

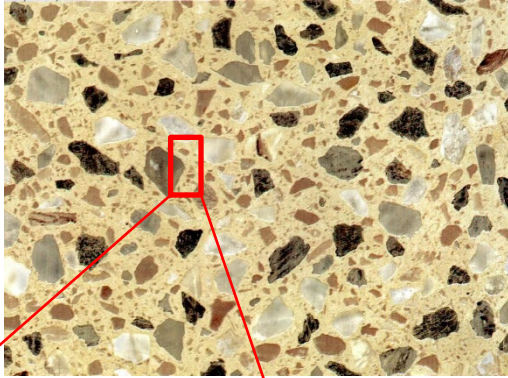
# Nanomechanical properties of C-S-H gel/cement grain interface by using nanoindentation and modulus mapping

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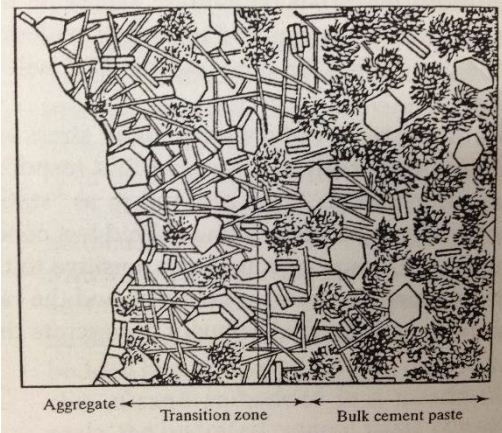
# Interface in Cementitious Materials

