PARTIAL REPLACEMENT OF CEMENT BY WASTE MARBLE SLURRY

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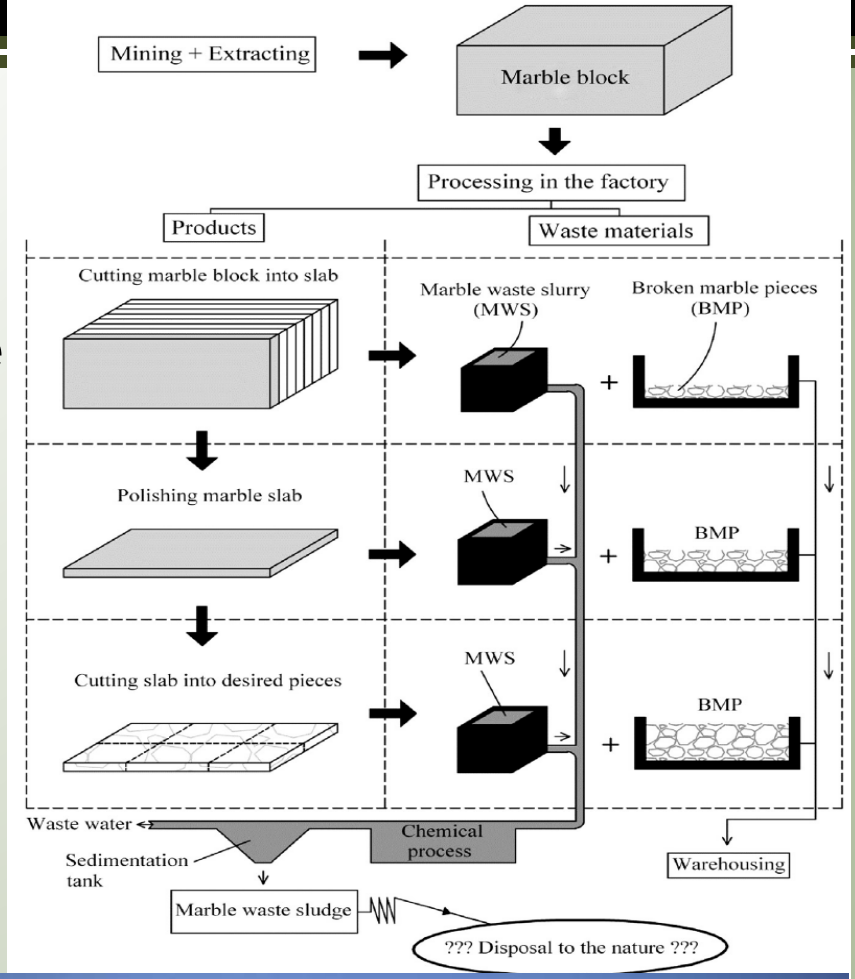
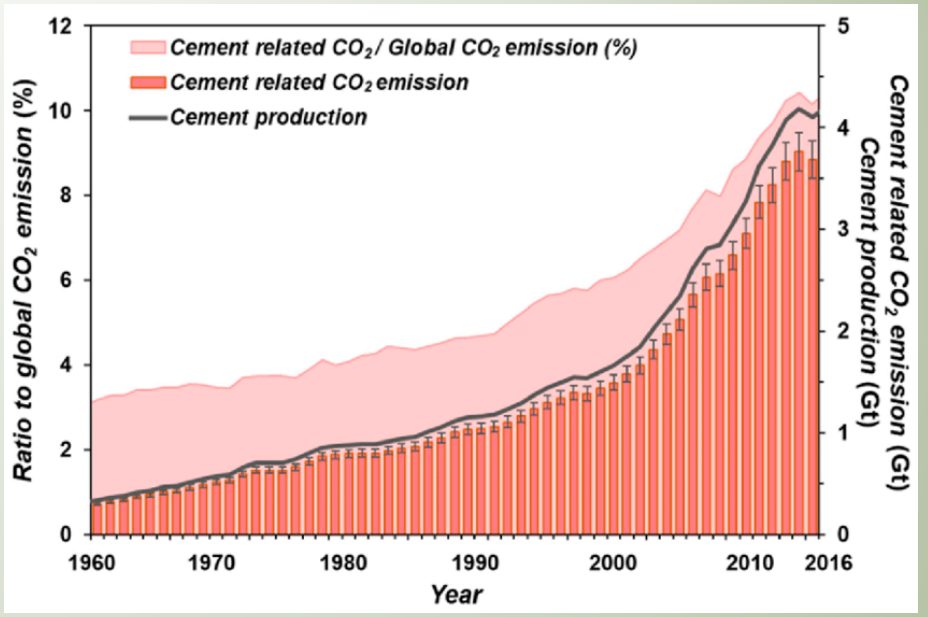
Marble slurry

- Liquid material comprised of marble particles, water and iron filings
- Waste marble slurry is treated to remove water as much as possible
- The final product “marble sludge” is collected
- Due to its huge volumes, no capability to be stored
- The waste is dumped into nature causing environmental hazards
- Recycling and utilization of waste marble is a critical issue for
  - the environmental sustainability
  - financial benefits



Cement industry environmental and economical impact

- Cement production releases CO_2 emissions
- 1 tone of clinker requires 3GJ of energy to be produced, and releases 1 tone of CO_2 in the atmosphere
- Cement industry responsible for about 5% of global anthropogenic carbon emissions.
- Cement is the most costly material when preparing concrete
- Goal of cement industry: introduction of alternative and innovative materials, methods and technics



CO_2 emissions related to the production of cement and its ratio to total CO_2 emissions, *Thomas D. Kelly and Grecia R. Matos, Historical statistics for mineral and material commodities in the U.S.; published by the United States Geological Survey (USGS), 2015*

Possible benefits from utilizing marble slurry in construction industry

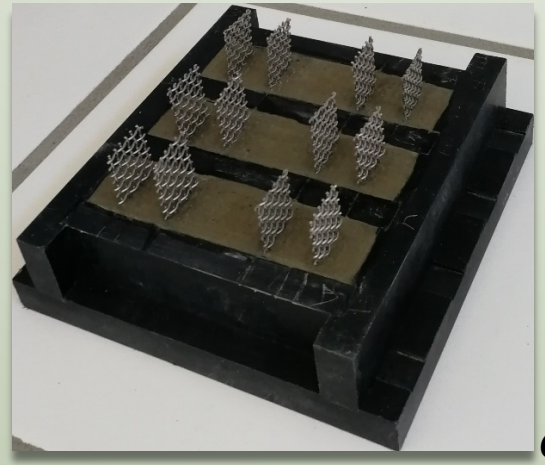
- reduce the CO_2 emissions
- lessen the usage of raw materials that are in great demand
- reduce the consumption of fuels and power
- offer economic advantages to cement industries
- increase the consumption of a waste material which otherwise would be dumped

