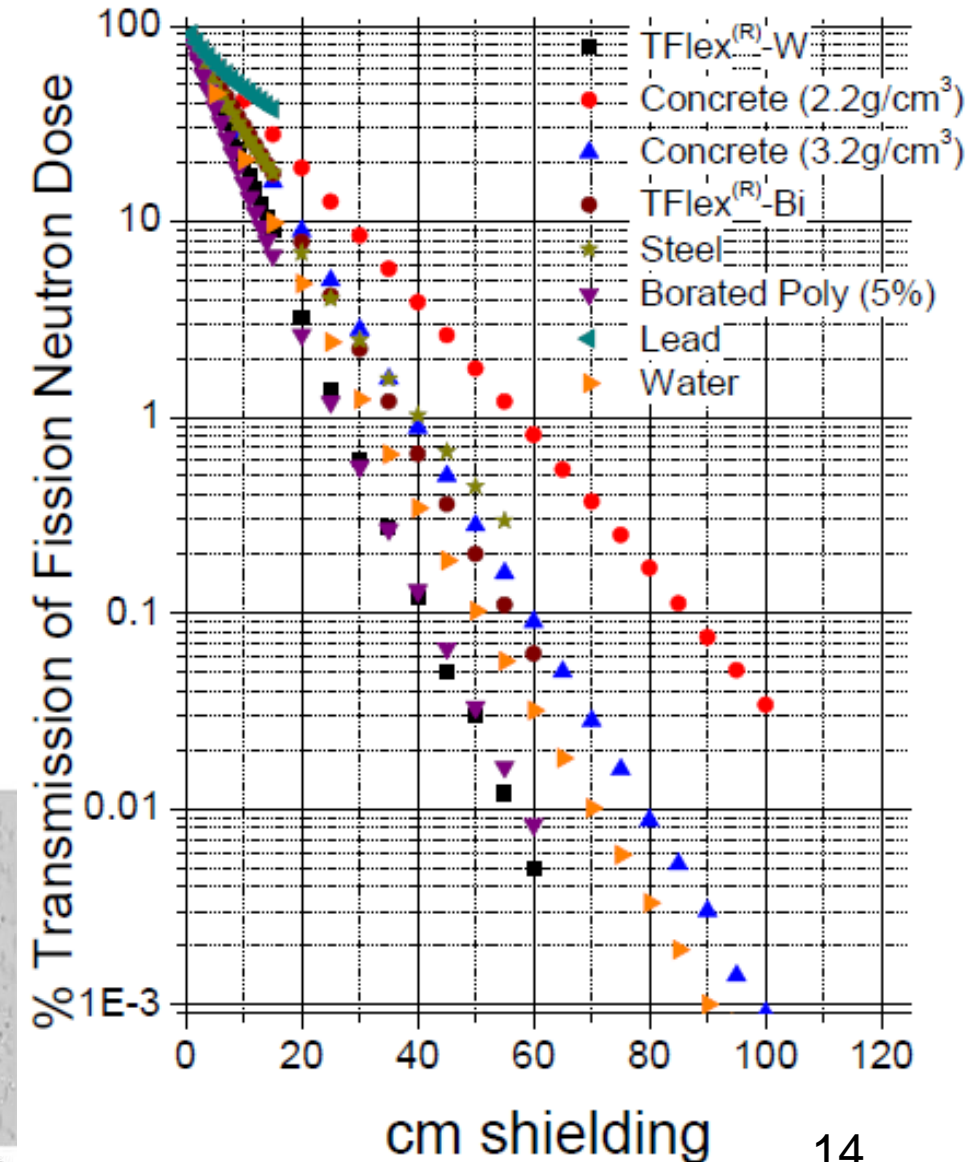
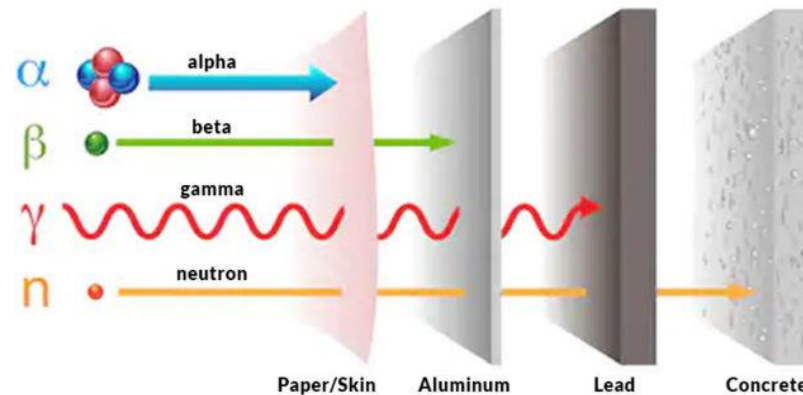
- Characterisation of ~10 samples over 2.5 days.
- Clear rearrangement of water molecules in the C-H-S structures;
- Dependence/independence of the cement hydration upon the fillers used;
- New insight on how to interpret the macroscopic results.



Other opportunities using neutrons? Yes

Optimising barite content in heavy concrete

- ISIS@MACH and neutron gate to ISIS proposal
- Industrial proponent: MARDEL s.r.l.
- Techniques: Electron microscopy and Neutron transmission
- Submitted to ISIS@MACH, approved, submitted via neutron gate to ISIS and approved.
- Scheduled at ISIS in September 2020



- Neutrons provide a probe at the atomic scale to complement other laboratory characterizations and results;
- Neutrons allow experiments on bulk materials (e.g. a piece of concrete) owing to their high penetration depth;
- Neutrons are particularly sensitive to hydrogen and water in materials;
- Inelastic Neutron Scattering highlights interactions (water/filler/cement);
- **ISIS@MACH provides know-how, an instrumentation suite, training, and help to access neutron beamlines at ISIS *via* the NEUTRON GATE.**

THANK YOU