At micro-scale

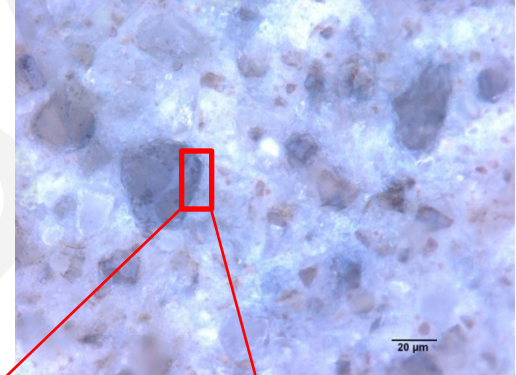


Interface between aggregate and paste

Testing: Microhardness

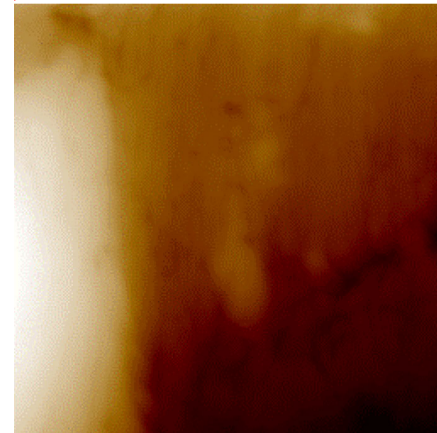


At nano-scale



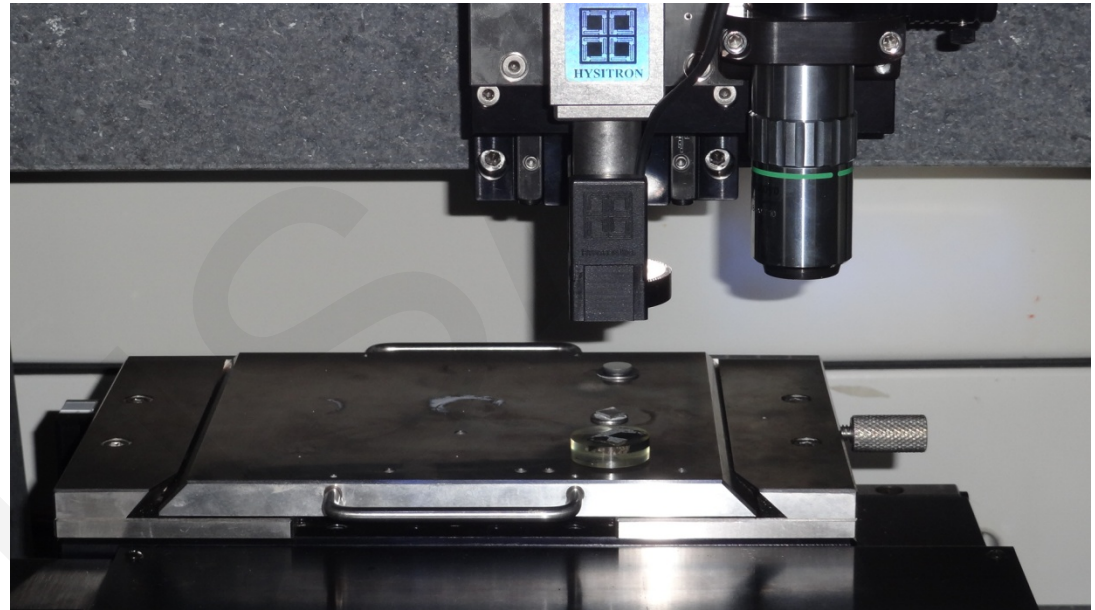
Interface between CSH and cement grain

Testing



?

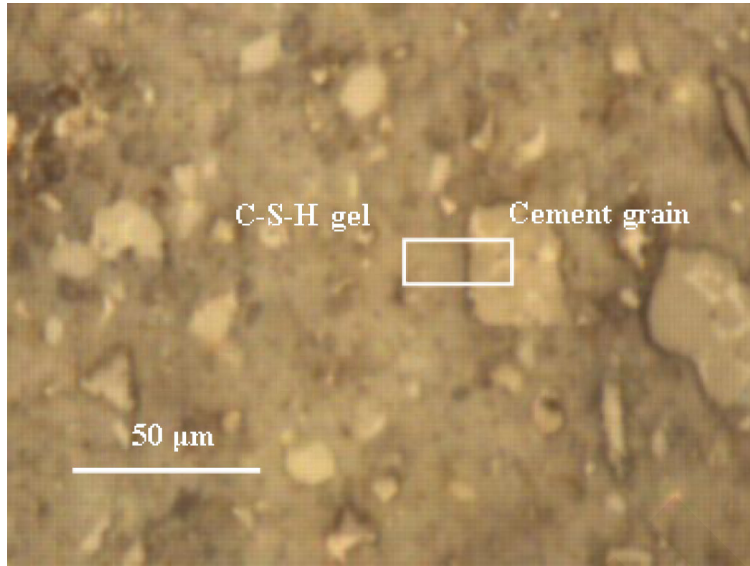
# Nanomechanical Investigation



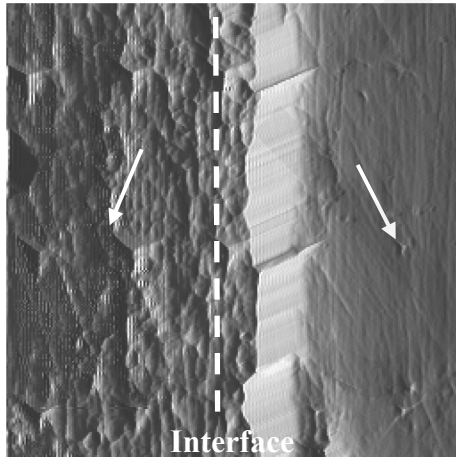
Testing at Nanoscale:  
Nanoindentation  
Nanoscratch  
Modulus Mapping

...