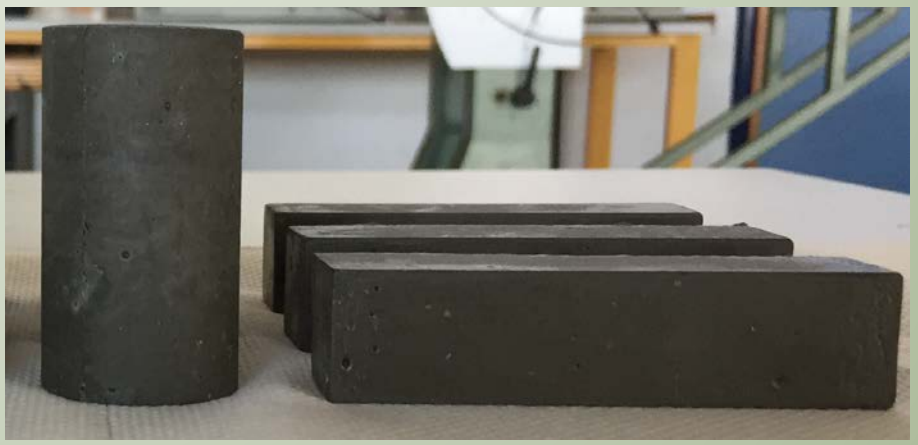
Aim of this research:

a) study the effect of the water content (water/cement ratio)

b) investigate the effect of the partial substitution of ordinary Portland cement with waste marble slurry determining the optimum marble slurry concentration

Marble slurry





Cement paste specimens with marble slurry

Experimental procedure

WATER/CEMENT=0.3

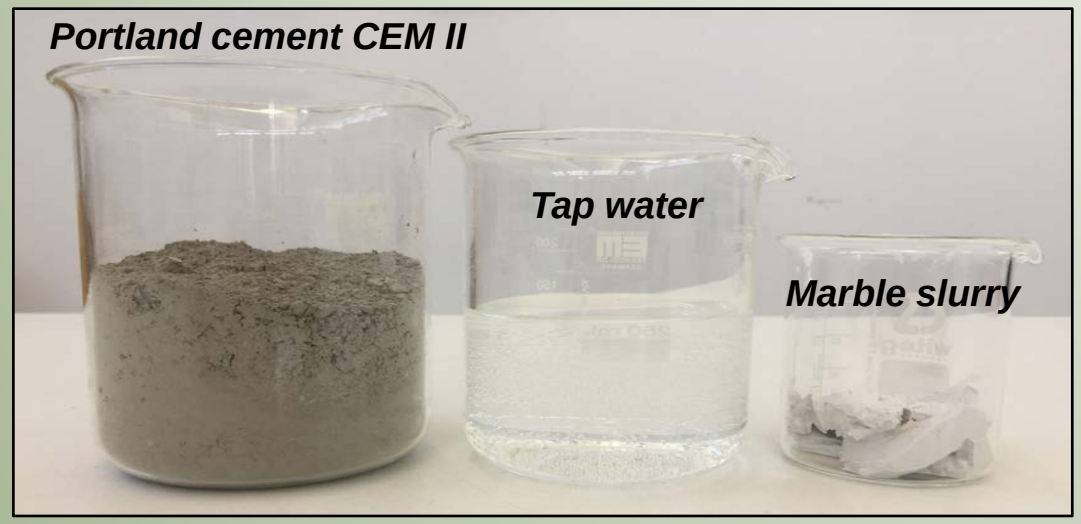
MARBLE CONCENTRATION (0%, 5%, 10%, 15%, 20%)

WATER/CEMENT=0.4

MARBLE CONCENTRATION (0%, 5%, 10%, 15%, 20%)

WATER/CEMENT=0.5

MARBLE CONCENTRATION (0%, 5%, 10%, 15%, 20%)



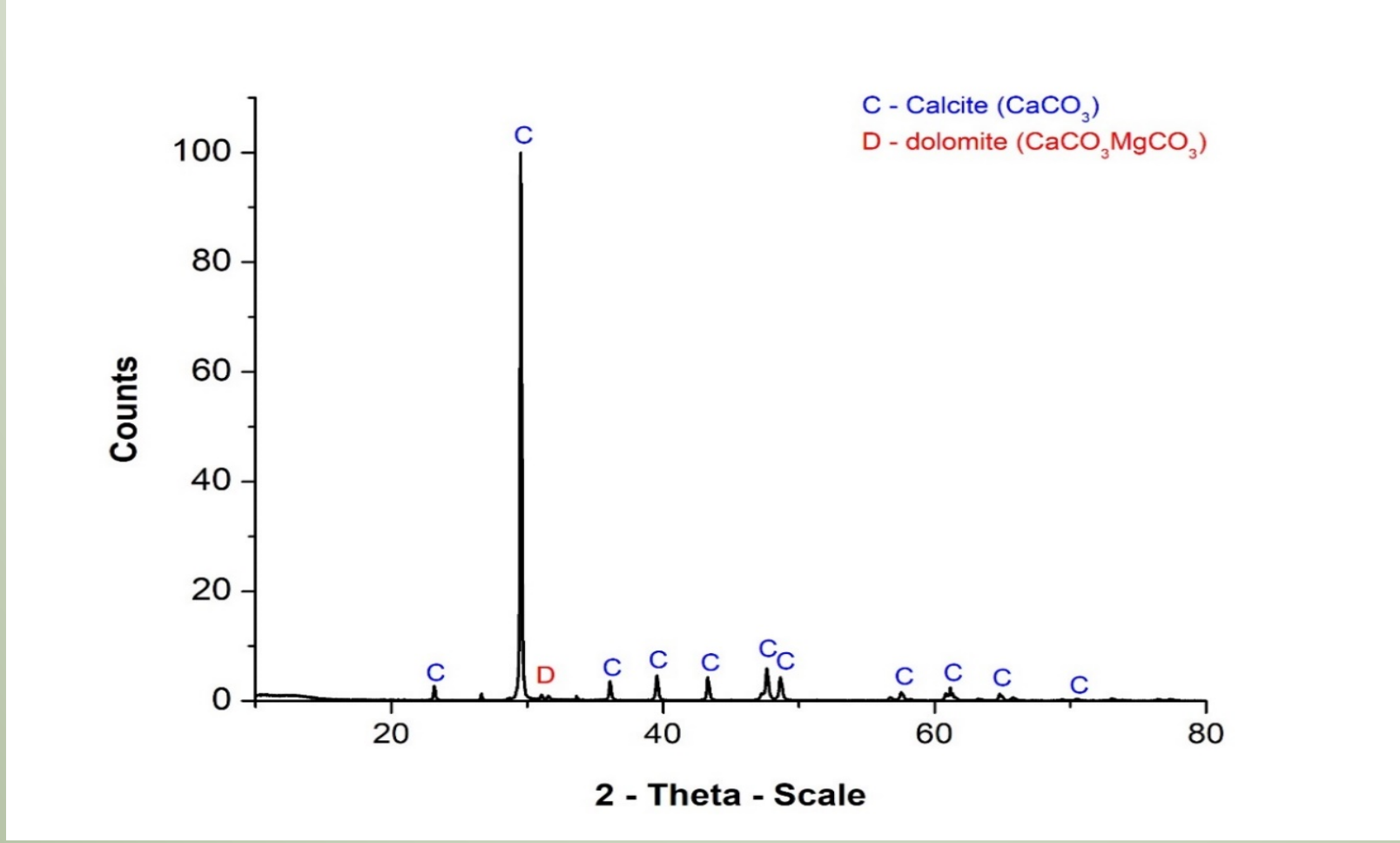
Raw materials

Testing methods:

- X-ray diffraction (XRD) analysis
- Fourier-transform infrared spectroscopy (FTIR) analysis
- Scanning electron microscopy (SEM) analysis
- Quasi-static compression
- Electrical resistance using the 4-wire method