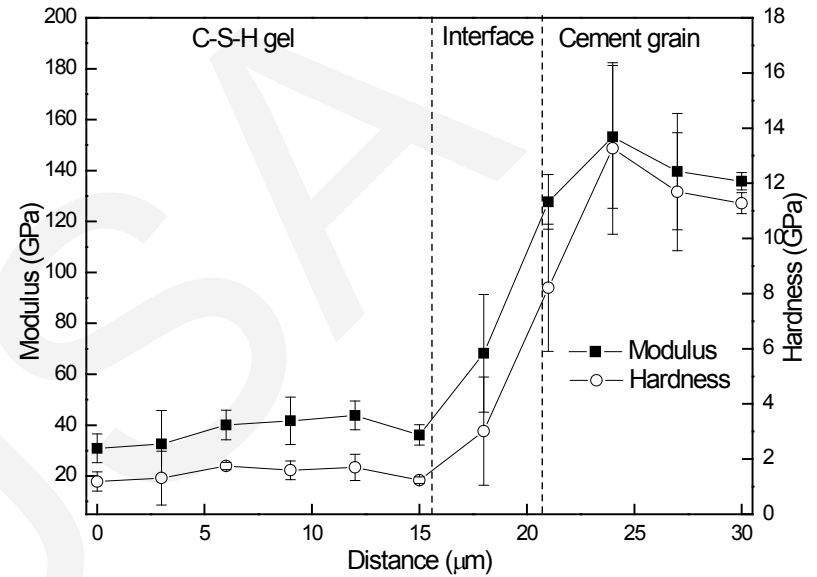
# Nanoindentation



Optical image



In situ image of the indents near interface



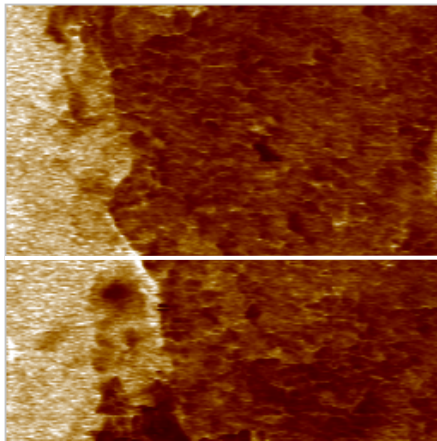
Modulus and hardness vs. position

Interface width: rough estimation <5 μm  
Interface modulus: 68 GPa  
Interface hardness: 3 GPa

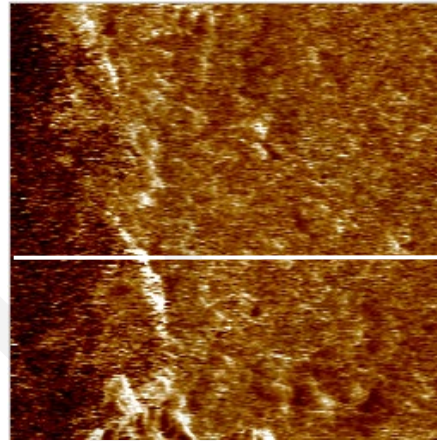
# Modulus Mapping

## Comparison of nanoindentation and modulus mapping

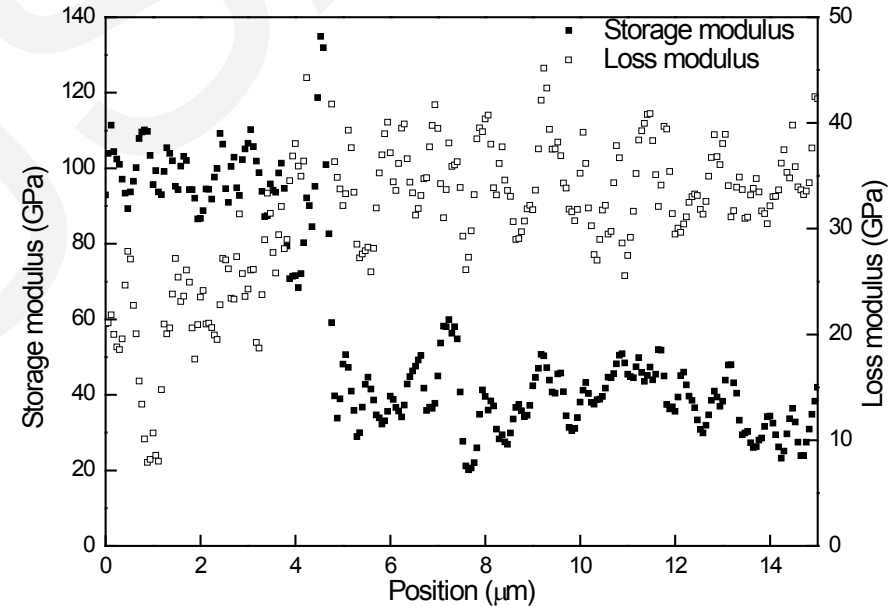
	Contact force ( $\mu\text{N}$ )	Step size (nm)
Nanoindentation	1200	3000
Modulus mapping	8	60