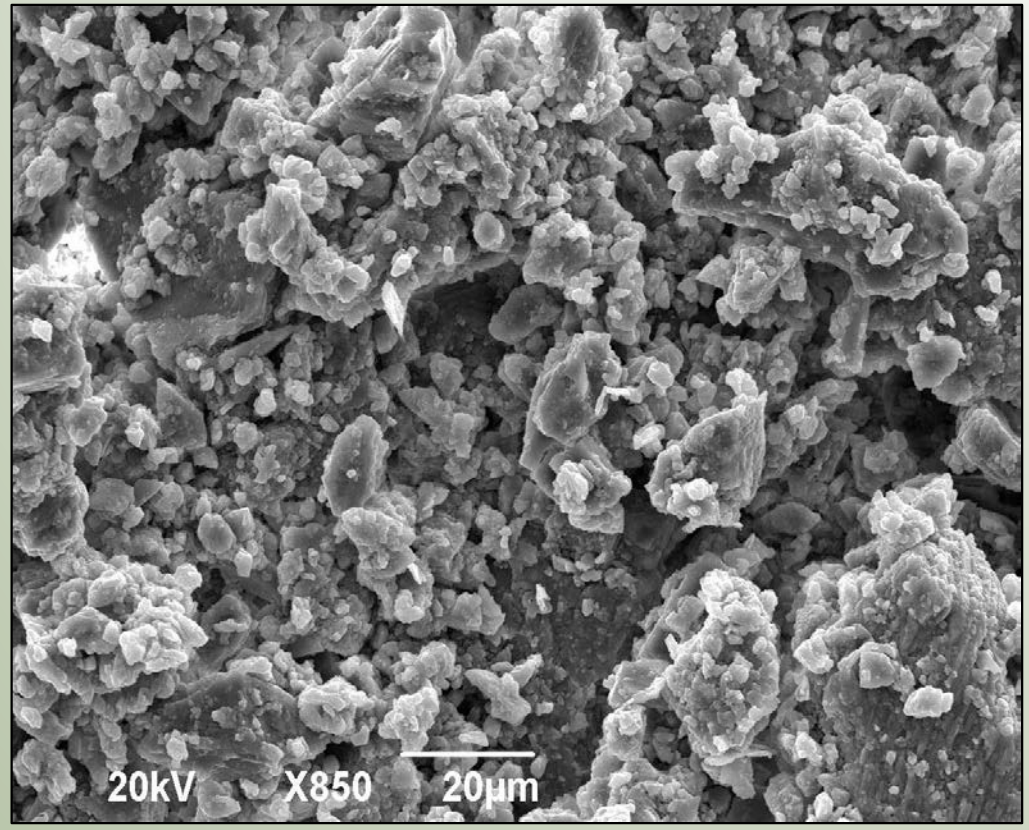
Characterization of waste marble slurry

X-ray Diffraction analysis (XRD)



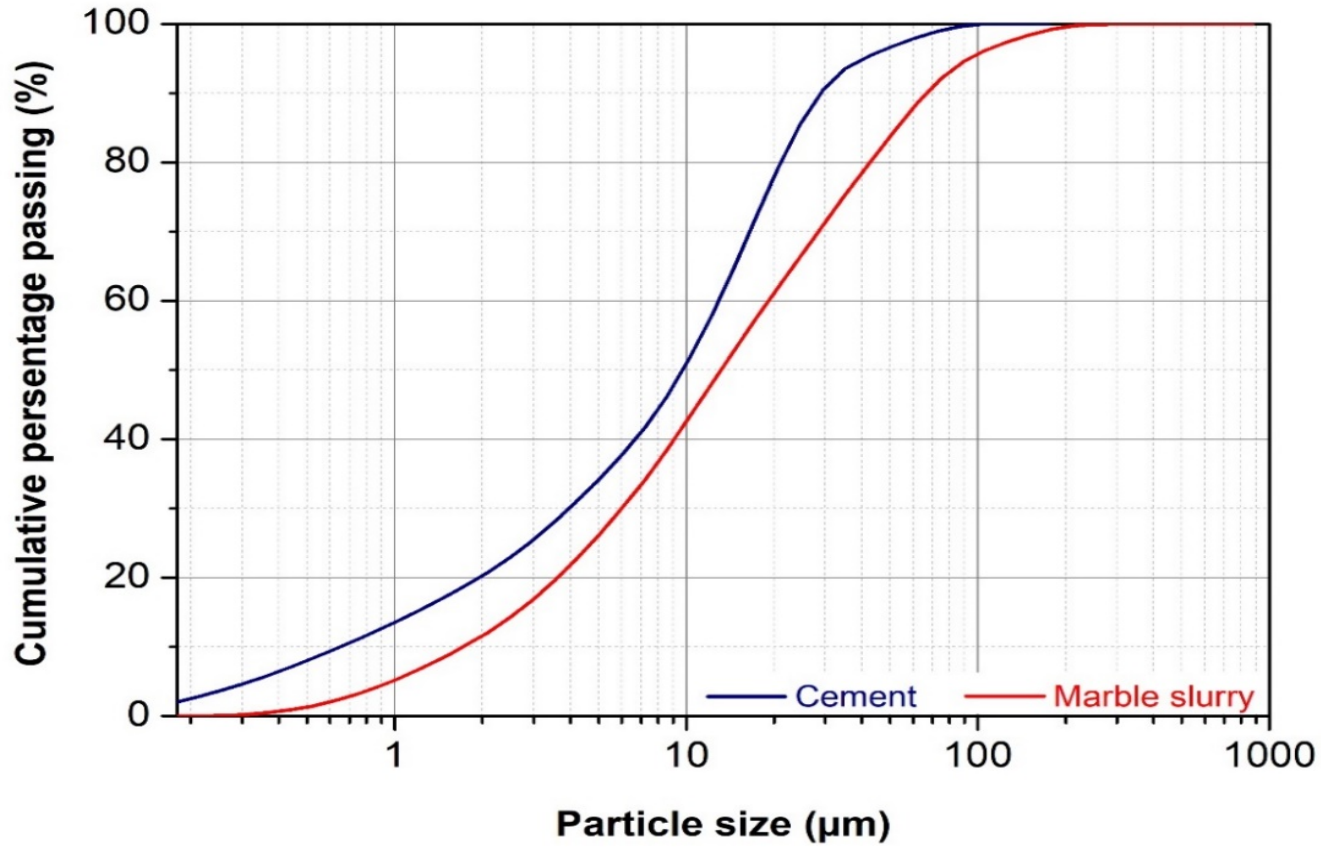
Characterization of waste marble slurry

Scanning electron microscopy (SEM)



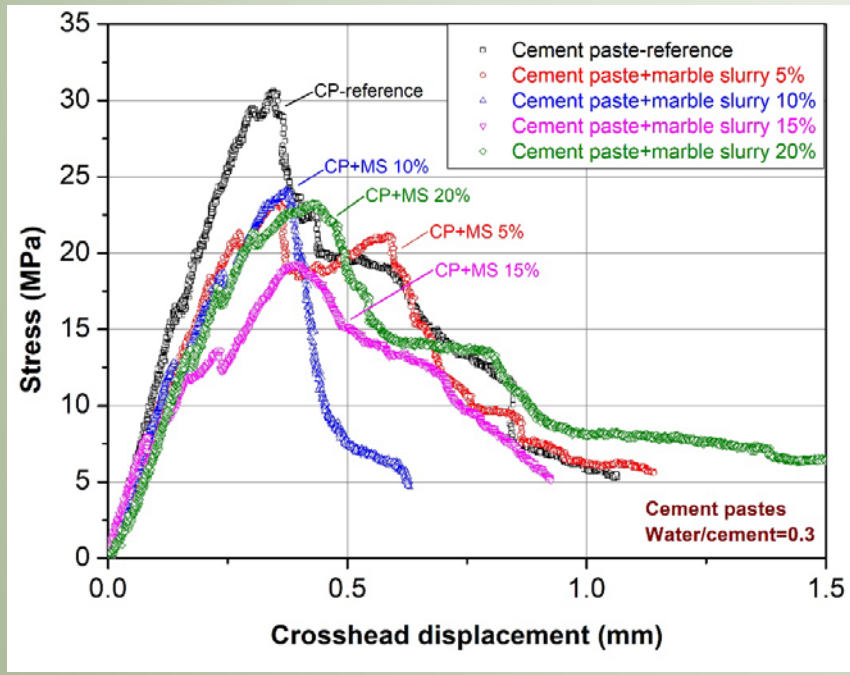
- Irregular structure
- Abrasive surface

Particle size distribution

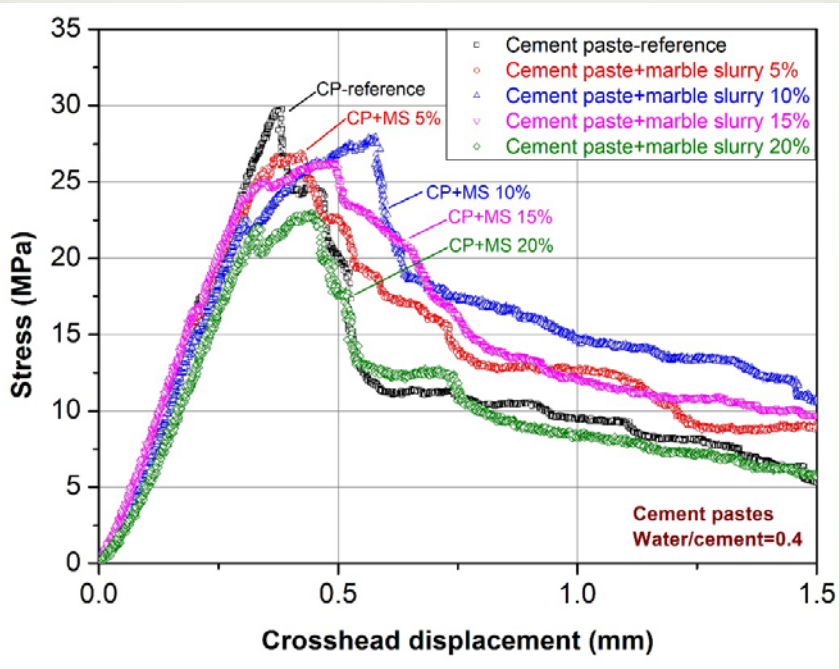


- **50% of cement particles<9.75 µm**
- **50% of marble particles<13.19 µm**

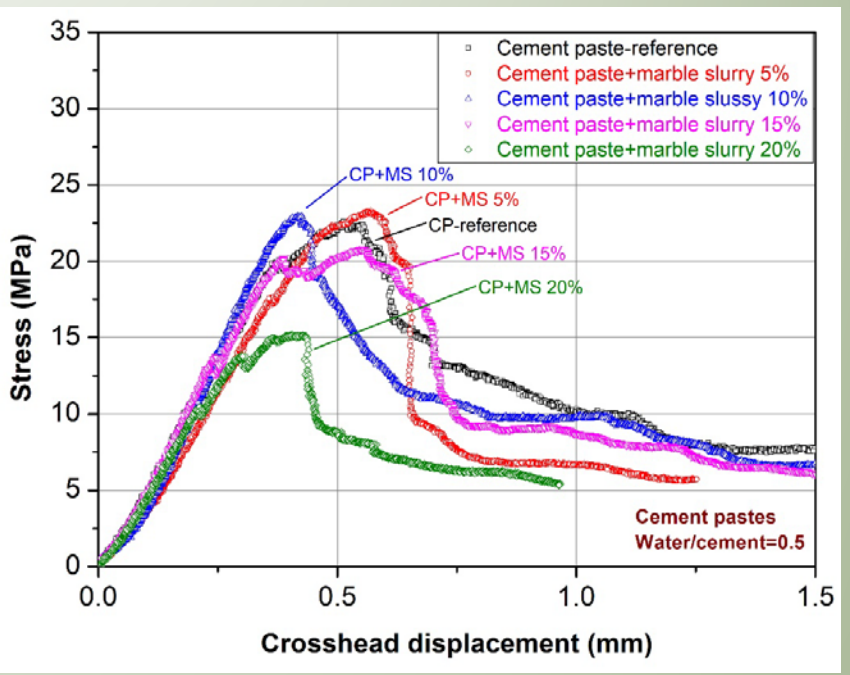
Typical stress-displacement graphs



Water/cement = 0.3

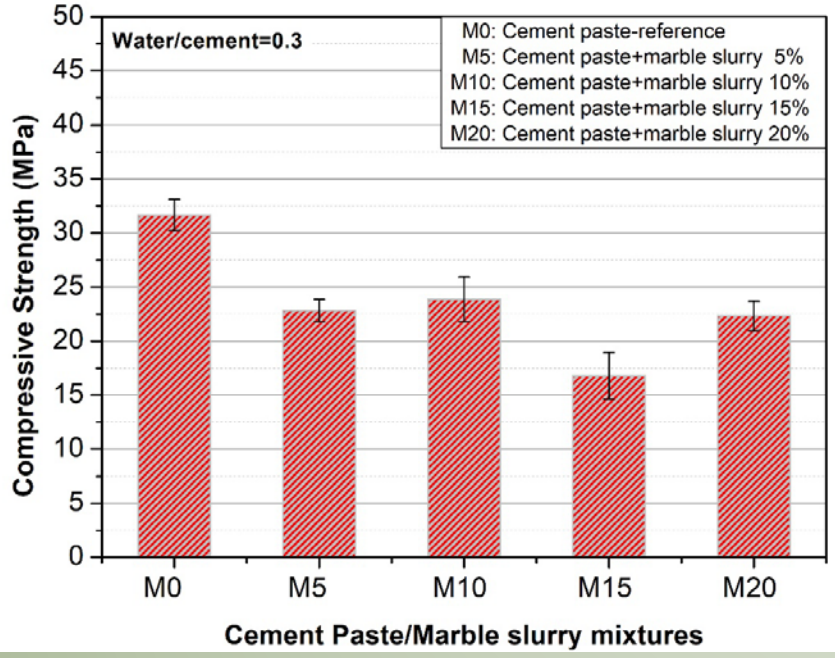


Water/cement = 0.4



Water/cement = 0.5

Average compressive strength