Storage modulus map

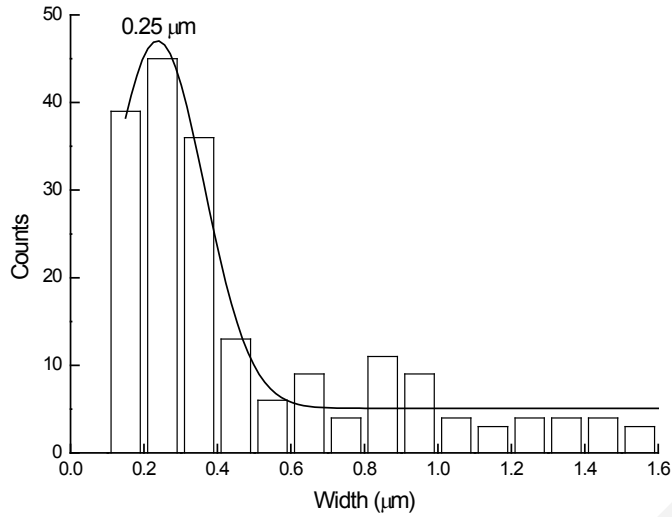


Loss modulus map

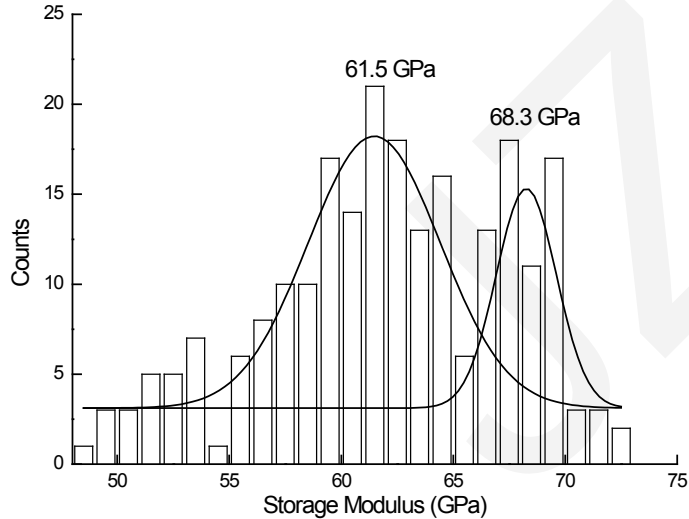


Variations at specific cross section

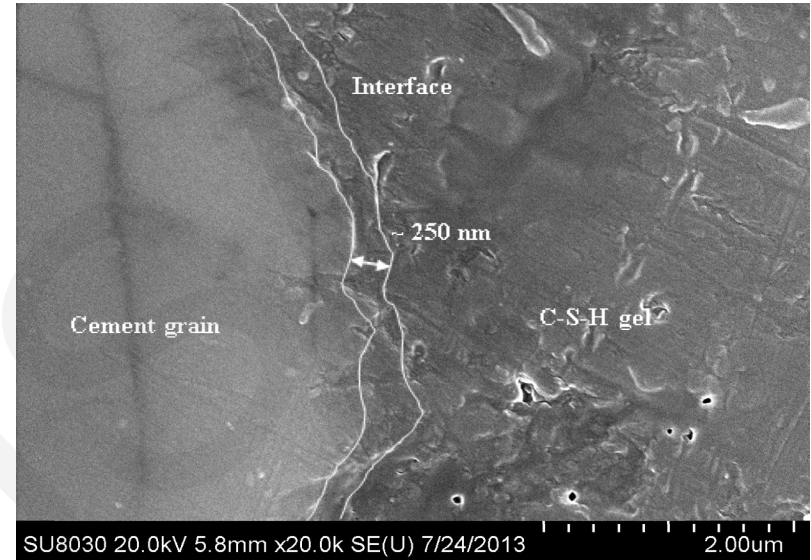
# Modulus Mapping



**Interface width distribution functions**



**Interface storage modulus distribution**



**SEM image of interface**

Interface width: 250 nm  
Interface modulus: 60-70 GPa

# Conclusions

- Nanoindentation results provided a rough estimate of interface width of less than 5  $\mu\text{m}$ . The modulus and hardness of the interface were 68 GPa and 3 GPa, respectively.
- Modulus mapping yielded an interface width of 250 nm. The packing density in the interface was non-uniform as two peaks of value 61.5 GPa and 68.3 GPa were observed for the storage modulus distribution. This interface could be regarded as a dense layer around cement grains.