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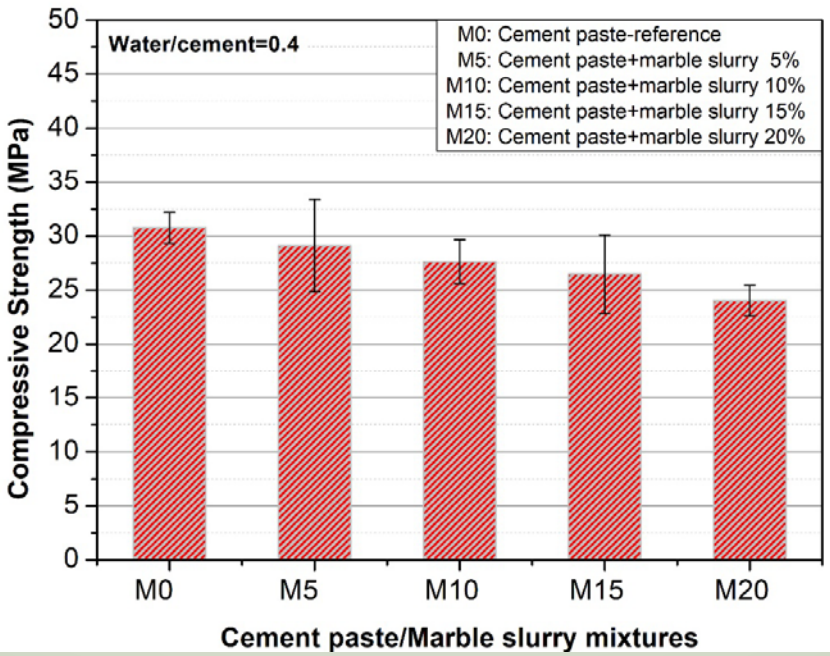
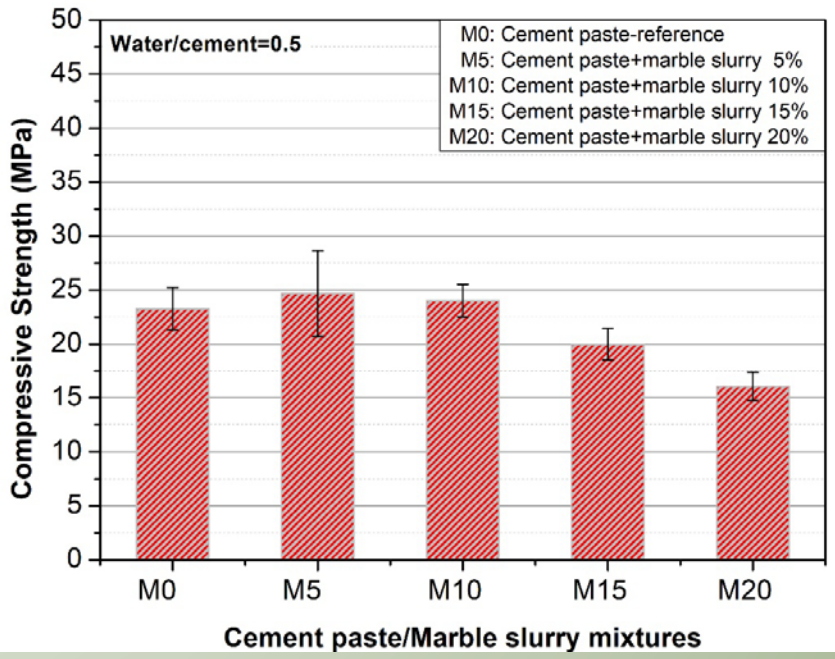
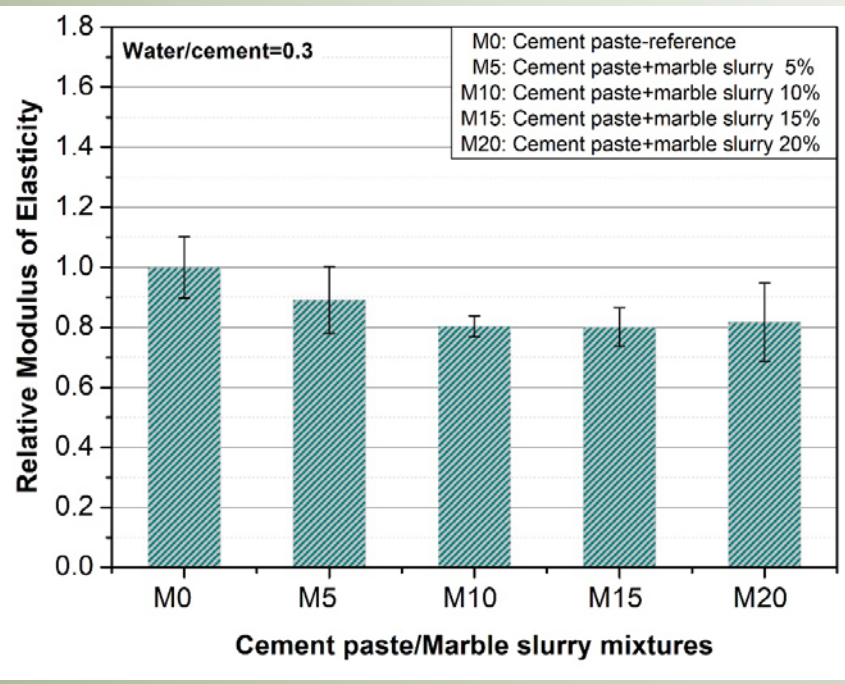


Water/cement = 0.4



Water/cement = 0.5

Modulus of Elasticity



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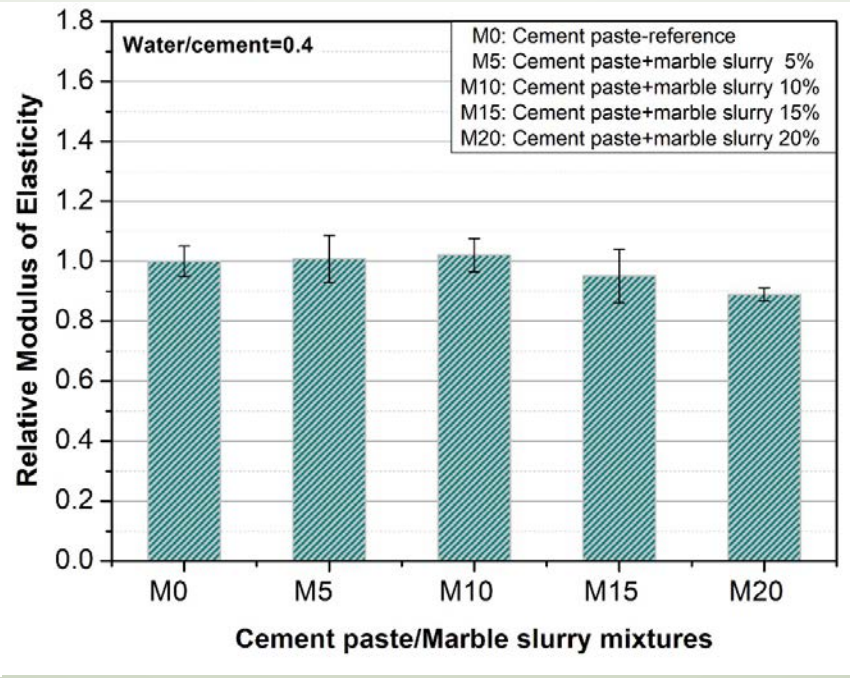

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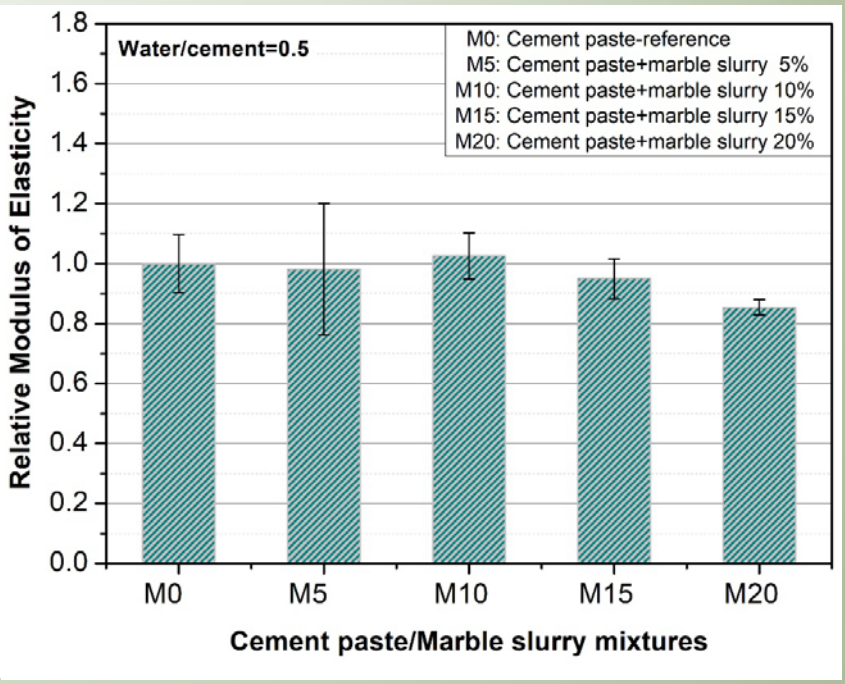
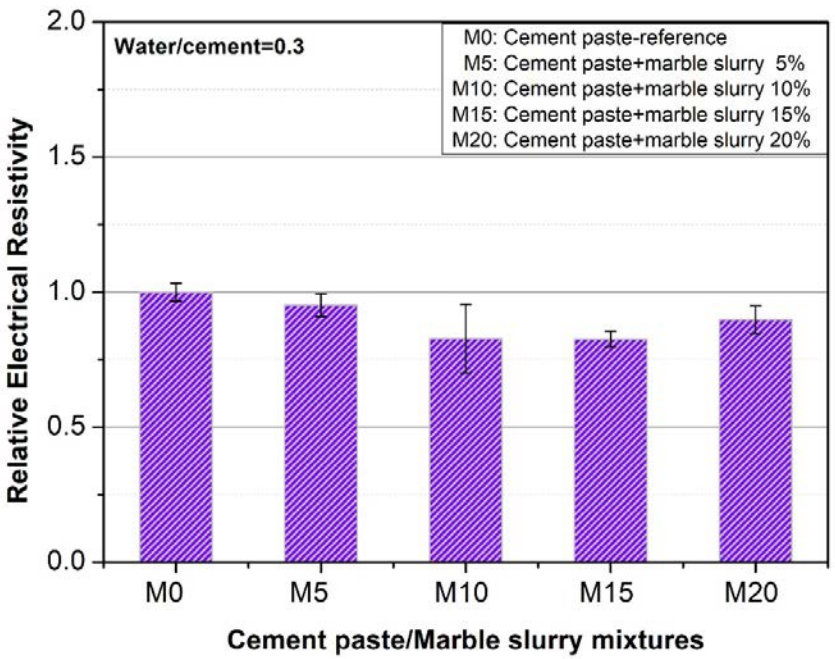
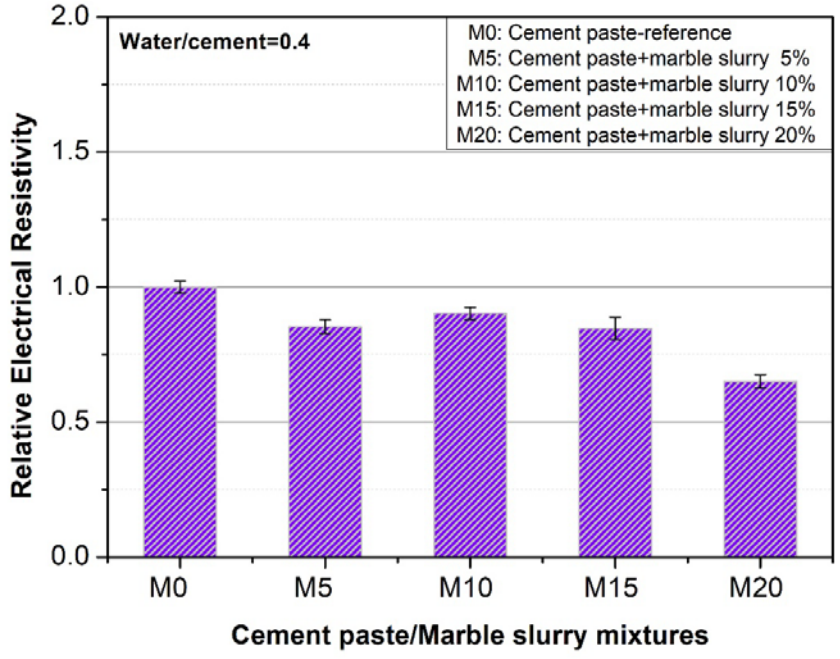


Water/cement = 0.5

Electrical resistivity



Water/cement = 0.3



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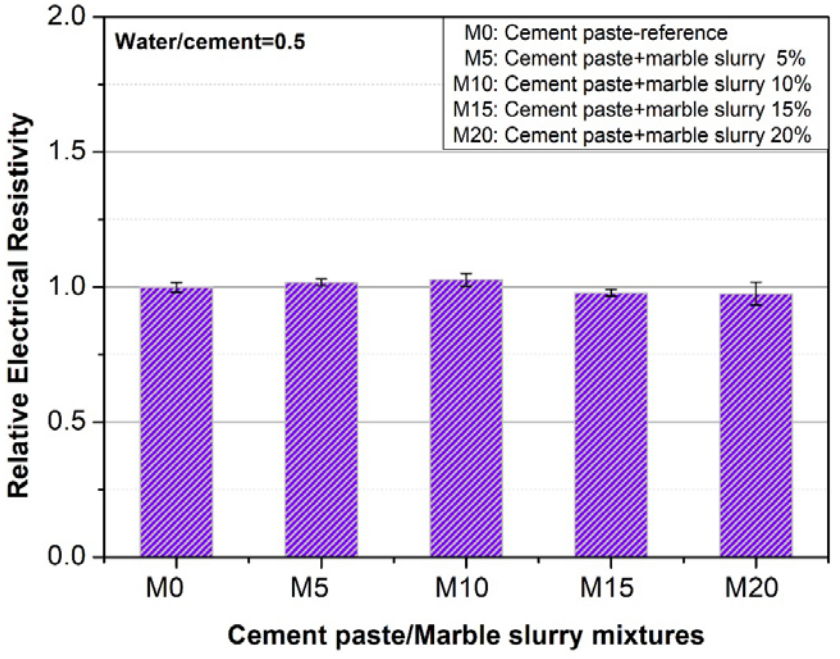
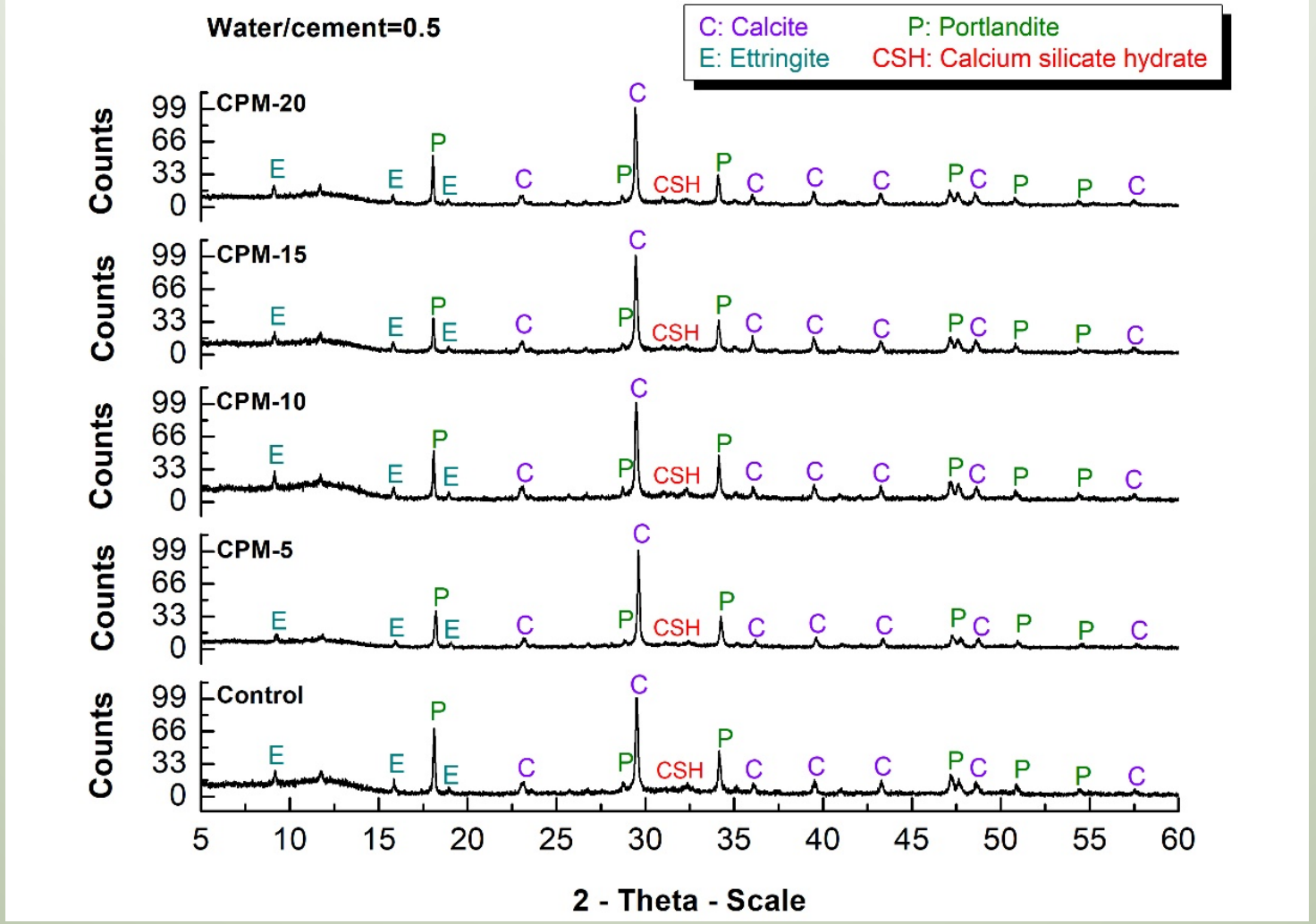
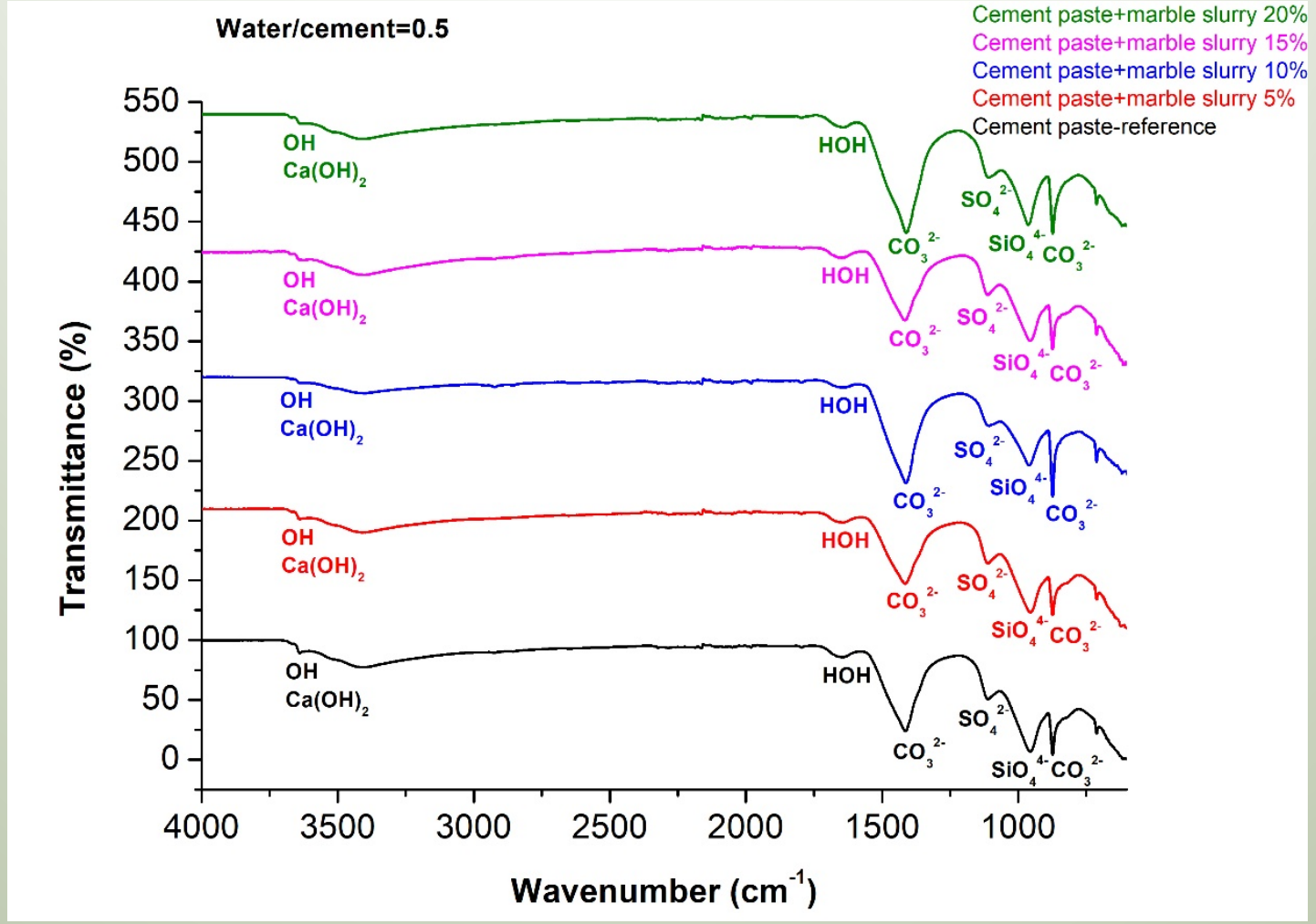


Water/cement = 0.5

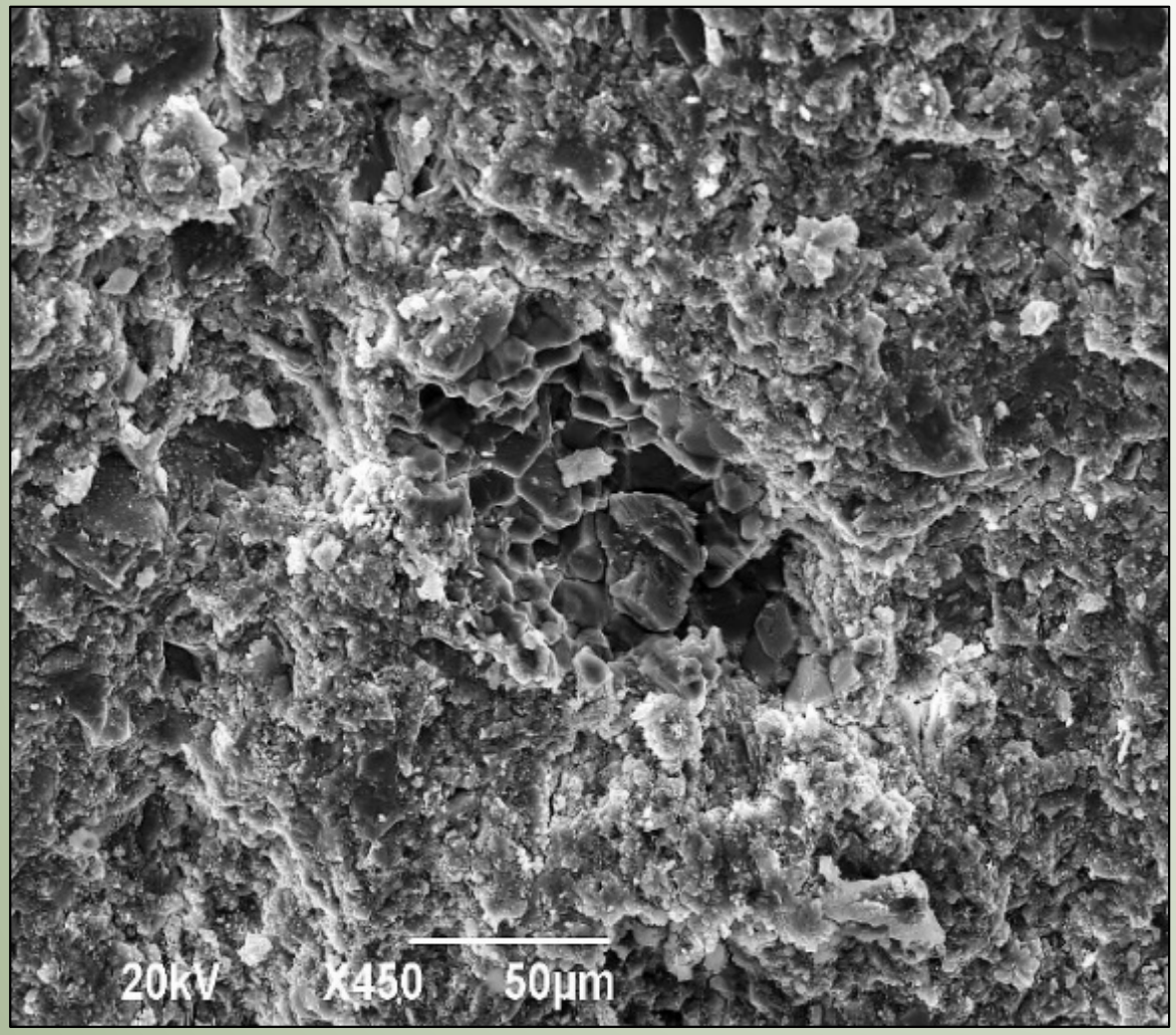
X-ray Diffraction analysis results



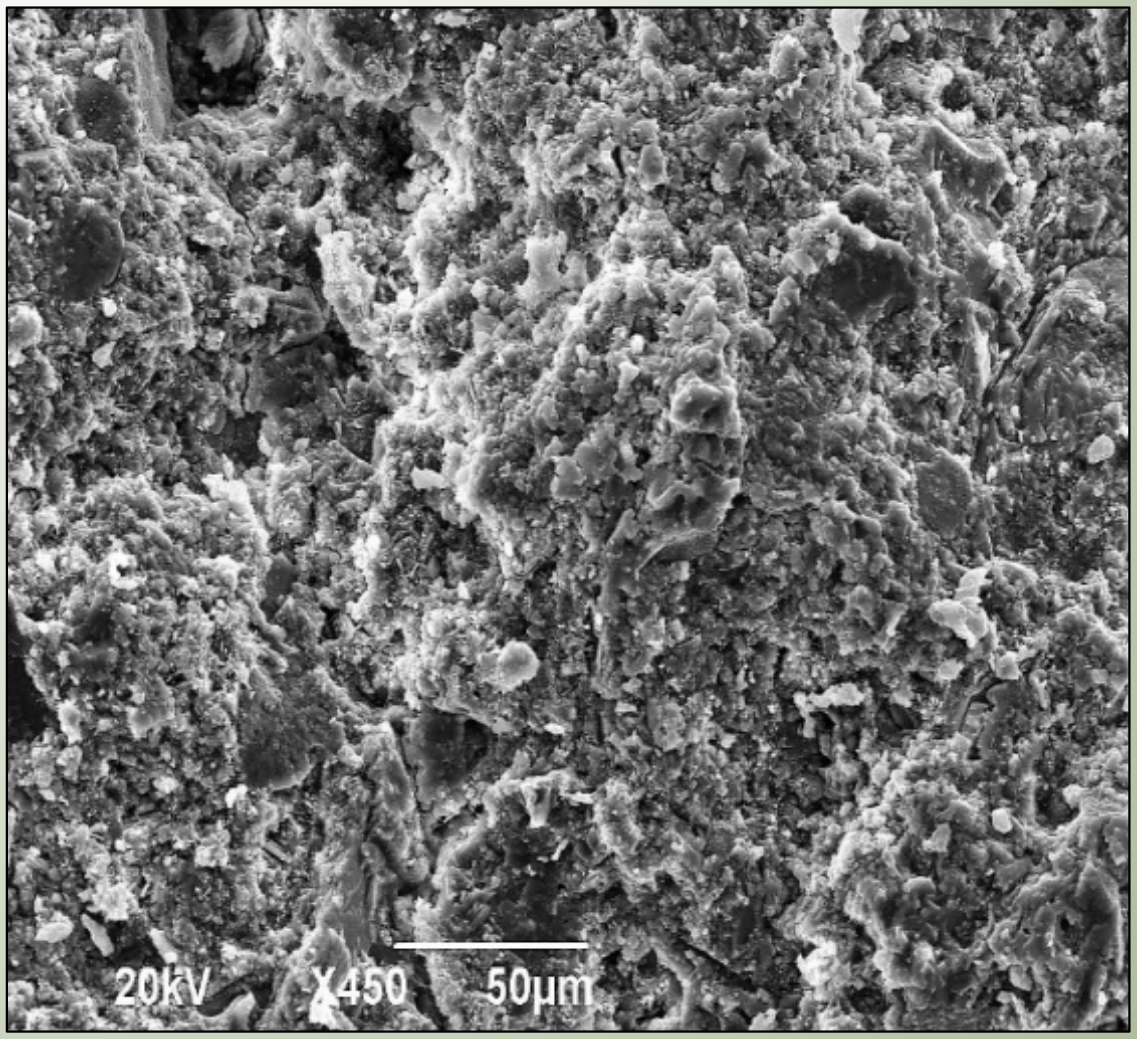
Fourier-transform infrared spectroscopy (FTIR) results



SEM results of samples with w/c=0.5



0% marble slurry



10% marble slurry

Conclusions

- Marble slurry can successfully substitute cement powder up to a 10% replacement level when a water to cement (w/c) ratio of 0.5 is used without altering the mechanical performance of the material
- The water to cement ratio strongly affects the effectiveness of marble slurry to be used as cement replacement
- Resistivity results show that at a w/c ratio of 0.5 the incorporation of marble slurry affects positively the pore microstructure of the samples. Possibly improves the porosity by filling the voids. As a result, the cement composites become denser and more resistant in the electrical current
- XRD and FTIR analysis show that marble slurry does not participate in the chemical reactions that take place during the hydration processes of cementitious mixtures
- SEM demonstrates the development of a thicker microstructure when marble slurry is incorporated at a w/c ratio of 0.5

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Any questions?